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Indian Ecological Society Conference 2016

Natural Resource Management: Ecological Perspectives

(February 18-20, 2016)

Editors

A.K. Dhawan
Sanjeev K. Chauhan
R. Peshin
R. Sharma

Organized by

Indian Ecological Society, Ludhiana-141 004, India
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu
Jammu-180 001, India

FOREWORD

The importance of natural resources, land, water and vegetation, is higher than ever before to ensure sustainability in agriculture growth in the face of depleting natural resources like land and, water, soil health, changing climate and declining resource productivity. Degradation and erosion of natural resources, namely, land, water, forest, biodiversity, livestock and fisheries along with climate variability are the root causes of the agrarian crisis in the country. *Widespread, serious and continuing degradation of India's natural resource base is now reflected in slow pace of growth rate in agriculture*. Loss of biodiversity and agricultural genetic resource are the critical issues for sustainability in production. Forests are the natural resource infrastructure for agriculture/primary production and rural economic growth. Over 120 million ha have been declared degraded .Total livestock output has been growing at a much faster rate of 3.6 per cent per annum against only 1.1 per cent registered for the crops during the past decade. Fisheries contribute significantly to food, nutrition, economic and employment securities, and fortunately are one of the fastest growing agricultural sub-sectors during the last three decades. Currently, fisheries contribute 4.6 per cent of the agricultural GDP. Reduction in cultivated land, loss of organic matter and C in most of the arable lands in India, groundwater depletion, water lost due to salinity and alkalinity, increase in losses due to insect pests, diseases and weeds are the areas of serious concern. In recent years, increases in agricultural productivity have come in part at the expense of deterioration in the natural resource base on which farming systems depend.

The world's climate is changing and will continue to change in the coming centuries at rates projected to be unprecedented in the recent human history. Human activities have increased green house gases and raised global temperature, resulting catastrophic changes in climate with added evaporation and precipitation, and vegetation movement towards poles by two to three hundred kilometers. The scientists have been putting their best efforts in developing ways to slow down the addition of carbon dioxide to the atmosphere and UN has fixed the target that the increase in temperature till 2100 should remain below 2°C and all efforts should be addressed to meet the proposed limit. The sustainable development goals are another target till 2030 to address the food requirements for nine billion expected population by 2050. All the countries (developed, developing and under developed) are taking remedial steps and committed for drastic cuts to meet the aspirations of future generation in development and environmental protection.

It is urgent that this trend be reversed by encouraging farmers to adopt more sustainable methods of farming that will have long-term benefits in environmental conservation and development of sustainable livelihoods. Globally, there are evidences about agri-environmental degradation, and consequent reinforcement of poverty and hunger by some of the policies and inputs that are designed to increase production but result in resource depletion and degradation. Regular monitoring and appraisal of natural resources is essential to develop appropriate planning. With acceleration of economic growth, these pressures are expected to intensify, and therefore, need to pay greater attention to the management of natural resources, viz. water, forests and land. Therefore Indian Ecological Society in collaboration with Sher-e-Kashmir University of Agricultural Science and Technology (SKAUST), Jammu has organized an international conference on **International Conference- Natural Resource Management Ecological Perspectives, SKUAST of Jammu, Jammu India (February 18-20, 2016) at beautiful campus of SKAUST, Jammu.** Three international organizations i.e., International Union of Forestry Research Organizations (IUFRO),World Wide Fund for Nature (WWF) and Centre for International Projects Trust (CIPT) are also collaborators in this important venture of global concern. The following theme are covered in the conference.

Land and Water Resources: Land resource management and land use planning, water management, management of problematic soils, soil and water conservation, watershed management, water saving technologies, crop diversification, rainfed/dryland farming, weed management, development of integrated farming systems, organic farming, resource conservation technologies, traditional ecological knowledge, people's movements in soil - water - development paradigm, technology transfer and impact.

Crop Environment Interactions: Adaptation to changing climate and resilience enhancement, diversification and mitigation through climate smart agriculture, vegetation-atmosphere exchange of green house gases, sustainability of environmental resources, biodiversity conservation and its rational use, crop environment interaction assessment using advanced technologies, shift in the manifestation of insect pests and diseases, improved weather and climate services, ICT enabled early warning systems.

Integrated Nutrient Management: Soil health and nutrition, crop and efficient nutrient management practices, crop residue management, management of pollutants in soil.

Integrated Pest Management: Protection technologies for horticultural and field crops, ecological basis of insect pest/disease management, impact on ecosystem and environment, pesticide residue, spray technology, insect biodiversity, useful insects, IPM programmes and their impact.

Horticulture Crops: Genetic resource management in fruit, vegetable and flower crops; vegetative propagating techniques; protected cultivation; intensive production technologies for higher productivity in horticultural crops; climate change mitigation; pre and post-harvest handling and value addition; good agricultural practices in horticultural crops; socio-economic impact of National Horticulture Mission.

Forestry Tree Plantations: Economic, social and ecological valuation, natural resource management, climate change mitigation, biomass energy, tree health and protection, trees outside forests – adoption and management, wood products and composites, eco-tourism, policy, education and training.

Eco-responsive Livestock and Fisheries Production: Integrated crop-livestock husbandry for optimum natural resource utilization, environmentally resilient livestock and fisheries management, water economy of livestock operations, health and production interventions for sustenance of fish production, conservation and management of aquatic resources, aquaculture in degraded lands, aquaculture impact on environment, livestock and fisheries for livelihood generation and socio-economic development.

Policies for Sustainable Development of Agriculture: Indicators of sustainable agricultural development, economic and social impacts of technological interventions on agricultural production, impacts of climate change on agriculture, crop livestock interactions, policies, institutions and regulations related to land , water and energy and their impacts, success stories on sustainable development, lessons learned for their up-scaling, strengthening the extension system in India: the role of the private sector.

Farmer-Industry-Scientists Interface: Strengthening the extension system in India: the role of the private sector.

The financial assistance received from Research and Development Fund of National Bank for Agriculture and Rural Development (NABARD) towards publication of journal is gratefully acknowledged. This first special issue of Indian Journal of Ecology contains 131 manuscript on various aspects of natural resource management presented in the conference by policy planners, researcher, students and extension/industry personnel for different institutions. The issues contains a wealth of information on all aspects of natural resource management and would prove indispensable not for only students, teachers and researchers in agricultural but also for administrators, planners, industrialists and field level extension functionaries.

Dr A.K. Dhawan
General Secretary cum Managing Editor

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Development and Evaluation of Subsoiler-cum-Organic Manures and Soil Amendments Applicator

J. P. Singh and T. C. Thakur[1]

Division of Agricultural Engineering
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009 India
[1]College of Technology, G.B. Pant University of Agriculture & Technology, Pantnagar-263 145, India
Email: jai12123@rediffmail.com

Abstract: A tractor operated machine was designed and developed for application of vermicompost (organic manures) either alone or in combination with inorganic fertilizers and other soil amendments in the subsoil at different depths up to 475 mm. The developed machine consisted of two main unit's viz. a subsoiling unit and a fertilizer metering and placement unit. The machine was tested under field conditions. The results revealed that the bulk density was uniform throughout the soil profile after operating at 400 mm depth and reduced to a maximum of 13.88%. The specific draft for 400 mm depth of operation was found lower by 33.26% than that at 250 mm depth. The machine was also evaluated in the farmer's field on mustard crop and data showed significant increase in crop growth parameters, yield and yield attributes by application of vermicompost and inorganic fertilizers at different depths. Significantly higher seed yield (2.108 t/ha) was obtained with placement of 50% N (inorganic) at 200 mm + 50% N through vermicompost(organic) at 400 mm depths and 22.56% higher as compared to control (1.72 t/ha).

Key Word*:* Mustard crop Subsoiler, Soil amendments, Vermicompost

India would need over 300 mt of food grains by the year 2025 from shrinking land resources. In order to achieve the required yield levels, one of the most important issue soil health management, not only the top cultivated soil but also the subsoil needs to address. Soil compaction is one of the major problems facing the modern agriculture which increases soil strength and bulk density, and decreases hydraulic conductivity, infiltration rates, porosity which impede root growth through decreased storage and supply of water, and plant nutrients (Ahmad *et al*., 2007). The soils generally found in subsoil are inherently poor in nutrient status, low in organic matter content and water holding capacity, and relatively deficient in available phosphorous and potassium contents due to hard impermeable layer. Subsoiling operation improves soil structure by establishing a system of deep cracks and fissures in the subsoil which aid in downward movement of water, air and roots through greater depth of soil profile that help the plants withstand short term drought conditions (Raper *et al*., 1998). The subsoil cultivation, in situation where it was needed, had increased the fertilizer use efficiency and yields of crops (Thakur *et al*., 2005). In India, *Tarai* region of Uttarakhand state, subsoiling has given yield increase of over 26, 16 and 35% in wheat, maize and sugarcane in comparison to conventional method of soil cultivation (Thakur *et al*., 2005; Singh, 2008).

Application of fertilizers is generally accomplished by manual spreading, broadcasting, placement or mixing in upper soil layers of 20-50 mm depths which create fixation problems of phosphorous (P) and potassium (K) and volatilization of nitrogen (N). Only 40 to 50% of N fertilizers and 20 to 30% of P and K fertilizers are effectively used by the crops, and the remaining get evaporated, volatilized, leached to the groundwater or get fixed with soil as per the properties of their contents. Organic manures are good sources of different macro and micro-nutrients, and have a significant role to play in nutrient supply. The aim of incorporating organic manures and soil amendments in the subsoil is to reduce losses of nutrients and improve soil physical properties and nutrient availability by enhancing aggregate stability which results in improved water holding capacity, aeration and increase in microbial activities besides reducing the application rate of inorganic fertilizers by increasing the fertilizer use efficiency. Vermicompost, which is an important and valuable source of plant nutrients, increases the root nodulation, microbial activity in the rhizosphere, soil organic carbon, crop growth and yield attributes, available NPKS and micronutrients, and decreases the bulk density of soil when used either alone or in combination with inorganic fertilizers (Manjunatha *et al.,* 2006; Singh, 2010). Oilseed crops play a vital role in Indian agricultural economy, occupying over 14% of the gross cropped area and contributing over 3% to GDP and 10% value of all agricultural products. Mustard being a short duration crop could be selected as a test crop for evaluation of machines developed for subsoil placement of organics and inorganic fertilizers.

In India different machines have been develop to apply the chemical fertilizer in subsoil. However, no suitable technology is presently available in the context of placement of organic manures in solid states into the subsoil zone. Therefore, a machine named as 'Subsoiler-cum-Organic Manures and Soil Amendments Applicator' have been develop and its performance were evaluated on mustard crop.

MATERIAL AND METHODS

The developed machine (Fig. 1) consisted of two main units i.e. subsoiling unit, and a fertilizers and soil amendments metering unit. The main components of subsoiling unit are: the frame, hitching system, winged straight leg tine with its various components and depth control device. The fertilizers and soil amendments metering unit consisted of a fertilizer hopper with supportive frame, materials metering device in form of a vertical screw conveyor, gear reduction unit and power transmission system from tractor power take off to the metering device. Specifications of the main components of developed machine are given in Table 1. An experiment was conducted at farmer's field, Pantnagar, Uttarakhand (India). The seven treatments were selected on basis of a field pot experiment conducted previously to examine the basic concept for placement of organic manures and inorganic fertilizers in subsoil on mustard crop.

The known quantity of fertilizers and vermicompost as per treatment were broadcast manually and mixed in 100 mm depth with two passes of rotavator in treatments T_1 [Control: manual broadcasting and mixing] T_2 [50% (inorganic + 50% (organic + Mixing (100 mm]. In treatments T_3 [subsoiling 400 mm **+** 100% inorganic + mixing (100 mm) with rotavator × 1] T_4 [Subsoiling (400 mm) **+** 50% (inorganic) + 50% (organic) + mixing (100 mm)with rotavator × 1] The subsoiling operation was performed at a depth of 400 mm by the developed machine i.e. 'Subsoiler-cum- organic manures and soil amendments applicator' without filling the hopper

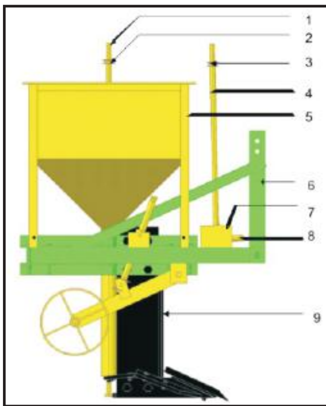

Fig. 1. Isometric view of designed machine

with vermicompost and a known quantity of fertilizers was broadcast manually and mixed in 100 mm depth with one operation ofrotavator. 'Pant-ICAR Subsoiler-cum-differential rate fertilizer applicator' was used in treatment T_5 [80% (inorganic) placed at 200 mm and 20% (inorganic) placed at 400 mm + rotavator × 1] for application of 80% (inorganic) placed at 200 mm and 20% (inorganic) placed at 400 mm depths as per treatment and seedbed was prepared with one operation of rotavator. In treatments T_6 [50% N (inorganic) + 50% N (organic) placed at 200 mm + rotavator × 1] with machine and T_7 [50% N (inorganic) placed at 200 mm + 50% N with machine (Fig. 3a,c). (organic) placed at 400 mm + rotavator × 1]

RESULTS AND DISCUSSION

Plant height: AT 30 days after sowing (DAS), significantly highest plant height (0.158 m) was obtained in treatment T_2 (application of 50% N through vermicompost and 50% N through inorganic fertilizer mixed in 100 mm) which was statistically at par with treatments T_4 and T_7 (Tabel 2). The lowest plant height of 0.116 m was obtained in treatment T_6 i.e. placement of 50% N (inorganic) + 50% N (organic) at 200 mm depth. At 60 DAS, the treatment T_7 i.e. 50% N (inorganic) placed at 200 mm + 50% N (organic) placed at 400 mm depths has shown significantly highest plant height of 1.347 m, which is at par with treatments T_6 and T_5. The lowest plant height of 1.166 m was noted in treatment T_2. However, at 90 DAS and at harvest significantly highest plant heights of 2.142 and 2.155 m were in T_5 (80% inorganic placed at 200 mm and 20% inorganic placed at 400 mm) which was at par with treatment T_7 at 90 DAS and at harvest. Significantly lowest plant heights of 1.763 m at 90 DAS and 1.885 m at harvest were obtained in treatment control).

Plant girth: The treatment T_7 i.e. 50% N (inorganic) placed at 200 mm + 50% N (organic) placed at 400 mm, produced significantly highest plant girth of 15.8, 19.6, 19.7 and 20.2 mm at all the crop growth stages i.e. 30, 60, 90 DAS and at harvest, respectively (Table 2). Significantly lowest plant girths were noted as 9.6 and 12.6 mm at 30 and 60 DAS in treatment T_1, and 13.6 and 14.7 mm at 90 DAS and at harvest in treatment T_2, respectively. Number of primary, secondary and tertiary branches per plant:At 60 DAS, placement of 50% N (inorganic) at 200 mm + 50% N (organic) at 400 mm depths (T_7) gave significantly highest number of primary and secondary branches (8.2 and 7.3) followed in order T_6, T_4 and T_5 (Table 2). Significantly lowest numbers of primary and secondary branches (4.9 and 5.3) were in T_2. Similarly, at 90 DAS, significantly highest number of primary and secondary

Table 1. Specifications of main components of developed machine

Components	Dimensions, mm
	a. Subsoiling unit
Leg (lxwxt)	900x200x25
Share	350x80x30
Wing plates (2 Nos.)	600x100x6
Gusset plates (2 Nos.)	330x100x60
Side plates /Shoe (2 Nos.)	500x100x15
Shin	500x25x25
Covering plate	150x100x6
Rake angle of share and wings	22^0
Sweep angle of a wing	35^0
Clearance angle	5^0
Angle between wing and side horizontal plane	5^0
Diameter of depth control wheels	325
Hitch system	Category-II
Frame (lxw)	1400x750 of 85x85 mm cross
	b. Organic manures / soil amendments metering and placement unit
Hopper size	0.33 m^3 for 200 kg vermicompost
Gear reduction unit	10 : 1
Pulley	300 mm o.d. double groove type
	Screw conveyor metering system
Diameter of shaft	26.0
Size of screw	62.5 (o.d.)
Circular casing	72.0
Pitch of screw	50.0
Length of screw	610.0
Thickness of screw flight	2.0
Number of bearings	3

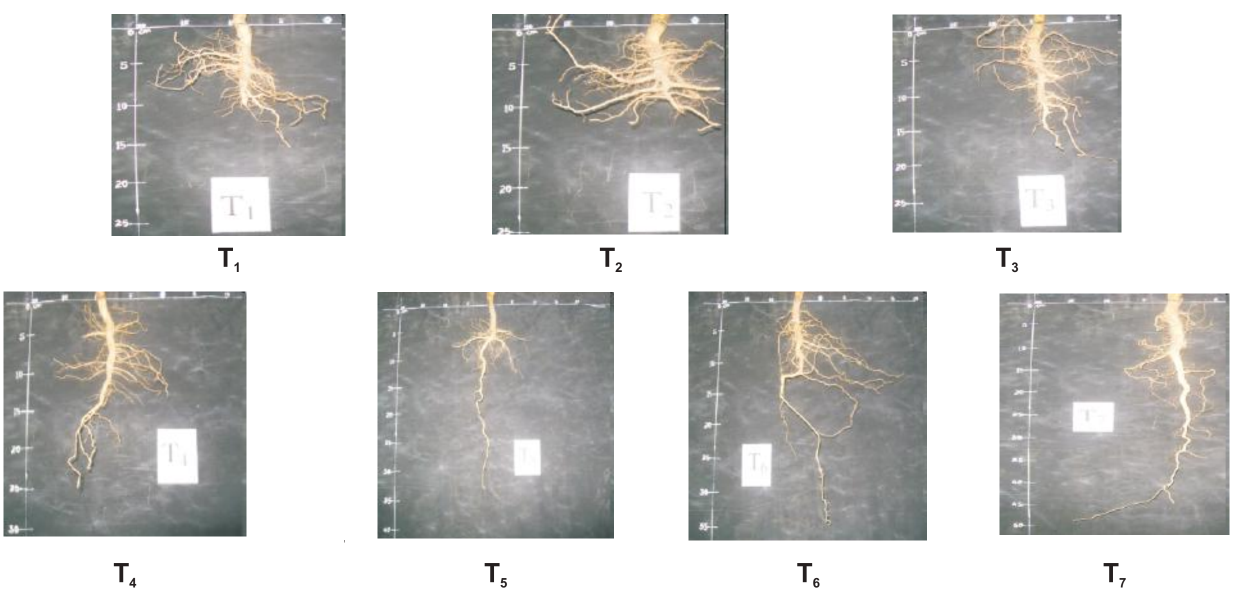

Fig. 2. Views of mustard crop roots at harvest in different treatments under field experiments

branches were obtained in treatment T_7 followed by T_6 T_5 8 and T_4 9. However, at harvest significantly higher number of primary (8.2), secondary (9.9) and tertiary (4.7) branches were in T_7 followed by T_6, T_5 and T_4, respectively Significantly lowest number of primary (5.2), secondary (6.3) and tertiary (3.2) branches were found in T_1 (control).

Root length: The placement of 50% N through inorganic fertilizer at 200 mm + 50% N through organic manure at 400 mm (T_7) had significant effect on root length of mustard crop. Significantly the highest root length was obtained in treatment T_7 (453 mm) followed by T_5 and T_6. The higher root length may be due to subsoiling up to 400 mm depth and placement of vermicompost and fertilizers at deeper depths which provided passage for easy penetration of roots to deeper soil layers in search of water and nutrients However, significantly lowest root length of 137 mm was obtained with 50% N through inorganic fertilizer + 50% N through vermicompost + mixing in 100 mm (T_2). In T_1 and T_2, where the tillage and placement of fertilizers was limited to top 100 mm depth of soil, the main tap root terminated at around tilling depth (100 mm) and roots grew laterally. However, the treatments with subsoiling and deep placement of fertilizers clearly indicate deeper penetration of the main tap roots to a depth of more than 500 mm (T_7). It is also evident that most of the primary and secondary roots have spread around 150 mm depth irrespective of treatments

Root density: There is no significant difference among root density of different treatments (Table 1; Fig. 2). However, the highest root density of 0.54 Mg/m^3 was obtained with placement of 50% N through inorganic fertilizer at 200 mm + 50% N through organic manure at 400 mm (T_7), which had significant effect on root length of mustard crop. The number of siliquae was generally higher in primary branches followed by secondary, main shoot and tertiary branches. The placement of vermicompost and inorganic fertilizers at different depths significantly increased the number of siliquae per plant (Table 3). The placement of 50% N and 100% P and K (inorganic) at 200 mm + 50% N (organic) at 400 mm (T_7) had significantly highest number of siliquae (482.5) followed by T_6 and T_5 (341.7). Significantly lowest number of siliquae (223.9) was noted in Control treatment (T_1).

Seed yield: The seed yield of mustard s at harvest was significantly higher (2.108 t/ha) with the placement of 50% N (inorganic) at 200 mm + 50% N (organic) at 400 mm depths (T_7) which is at par with T_6 (1.936 t ha^{-1}) with placement of 50% N (inorganic) + 50% N (organic) at 200 mm depth followed by T_5 (Table 3). Significantly lowest seed yield of

Table 2. Variations in crop parameters at different growth stages of mustard crop in field experiment

Treatments	Average plant height, m				Average plant girth, mm				Average number of branches							Root development at harvest			
	At 30 DAS	At 60 DAS	At 90 DAS	At harvest	At 30 DAS	At 60 DAS	At 90 DAS	At harvest	At 60 DAS		At 90 DAS		At harvest			Root length, mm	Root weight, g	Root vol., 10^{-6} m^3	Root density, Mg/m^3
									P	S	P	S	P	S	T				
T_1	0.13	1.20	1.76	1.89	9.60	12.60	13.60	14.70	5.9	5.3	5.0	7.0	5.0	6.0	3.2	151.0	9.7	20.33	0.48
T_2	0.16	1.17	1.85	1.95	11.10	12.90	13.50	13.70	4.9	5.3	5.5	6.6	6.3	6.6	3.3	137.0	11.7	26.7	0.44
T_3	0.13	1.25	1.93	1.95	12.30	14.70	16.10	16.40	5.9	6.1	5.7	8.7	6.5	7.3	3.9	240.0	10.5	21.3	0.49
T_4	0.15	1.28	1.95	1.95	13.50	14.30	15.50	16.60	7.0	6.3	6.1	6.9	6.7	7.5	3.7	260.0	13.5	27.0	0.50
T_5	0.13	1.32	2.14	2.16	12.30	15.60	15.80	15.90	7.0	6.1	6.7	6.8	7.1	8.1	4.4	358.0	14.7	31.0	0.48
T_6	0.12	1.32	1.93	2.05	13.90	16.00	16.90	17.30	7.6	6.7	6.9	10	7.6	8.9	4.5	356.0	16.0	31. 7	0.51
T_7	0.14	1.35	2.12	2.14	15.80	19.60	19.70	20.20	8.2	7.3	8.7	9.2	8.2	9.9	4.7	453.0	22.5	41.7	0.54
CD (p=0.05)	0.02	0.04	0.13	0.09	2.18	1.71	1.29	1.16	1.1	0.9	0.7	1.2	0.5	1.1	0.6	10.1	2.2	5.7	NS

P =Primary, S = Secondary, T = Tertiary

Table 3. Yield attributes of mustard crop in field experiment

Treatments	Yield attributes						
	No. of siliquae per plant	Seed yield (t/ha)	Stover yield, (t/ha)	Harvest index, (%)	Test (1000- seed) weight, (g)	Oil content, (%)	Oil yield, (t/ha)
T_1	223.9	1.720	5.638	23.494	4.13	40.12	0.690
T_2	246.7	1.751	6.105	22.402	4.22	40.35	0.707
T_3	283.9	1.738	6.346	21.630	4.09	40.23	0.699
T_4	286.1	1.783	6.598	21.297	4.28	39.75	0.709
T_5	341.7	1.911	6.780	22.002	4.21	39.64	0.758
T_6	401.0	1.936	6.923	21.850	4.39	39.59	0.766
T_7	482.5	2.108	7.693	21.498	4.45	39.75	0.838
CD (p=0.05)	40.36	0.19	0.99	NS	NS	NS	0.078

1.720 t ha^{-1} was obtained in T_1 (control). The higher seed yield in treatment T_7 may be due to better plant vigour throughout

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Development of Water Resources Through Rejuvenating Rivulets to Mitigate The Drought Conditions in Rainfed Agriculture

S. M. Taley, K. A. Jadhav[1], V. P. Ubarhande[1] and A. N. Mankar[2]

Department of Soil and Water Conservation Engineering; [1]Agro-Ecology and Environment Centre
[2]Department of Agricultural Engineering
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola-44 4 104, India
E-mail: smtaley@rediffmail.com

Abstract: The experiment was conducted on the rivulet of about 2 km length provided with six check dams (CNBs) in series. During the study 16 open wells located on both sides of stream in 200 ha area were monitored before and after rejuvenation. The result shows that the average maximum ground water fluctuation was 5.16 m before and 7.01 m (2013) and 3.32 m (2014) after widening and deepening in October, 5.16 m before and 7.01 m (2013) and 3.32 m (2014) after rejuvenatingin the month of October.The average gravity yield was observed 1.81 per cent before and 6.54 per cent (2013) and 3.27 per cent (2014) after rejuvenating rivulets. The analysis of pumping test revels that the average recovery of the well enhanced from 7 m^3 hr^{-1} to 10.74 m^3 hr^{-1} i.e. 35 per cent. Results indicate that the water availability in the aquifer was enhanced by 10 times and 6 times in the month of April and gravity yield by 3 times and 2 times in 2013 and 2014, respectively, as a result of rejuvenating rivulets provided with check dams in series. Thus, by rejuvenating rivulets the water resources can be strengthen to mitigate the drought conditions.

Key Words: Ground water, Gravity yield, Hydraulic drop, Rivulets, Rainfed agriculture

The most significant large-scale environmental challenge that many countries, especially in the arid and semi-arid regions are water scarcity problems, which are attributed to climate change impacts such as temperature increase, abundance of high solar radiation, and aridity in addition to population pressure. The current water resources use has already exceeded sustainable and renewable supply. Various methodologies are suggested to increase the sources of water supply, among which one of the alternatives is rainwater and runoff harvesting. Water scarcity and additional stress are among the most specific problems in arid and semi-arid regions. Present global warming, climate change impacts, and their future patterns are expected to cause increase in the evapotranspiration rates and hence reduction in the groundwater recharges. Under such circumstances, any simple but effective water storage augmentation facility as the artificial groundwater recharge gains vital importance for sustainability of water supply and survivals such ecosystems. It is, therefore, necessary to enhance artificial groundwater recharge from consequent frequent runoffs through suitable hydraulic structures.

In many regions having limited water resources, including surface or sub-surface water, the available water is no longer sufficient to cover the ever increasing water demand. For this reason, groundwater is used in irrigation to cover the shortages. As a consequence, excessive pumping of ground water is being practiced, which is leading to fall of water tables. Thus, water scarcity is one of the major challenges being faced by farmers.The limitation of water sources, rising water demand in addition to mismanagement of water resources is contributing to the water scarcity problems (Prinz and Singh, 2000).

Most of the Maharashtra is underlain by rocks called “Basalt”. These rocks show extreme diversity in ground water conditions on account of the heterogeneous conditions in the basalt. Water level depletion in basalt and associated alluvium is not just a consequence of reduced recharge to underlined aquifers, but also due to large scale pumping of groundwater from the different part of the aquifer. Desilting is the one avenue for exposing underlying aquifers and recharging them. However, if the most ground water flows towards a stream and then downslope along its channel, the most stream channels are in the ground water discharge zones of the stream although some of those acts as recharge zones only seasonally. De-siltation, widening, deepening of rivulets and other water bodies like farm ponds and construction of RCC Cement Nallah Bandh (CNB) in series play a major role in catching runoff and storing rainwater in beats. From one check dam atleast about 8 to 10 ha irrigation potential can be created directly or indirectly through surrounding wells. Encouraging trends of utilization pattern of check dams (CNB's) constructed under various programmes in recent decades reiterates the need for rejuvenating rivuletsand construction of small-scale runoff harvesting structures. This activity is useful for the augmentation of water resources and to moderate the hydrology of the large farms of the university.

Excess runoff harvested in the farm pond and check dams recharges existing wells. Further, with conserved water applied through micro-irrigation systems such as drip and sprinkler irrigation, it will be possible to double the area of protective irrigation. Experiences elsewhere suggest that scientific approach for *in-situ* conservation and harvesting of rainwater provide substantial benefits by not only facilitating lifesaving irrigation at critical periods and creating opportunities for second sowing but also by ensuring effective management of assets created. In view of above by considering the Geological formations and non-availability of the adequate perennial water source "Rejuvenating rivulets on ground water potential" in concurrence to the geological profiles, topography and soils, the study was undertaken to study the ground water fluctuations, compute gravity yield and ground water storage and determine the aquifer parameters.

MATERIAL AND METHODS

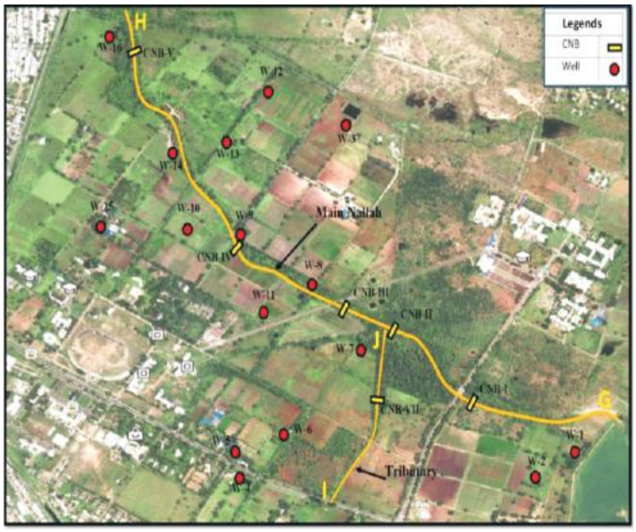
Akola is located at latitude 20.7° North and longitude 77.07° East. It is at an altitude of 282m above sea level. The rivulet of 2 km length was selected for the study. Topography is very gently sloping. Soils are moderately eroded, well drained and classify as fine clayey, montmorillonitic (calcareous) and hyperthermic family of Udic Chromusters. The geology comprises predominantly to volcanic rocks consisting chiefly of basalt.

The climate is semiarid monsoonic characterised by three distinct season Summer with hot and dry weather from March to May. Monsoon with warm and rainy from June to October and winter with dry mild cold from November to February. The average precipitation is about 815 mm distributed over the 48 rainy days in the year. During the last decade the rainy days reduced up to 39 days and about 86 per cent of the mean annual rainfall received during monsoon period in 35 rainy days (June to September). Temperature ranges from 30 to 46^{o}C.

Considering the geology, climate, topography and soils classification, peak runoff rate of rivulets, which located at average elevation of 293 to 324m above mean sea level was calculated. For the purpose of the study, the pilot project was implemented.

The deepening and widening of existing rivulets was carried out as shown in Map1. The average top and bottom width of rivulets was increased up to 10 to 12m and 6 to 7 m respectively and the depth was increased up to 3 m. The CNB's were constructed in series by maintaining bottom of the CNB at upstream side to the top of the CNB (HFL) of the downstream with the height of 2 to 2.5 m. In this fashion, all the CNB's were constructed in series in view to store the runoff in beats. After deepening and widening, the depressions were created of 100 m length, 4-5 m width and 0.3 m depth in between the two CNB's along the drainage network to increase the storage capacity and opportunity time to conserve the water.

The study of impact of deepening, widening and construction of CNB's in series on ground water fluctuationswas carried out by monitoring 16 open wells located around the drainage network (GH and IJ) as shown in Map 1.



Map 1. Drainage network of study area

The data related to precipitation, surface runoff, ground water fluctuations and open pan evaporation were recorded. Precipitation (daily rainfall) was recorded by automatic siphon type recording rain gauge. The surface runoff from the watershed was measured with the help of 'H' flumes and Automatic stage level recorders. The total evapotranspiration from the study area was calculated by the methods suggested by Gulati and Murty (1979). To record the ground water fluctuations, 16 open wells in study area spread around the drainage network were selected as shown in Map 1. The water table depths were measured once every week during the monsoon season and fortnightly during the pre and post monsoon season, with the help of electrical water level indicator. The reduced level of ground water were obtained by subtracting the recorded water table depths from the reduced levels of top of wells. This difference was further subtracted from the elevations of top of wells above MSL in order to express the ground water elevations with reference to MSL.

The gravity yield (Y_g) is the percent of rainfall directly contributing to the ground water. The gravity yield of each observation wells was calculated by the equation,

$$Y_g = \frac{S_g}{H} = \frac{P - R - ET}{H} \times 100$$

Where,

Y_g = gravity yield (ground water recharge, %)

S_g = change in ground water storage, mm

H = difference in ground water elevation at each well, mm

P = total precipitation, mm

R = Cumulative surface runoff, mm

ET = seasonal evapotranspiration, mm

Average gravity yield (Y_g) for the study area was calculated and the monthly ground water storage per unit area (S_g/area) was calculated by the equation,

$$S_g \quad Y_g \quad H$$

These values of S_g/area were further converted for whole watershed area.

Pumping test: Pumping test was performed to estimate the hydraulic properties of aquifers including hydraulic conductivity, transmissibility, hydraulic resistance and leakage factor which are discussed below. Standard procedure was adopted for conducting the pumping test and drawdown and recovery data of the well was recorded. The drawdown and recovery was recorded for 6 hours and 30 minutes and the details are presented in Table 9.For the study it was assumed that the flow in the aquifer is steady and the well is unconfined. The well selected for the test was 10.43m deep with 7.5 m diameter. The discharge of pump was 3 lps.

Hydraulic conductivity: Hydraulic conductivity is a measure of a material's capacity to transmit water and it was calculated by equation (Darcy's law).

í = -Ki

Where í is specific discharge (m sec^{-1}), K is hydraulic conductivity (m day^{-1}) and i ishydraulic gradient.

Transmissivity: The transmissivity of an aquifer is related to its hydraulic conductivity as follows

T = Kb

Where, T is transmissivity (m^2 day^{-1}) and b is aquifer thickness (m).

Hydraulic resistance: Hydraulic resistance was calculated by

$$c \quad \frac{B^2}{Kb}$$

Where c is hydraulic resistance (days), B is leakage factor (m), K is hydraulic conductivity of aquifer(m day^{-1}) and b is aquifer thickness (m)

Leakage factor: The leakage factor was calculated by

$$B \quad \sqrt{Kbc}$$

Where B is leakage factor (m), K is hydraulic conductivity of aquifer (m day^{-1}), b is aquifer thickness (m) and c is hydraulic resistance (days).

RESULTS AND DISCUSSION

During the year 2012-13, 612.9mm total rainfall was recorded. The surface runoff was estimated as 49.032mm (8%) of the rainfall. The average evapotranspiration over the season was observed to be 499.73mm. The monthly fluctuations in the ground water levels for the period June 2012 to April 2013 were calculated with respect to the water levels in the month of May 2012, which was considered as the driest month.During the year 2013 (June to September) total rainfall was 774.1 mm and surface runoff was estimated as 61.93 mm (8%) of the rainfall was recorded. The average evapotranspiration over the season was observed to be 411.95 mm. The monthly fluctuations in the ground water levels for the period June 2013 to February 2014 were calculated with respect to the ground water levels in the month of May 2013, which was considered as the driest month.During the year 2014 (June to September) total rainfall recorded was 570 mm. The surface runoff was estimated as 45.6 mm of the rainfall. The average evapotranspiration over the season was observed to be 412.79 mm. The monthly fluctuations in the ground water levels for the period July 2014 to March, 2015 were calculated with respect to the ground water levels in the month of June 2014, which was considered as the driest month.

The data indicates that the average maximum water fluctuation was observed 5.16 m before and 7.01 m (2013) and 3.32 m (2014) after rejuvenating in the month of October. The maximum groundwater fluctuation was observed to 7.33 m before rejuvenatingfor 10 followed by well 14 as 6.7 m. The maximum groundwater fluctuation was observed to 10.95 m (2013) for well 10 followed by well 14 as 6.7 m and 9.0 m (2013) in October after rejuvenating. The maximum groundwater fluctuation was observed to 5.45 m (2014) for well1 followed by well 5 as 5.07 m (2014) in October after rejuvenating. The water level fluctuation in the wells with respect to the driest May was observed enhanced after rejuvenating rivulets. The average gravity yield was observed as 1.81 per cent before and 6.54 per cent (2013) and 3.27 per cent (2014) after rejuvenating rivulets (Table 2, 5 and 8).

During the year 2013-14 volume of water stored in CNB-I, II, III, IV and V was observed to the tune of 48.94, 8.65 and 35.53m^3, 44.76 and 50.55 (000m^3), respectively and water lost through evaporation was observed about 3.55, 0.63, 2.29, 2.97 and 4.79 (000m^3), respectively. About 45.39,

Table1. Runoff stored and Recharge in CNB (2013-14 and 2014-15)

Structure	Back water spreading (m)	Maximum storage capacity (000 m^3)	Volume of water stored (000 m^3)		Evaporation loss (000 m^3)		Water recharge (000 m^3)	
			2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
CNB-I	450	9.37	48.94	24.39	3.55	1.3	45.39	23.09
CNB-II	250	2.67	8.65	7.3	0.63	0.21	8.02	7.09
CNB-III	275	5.72	35.53	15.51	2.29	0.81	33.25	14.7
CNB-IV	450	9.37	44.76	24.12	2.97	1.22	41.79	22.9
CNB-V	780	9.95	50.55	24.8	4.79	1.51	45.76	23.29
Total	2205	37.08	188.43	96.12	14.23	15.05	174.21	91.07

Table 2. Computation of gravity yield of the wells before rejuvenating rivulets (2012-13)

Well no.	ΔH (mm)	Rainfall (mm)	Runoff (mm)	ET (mm)	Gravity yield yg (%)
W1	3340	612.9	49.032	499.73	1.92
W2	3250	612.9	49.032	499.73	1.97
W3	3770	612.9	49.032	499.73	1.70
W4	3500	612.9	49.032	499.73	1.83
W5	3740	612.9	49.032	499.73	1.71
W6	3390	612.9	49.032	499.73	1.89
W7	3270	612.9	49.032	499.73	1.96
W8	5520	612.9	49.032	499.73	1.16
W9	5630	612.9	49.032	499.73	1.14
W10	6690	612.9	49.032	499.73	0.96
W11	5100	612.9	49.032	499.73	1.26
W12	1580	612.9	49.032	499.73	4.06
W13	2040	612.9	49.032	499.73	3.14
W14	5150	612.9	49.032	499.73	1.25
W15	5030	612.9	49.032	499.73	1.28
W16	3730	612.9	49.032	499.73	1.72
Average gravity yield (%)					1.81

Table 3. Computation of monthly ground water storage before rejuvenating rivulets (2012-13)

Month	Av. H (cm)	H (cm)	Av. Y_g (%)	S_g/area (cm)	S_g (ha-m)	*cum. S_g (ha-m)
May, 2012	0	0	1.81	0.00	0.00	0.00
June, 2012	50	50	1.81	0.91	1.81	1.81
July, 2012	158	108	1.81	1.95	3.91	5.72
August, 2012	324	167	1.81	3.02	6.05	11.77
September, 2012	454	130	1.81	2.35	4.71	16.47
October, 2012	516	61	1.81	1.10	2.21	18.68
November, 2012	499	-16	1.81	-0.29	-0.58	18.10
December, 2012	424	-75	1.81	-1.36	-2.72	15.39
January, 2013	351	-73	1.81	-1.32	-2.64	12.74
February, 2013	269	-82	1.81	-1.48	-2.97	9.77
March, 2013	205	-64	1.81	-1.16	-2.32	7.46
April, 2013	130	-75	1.81	-1.36	-2.72	4.74

* Cumu. ?S_g is the total ground water storage (ha-m) available in aquifer

8.02 and 33.25, 41.79 and 45.76 (000m^3) of water recharged into the soil profile through CNB-I, II, III, IV and V, respectively (Table 1). Total groundwater recharge was observed 174.21 (000m^3). During the year 2014-15 volume of water stored in CNB-I, II, III, IV and V was observed to the tune of 24.39,7.3, 15.51, 24.12 and 24.80 (000m^3), respectively and water lost through evaporation was observed about 1.30, 0.21,0.81, 1.22 and 1.51 (000m^3), respectively. About 23.09, 7.09, 14.70, 22.90 and 23.29 (000m^3) of water recharged in to the soil profile through CNB-I, II, III, IV and V, respectively. Total groundwater recharge was observed 91.07 (000m^3).

Ground water status: The minimum hydraulic drop was observed 14.23 m before and 13.57 m in the month of August 2013 and 13.70 m in the month of July 2014 after rejuvenating rivulets (Table 5). The increase in cumulative ground water storage was observed from June (1.81 ha-m) to the October (18.68 ha-m) before and 12.03 ha-m in June (2013) to 91.69 ha-m in October (2013) and 10.14 ha-m in the month of August (2014) to 21.71 ha-m in October (2014) after rejuvenating rivulets. Onward the month of October the cumulative storage was observed decreased and minimum 9.77 ha-m before and 59.64 ha-m (2013) and 9.48 ha-m (2014) after rejuvenating rivuletsin the month of February. The contour maps of the ground water potential for the study area of 200 ha. shown in Fig. 1 for the month of August and September (2012, 2013 and 2014) clearly indicates the impact of rejuvenating rivuletson ground water potential.

Pumping test: Figure 2 and 3 shows the trend of drawdown

Table 4. Computation of gravity yield of the wells after rejuvenating rivulets (2013-14)

Well no.	H (mm)	Rainfall (mm)	Runoff (mm)	ET (mm)	Gravity yield, Yg (%)
W1	4755	774.1	61.928	411.95	6.31
W2	4572.5	774.1	61.928	411.95	6.56
W3	5740	774.1	61.928	411.95	5.23
W4	4953	774.1	61.928	411.95	6.06
W5	7158.5	774.1	61.928	411.95	4.19
W6	5332.5	774.1	61.928	411.95	5.63
W7	5670.5	774.1	61.928	411.95	5.29
W8	5784.5	774.1	61.928	411.95	5.19
W9	4395	774.1	61.928	411.95	6.83
W10	5996.5	774.1	61.928	411.95	5.00
W11	5778.5	774.1	61.928	411.95	5.19
W12	3095	774.1	61.928	411.95	9.70
W13	4332.5	774.1	61.928	411.95	6.92
W14	5664	774.1	61.928	411.95	5.30
W15	1995	774.1	61.928	411.95	15.04
W16	4829.5	774.1	61.928	411.95	6.21
Average gravity yield (%)					6.54

Table 5. Computation of monthly ground water storage after rejuvenating rivulets (2013-14)

Month	Av. H (cm)	H (cm)	Av. Y_g (%)	S_g/area (cm)	S_g (ha-m)	cum. S_g (ha-m)
May	0	0	6.54	0.00	0.00	0.00
June	92	92	6.54	6.02	12.03	12.03
July	278	186	6.54	12.16	24.33	36.36
August	592	314	6.54	20.54	41.07	77.43
Sept.	634	42	6.54	2.75	5.49	82.93
Oct.	701	67	6.54	4.38	8.76	91.69
Nov.	630	-71	6.54	-4.64	-9.29	82.40
Dec.	553	-78	6.54	-5.10	-10.20	72.20
Jan.	507	-45	6.54	-2.94	-5.89	66.32
Feb.	456	-51	6.54	-3.34	-6.67	59.64

Table 6. Computation of gravity yield of the wells before rejuvenating rivulets (2014-15)

Well no.	H (mm)	Rainfall (mm)	Runoff (mm)	ET (mm)	Gravity yield, Yg (%)
W1	3745.0	570	45.6	412.79	2.98
W2	4440.0	570	45.6	412.79	2.51
W3	3880.8	570	45.6	412.79	2.88
W4	4072.5	570	45.6	412.79	2.74
W5	5162.5	570	45.6	412.79	2.16
W6	3441.6	570	45.6	412.79	3.24
W7	3755.0	570	45.6	412.79	2.97
W8	3218.3	570	45.6	412.79	3.47
W9	2635.0	570	45.6	412.79	4.24
W10	2681.6	570	45.6	412.79	4.16
W11	2952.5	570	45.6	412.79	3.78
W12	2980.0	570	45.6	412.79	3.75
W13	3287.5	570	45.6	412.79	3.39
W14	2857.5	570	45.6	412.79	3.91
W15	3273.3	570	45.6	412.79	3.41
W16	4197.5	570	45.6	412.79	2.66
Average gravity yield (%)					3.27

Table 7. Computation of monthly ground water storage before rejuvenating rivulets (2014-15)

Month	Av. H (cm)	H (cm)	Av. Y_g (%)	S_g/area (cm)	S_g (ha-m)	cum. S_g (ha-m)
May-2014	0	0	0.0327	0.00	0.00	0.00
June	0	0	0.0327	0.00	0.00	0.00
July	-33	-33	0.0327	-1.08	-2.16	-2.16
August	155	188	0.0327	6.15	12.30	10.14
September	321	166	0.0327	5.43	10.86	20.99
October	332	11	0.0327	0.36	0.72	21.71
November	253	-79	0.0327	-2.58	-5.17	16.55
December 2014	178	-75	0.0327	-2.45	-4.91	11.64
January-2015	216	38	0.0327	1.24	2.49	14.13
February	145	-71	0.0327	-2.32	-4.64	9.48
March	72	-73	0.0327	-2.39	-4.77	4.71

Table 8. Gravity yield, cumulative storage and hydraulic drop before and after rejuvenating rivulets

Month	Before widening and deepening 2012-13			After widening and deepening					
				2013-14			2014-15		
	Av. Y_g (%)	Hydraulic drop (m)	cum. S_g (ha-m)	Av. Y_g (%)	Hydraulic drop (m)	cum. S_g (ha-m)	Av. Y_g (%)	Hydraulic drop (m)	cum. S_g (ha-m)
May	1.81	17.42	0.00	6.54	16.23	0.00	3.27	13.33	0.00
June	1.81	16.73	1.81	6.54	14.48	12.03	3.27	13.04	0.00
July	1.81	16.17	5.72	6.54	13.97	36.36	3.27	13.70	-2.16
Aug.	1.81	14.23	11.77	6.54	13.57	77.43	3.27	15.08	10.14
Sept.	1.81	14.83	16.47	6.54	15.11	82.93	3.27	14.70	20.99
Oct.	1.81	14.58	18.68	6.54	13.81	91.69	3.27	14.38	21.71
Nov.	1.81	15.25	18.10	6.54	13.98	82.40	3.27	14.83	16.55
Dec.	1.81	15.41	15.39	6.54	14.28	72.20	3.27	15.19	11.64
Jan.	1.81	15.19	12.74	6.54	14.65	66.32	3.27	14.92	14.13
Feb.	1.81	15.51	9.77	6.54	15.13	59.64	3.27	15.15	9.48

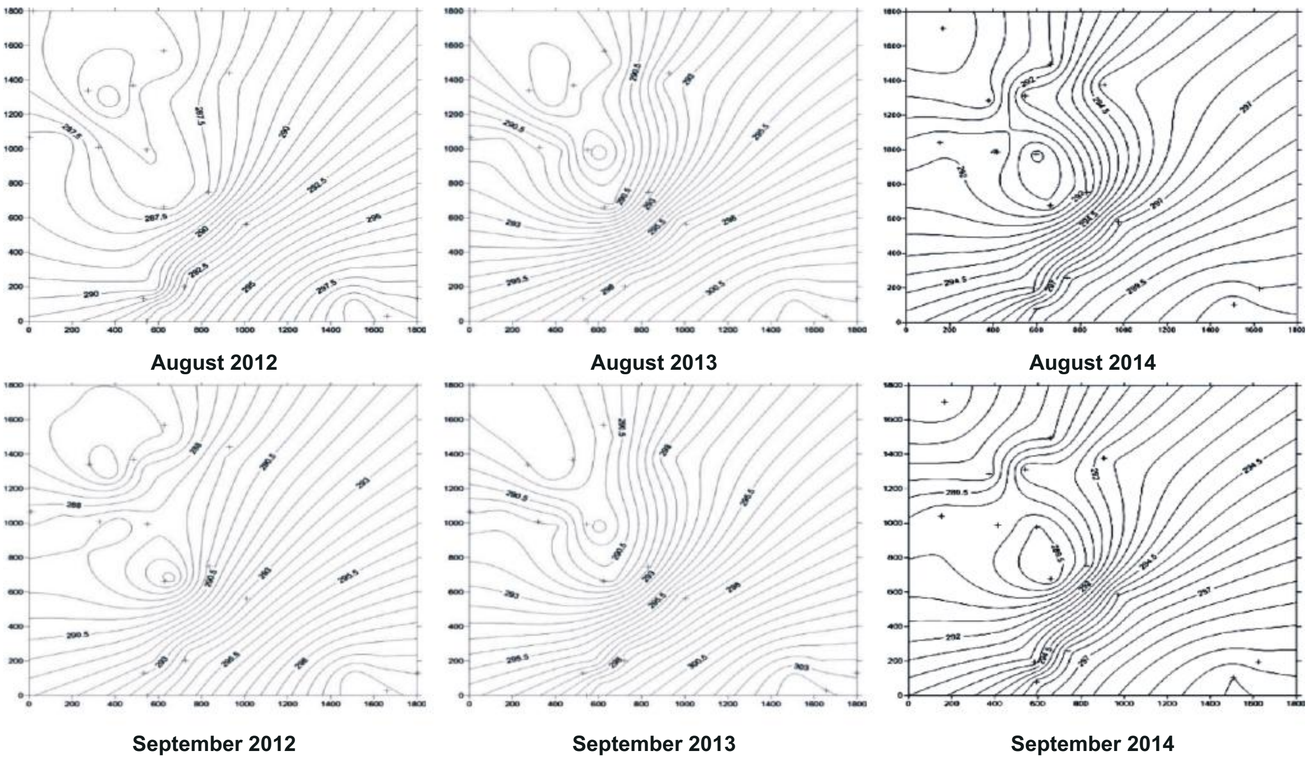


Fig. 1. Contour map of ground water fluctuations in the month of August and September during 2012, 2013 and 2014

Table 9. Details of drawdown test

Elapsed time t (min)	Drawdown		Recovery		
	Depth of water level in the well (m)	Drawdown S (m)	Depth of water level in the well (m)	Recovery (m)	Amount of water (m^3)
0	2.48	0.37	4.29	0.31	13.69
30	2.85	0.27	3.98	0.24	10.60
60	3.12	0.23	3.74	0.22	9.71
90	3.35	0.17	3.52	0.17	7.51
120	3.52	0.15	3.35	0.13	5.74
150	3.67	0.1	3.22	0.07	3.09
180	3.77	0.11	3.15	0.07	3.09
210	3.88	0.1	3.08	0.05	2.21
240	3.98	0.1	3.03	0.05	2.21
270	4.08	0.06	2.98	0.05	2.21
300	4.14	0.08	2.93	0.05	2.21
330	4.22	0.05	2.88	0.03	1.32
360	4.27	0.02	2.85	0.02	0.88
390	4.29		2.83		
				Total	64.47
				Avg./hr	10.74

and recovery of the well observed during the pumping test. The average recovery of the well was found enhanced by 35% from 7 $m^3 hr^{-1}$ to 10.74 $m^3 hr^{-1}$ (Table 9).

On the basis of drawdown and recovery trend the aquifer parameters were determined and average values of the aquifer parameters are given below -

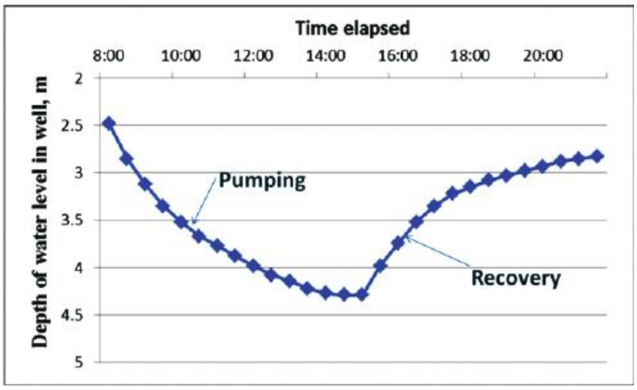


Fig. 2. Trend of drawdown and recovery in the well

Aquifer parameters determined by pumping test are

Aquifer parameters	Values
Hydraulic conductivity (K)	2.79 x 10^{-5} m sec^{-1}
Transmissibility (T)	2.91 x 10^{-4} m^2 sec^{-1}
Hydraulic resistance ©	37.72 min
Leakage factor (B)	0.1 m

From the results it was concluded that due to rejuvenating rivuletsin the watershed gravity yield of aquifer enhanced subsequently by 1.8 to 3.5 times. The well water levels in the study area increased drastically as a result the ground water storage (ha-m) in the study area was enhanced by 1.5 to 5 times. Thus, the rejuvenating rivuletsin the watersheds can strengthen the surface and subsurface water resources.The enhanced water resources can useful for protective irrigation to the crops during moisture deficit period.

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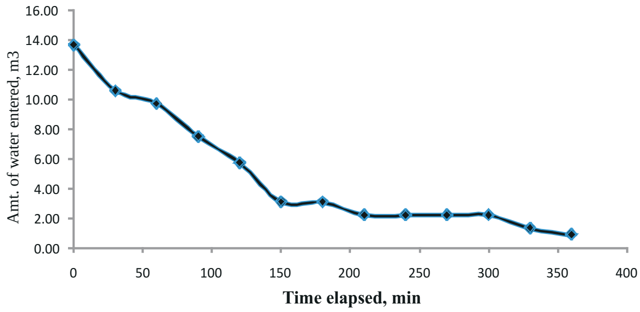

Fig. 3. Trend of recovery of water into the well

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Assessment of Areas Vulnerable to Soil Erosion and Deposition in a Himalayan Watershed

S. S. Rawat, Pradeep Kumar and P. G. Jose

Western Himalayan Regional Centre, National Institute of Hydrology, Jammu-180 003, India
E-mail: soban.singh@gmail.com

Abstract: The United Nations Environmental Program reported that the productivity of soil has reduced, resulting in economically unfeasible cultivation on about 20 million hectare of land each year due to soil erosion and resulting degradation of land. The eroded soil is also a major reason for loss of storage capacity (1 to 2% annual reduction globally) of multipurpose reservoirs due to sedimentation which affects society at large. In developing countries like India, limited data availability constrains the application of sophisticated models for proper planning of erosion control measures. In the present study, a simple spatially distributed model has been formulated in GIS environment for mapping areas vulnerable to soil erosion and deposition in a Himalayan watershed from India. The model discretizes the spatial domain of catchment into homogenous grids/cells to capture the catchment heterogeneity. The developed model estimated sediment yield with very high accuracy i.e. 0.6%, -1.1% and -10.8% deviations were found during the respective years of validation. Study reveals that soil loss in about 10.6% of area of studied watershed is above soil loss tolerence limit, which is defined as the acceptable rate of soil erosion at which the quality of a soil as medium for plant growth can be maintained. Finally, the entire watershed has been classified into six different severity levels of erosion i.e. slight, moderate, high, very high, severe and very sever. Such maps have immense significance to prioritize area specific watershed conservation and management measures.

Key Words: GIS, RS, Soil erosion, Sediment yield, Transport capacity, USLE

Soil erosion is a serious problem in Himalayas and foothill ecosystem. Eighty percent of the sediment material delivered to the world's oceans each year comes from Asian rivers, and amongst these, Himalayan rivers are the major contributors (Stoddart, 1969). The Himalayan and Tibetan regions cover only about 5% of the earth's land surface but supply about 25% of the dissolved load to the world ocean (Raymo and Ruddiman, 1992). Although, Himalayan region is hydrologically very important as it is the origin of three world's major river system viz. the Indus, the Ganges, and the Brahmaputra but very few studies have been reported on rainfall, runoff and its induced sediment yield processes in this region. In Himalayan or mountainous regions the data whether on economic, social, or environmental are usually incomplete when they exist at all. Therefore, lack of scientific knowledge about this planet's most complex landscape is main hurdle to plan the developmental agenda for this region.

Soil erosion and subsequent sediment outflow from a watershed are dependent on several parameters which are responsible for the soil detachment and the transport capacity of the path followed by the eroded soil to reach the outlet. However, lack of detailed data with respect to these parameters at river catchment scale is a major constraint in estimation of sediment yield at catchment scale (Van Rompaey *et al*., 2001). Therefore, a simple empirical lumped sediment delivery ratio (SDR) approach is used to link the soil erosion within a watershed to the sediment yield at outlet (Ferro and Minacapilli, 1995). Since, SDR-based sediment yield estimation approach is an empirical lumped approach (Verstraeten and Poesen, 2001), it performs well only if the data of catchment belongs to inherent region. Applications of such empirical approach to other catchments are questionable and require rigorous calibration before extension. Also due to lumped nature of SDR approach, it is not helpful in prioritization of watershed management/ treatment activities within a river basin/catchment. However, soil erosion and sediment yield exhibit large spatial variability due to heterogeneity involved in various parameters (catchment physical as well as climatic) responsible for theirs occurrence. The technique of Geographical Information System (GIS) is well suited for quantification of heterogeneity (not only in space but also in time) in the topographic, cover type, and drainage features of a watershed by partitioning the watershed into small homogenous grids (Jain *et al*., 2005; Wu *et al*., 2005; Naik *et al*., 2009). Furthermore, accessibility of data even in remote areas like Himalayan catchment is the major advantage of GIS and remote sensing (RS) techniques.

Keeping in view, limited data availability in Himalayan catchment and spatial variability and complexity involved in soil erosion and sediment production process, a simple spatially distributed model has been formulated in GIS environment. The model produces outputs showing spatial variability due to spatial discretization adopted and, therefore, helpful in identification as well as quantification of the areas vulnerable to soil erosion and deposition within entire catchment and accordingly prioritization of watershed management activities. However, model structure is kept simple so that the application of model can be easily extended in developing countries like India where availability of data in space and time is always a challenge.

MATERIAL AND METHODS

The proposed model comprises of three major components (1) the assessment of seasonal gross soil erosion (GSE) for each grid/cell; (2) the assessment of seasonal local transport capacity (TC) for each grid/cell; and (3) transport limited accumulation algorithm for routing sediment from each of the discretized grid/cell to the outlet of the catchment by taking into account the local transport capacity of each cell.

Estimation of gross soil erosion (GSE): Universal soil loss equation (USLE) produce realistic estimates of surface erosion over small size areas (Jain and Goel, 2002; Lee, 2004; Jain and Das, 2010). Although USLE is a lumped empirical model, this equation has been a part of several spatially distributed process-based models such as Soil and Water Assessment Tool (SWAT) (Arnold *et al*., 1993), Agricultural Nonpoint Source Pollution Model (AGNPS) (Young *et al*., 1989), Chemical Runoff and Erosion from Agriculture Management System (CREAMS) (Knisel, 1980), SedNet (Prosser *et al*., 2001) and Erosion Productivity Impact Calculator (Williams, 1983). This is possible due to the discretization of heterogeneous catchment into small homogeneous grids/cells. In this paper USLE is used for estimation of GSE within a cell is expressed as:

$$GSE_i = RK_i LS_i C_i P_i \qquad (1)$$

Where, GSE_i = gross amount of soil erosion in cell *i* (MT ha^{-1} $year^{-1}$); R = rainfall erosivity factor (MJ mm ha^{-1} h^{-1} $year^{-1}$); K_i = soil erodibility factor in cell *i* (MT ha h ha^{-1} MJ^{-1} mm^{-1}); LS_i = slope steepness and length factor for cell *i* (dimensionless); C_i = cover management factor (dimensionless) and P_i = supporting practice factor for cell *i* (dimensionless).

Estimation of USLE Input Parameters

Rainfall erosivity (R): Rainfall erosivity or erosion index (R) is one of the important parameters in estimation of soil loss from USLE. In the present study, rainfall erosivity was calculated by the relationship developed by Ram Babu *et al.* (2004) for this particular zone of India and presented as:

$$R = 71.9 + 0.361\ P \quad (r = 0.91, \text{ for } 293 \leq P \leq 3190) \qquad (2)$$

Where, *P* is the average seasonal rainfall in mm. In the present study, Equation 2 is used to compute seasonal values of *R*-factor by replacing *P* with observed seasonal rainfall of a particular year.

Soil erodibility (K): Soil map of the watershed was prepared by digitization of soil maps available in survey report obtained from National Bureau of Soil and Landuse Planning (NBSS&LUP, 2004) using ArcGIS. The digitized polygon map of study watershed was then rasterized at 90 m grid cells by using vector to raster tool. Based on the soil characteristics such as texture, depth, erosion, surface, drainage, and slope (NBSS&LUP, 2004), total nine soil mapping units have been identified in the entire study area. K-values for different soil categories were calculated according to the procedure given by Haan *et al.* (1994).

Length-Slope factor (LS): The combined length-slope (LS) factor reflects the effects of topography on soil erosion; however estimation of LS factor for real landscapes as part of a GIS is complex. The method proposed by Moore and Wilson (1992) based on unit stream power theory is best suited for integration with the GIS and given as:

$$LS_i = \left(\frac{A_{si}}{22.13}\right)^n \left(\frac{\sin\theta_i}{0.0896}\right)^m \qquad (3)$$

Where, A_{si} is the specific area at cell *i* defined as the upslope contributing area for overland grid (A_{up}) per unit width normal to flow direction; θ_i is the slope gradient in degrees for cell *i*. Upslope contributing area and slope gradient were estimated from Digital Elevation Map (DEM) of the study area. Since, preparation of DEM from toposheets is very tedious and time consuming work, Shuttle Radar Topographic Mission (SRTM) DEMs data downloaded from www.landcover.org/data/srtm/ were used for extraction of DEM in this study.

Crop management factor (C): To assign the spatial values of crop management factor (C), land use map of the study area was prepared by classification of LANDSAT TM satellite image using unsupervised and supervised classification in ERDAS image processing software. Overall, six different classes viz., forest, agriculture, river bed, pasture, water and settlement are identified in the study area with the help of limited ground truth information. Based on the land cover categories, the attribute values for the C-factor are assigned to individual cells from the tabulated values suggested by Haan *et al.* (1994).

Management practice factor (P): Based on experimental investigations, values for P-factor have been tabulated for many management conditions (Haan *et al.,* 1994). The P-factor is taken equal to 0.7 for agricultural land as mostly contour cultivation is followed on agricultural land in the study area, and unity for other land use/land cover types.

Assessment of seasonal sediment transport capacity: Sediment transport capacity expresses the erosive power of overland flow or channel flow which is responsible for the movement of eroded soil. In fact, the process of soil erosion and deposition is governed by the sediment transport capacity of overland flow and subsequent channel flow. Therefore, sediment transport capacity equation is an essential part of all physically based sediment yield computation models. Several simple to complex equations have been developed for estimation of transport capacity of different grid/cell within the catchment. One of the most recently developed (Verstraeten *et al.*, 2007) transport capacity equation is as follows:

$$TC_i \quad K_{TC} R K_i S_i^{\hat{a}} A_{si}^{\tilde{a}} \qquad (4)$$

Where, K_{TC} is transport capacity coefficient; A_{si} is the upslope contributing area for cell *i* which represents the actual flow accumulation value of any cell. Most of the transport capacity equations do not account the upslope contributing area and hence application of such models underestimates the sediment yield at the outlet of watershed. To overcome this problem Eq. 4 has been developed and successfully applied in hilly watershed especially in the areas where slope is drastically reduced.

Sediment routing using transport limited accumulation: Eroded sediment from each cell follows a definite path defined by direction of flowing water. The amount of sediment outflow from one cell to its downstream cell depends on local sediment transport capacity (TC) for a cell. If the local TC is smaller than the sediment flux, then sediment deposition is modeled. If TC is higher than the sediment flux, then sediment transport will be supply limited. Thus, by introducing the transport capacity, a more realistic representation of overland flow in sediment transport can be simulated. The model produces different maps of erosion, sediment transport, and sediment deposition rates. For cell-based discretization system, transport limited accumulation can be computed as:

$$T_{out_i} \quad \min(GSE_i \quad T_{in_i}, TC_i) \qquad (5)$$

$$D_i \quad GSE_i \quad T_{in_i} - T_{out_i} \qquad (6)$$

where $T_{in\,i}$ = sediment inflow from upstream cells, $T_{out\,i}$= sediment outflow from the cell *i*. D*i* = deposition in cell *i*.

Study area and data used: The proposed model has been used to model the sediment yield from a hilly watershed named Bino with elevation ranging from 824 m to 2885 m and geographically located between 29°47'N and 30°3'20''N latitudes and 79°06'15''E and 79°18'15''E longitudes in the middle Himalayan region of Uttarakhand state of India (Fig.1). Bino watershed is a hydrologically important sub-watershed of Ramganga reservoir catchment (3134 square km area). Ramganga reservoir, a multipurpose project (127 meter heigh earth and rockfill dam) of Government of India built in year 1974, produces approximately 452 MW of electricity and also facilitates irrigation on an area of about 5120 square km during non-monsoon period.

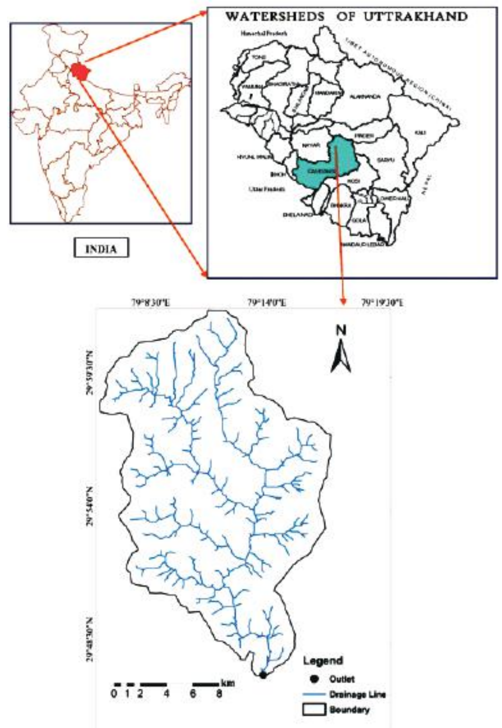

Fig. 1. Location map of Bino watershed

Bino watershed covers hilly portion of Ramganga catchment (295 square km drainage area) and is the largest sediment contributor to the reservoir. The topography of the watershed is undulating and irregular with slope varying from moderate to steep. Daily rainfall data of five raingauge stations located inside/outside of Bino watershed were collected from the Divisional Forest Office (Soil Conservation) Ranikhet, Government of Uttarakhand and used to calculate the weighted rainfall of Bino watershed.

RESULTS AND DISCUSSIONS

Generation of gross soil erosion maps: The layers of topographic factor (LS), crop management factor C, soil erodibility factor K, and support practice factor P are overlaid using ArcGIS. For estimation of gross soil erosion in the watershed for different years/season, the composite map of KLSCP factor is multiplied by R-factor in raster calculator of ArcGIS. Figure 2 represents gross soil erosion map of Bino watershed for the year 1987 as illustration.

Generation of transport capacity maps: Transport capacity of overland flow was calculated for each season and each pixel using equation (4) in ArcGIS. Goodness of fit criteria such as Model Efficiency (ME), (Nash and Sutcliffe, 1970) and Relative Root Mean Square Error (RRMSE) have

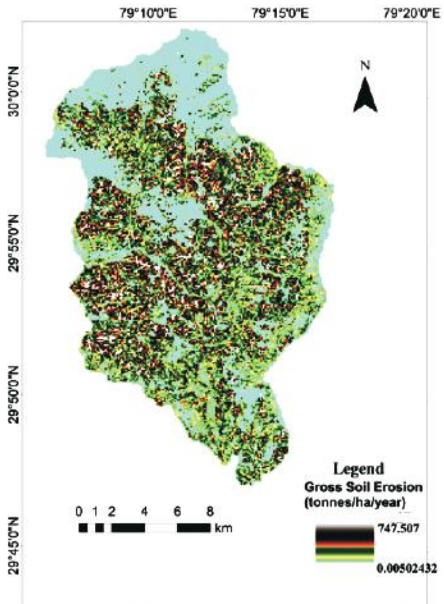

Fig. 2. Gross soil erosion map of Bino watershed

been used to calibrate the value of K_{TC} appearing in equation (4) using five year observed (1979-83) and computed sediment outflow data (estimated from Equation 4). Model efficiency (ME) can be calculated as follows:

$$ME = 1 - \frac{\sum (Y_{obs} - Y_{pred})^2}{\sum (Y_{obs} - Y_{mean})^2} \qquad (7)$$

Where, Y_{obs} observed seasonal sediment (tons), Y_{pred} is predicted seasonal sediment (tons), Y_{mean} is mean of the observed sediment (tons). Value of ME ranges from $-\infty$ to 1. Values close to 1 indicate better model fit. However the negative value of ME implies inefficiency of the model in prediction. Relative Root Mean Square Error is estimated by the following formula:

$$RRMSE = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(Y_{obs} - Y_{pred})^2}}{\frac{1}{n}\sum_{i=1}^{n} Y_{obs}} \qquad (8)$$

Where, *n* is the number of data points. For wide range of K_{TC}, value of ME (Equation 7) and RRMSE (Equation 8) have been calculated and shown in Figure 3. It is evident from Figure 3 that at $K_{TC}=3x10^{-5}$, ME is the highest (0.74) and RRMSE is at the lowest (0.29). Any change in the value of K_{TC} ($=3x10^{-5}$) leads to increase and decrease in RRMSE and ME, respectively. Transport capacity maps are generated using calibrated K_{TC} value for all years (1979-87). Transport capacity map for year 1987 is presented in Figure 4 as illustration. It is evident from this figure that the ridges and the flattened area near the channel, generally cultivated (viz., south-west direction of Chaukhutia gauging site) are the areas possessing low transport capacity. However, transport capacity is high in channel areas and the steep head water areas.

Sediment routing considering local transport capacity: Gross soil erosion was estimated using raster calculator tool of ArcGIS, but the quantity of eroded soil delivered to the next cell will depend on the transport capacity of the cell. However, at present there is no ready to use tool available in GIS, which estimates the quantity of sediment moved in the next cell by considering gross soil erosion and transport capacity of the cell. Therefore using the basic principal of overland flow

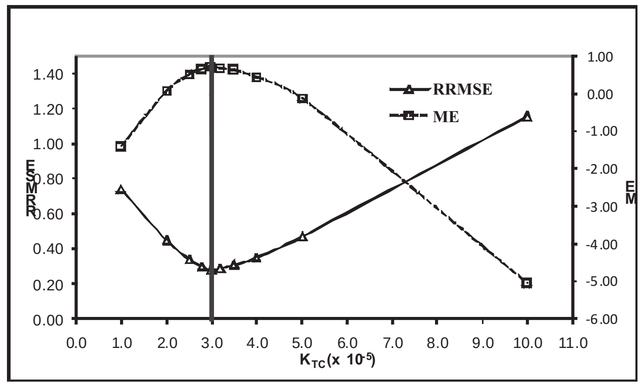

Fig. 3. Calibration of K_{TC} for Bino watershed using seasonal rainfall-sediment yield data

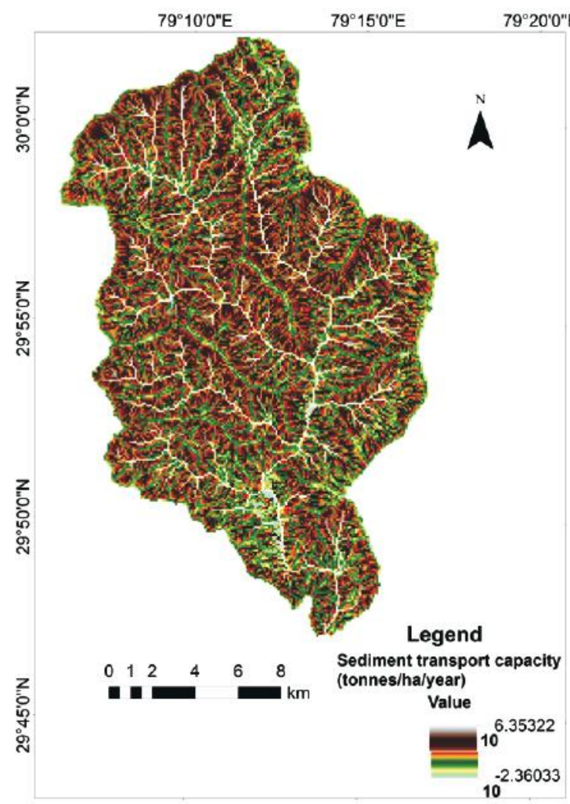

Fig. 4. Transport capacity map of Bino watershed

routing (Equation 5) a programme was developed in Interactive Data Language (IDL). The developed tool/ programme estimates the sediment moved out from each pixel using flow direction, flow accumulation, gross soil erosion, and transport capacity maps. Tool compares the gross soil erosion (total soil ready to move out of a particular pixel) and transport capacity of the flow in that pixel, if transport capacity is equal or greater than gross soil erosion then entire eroded soil will be transported into the next pixel. The destination of this transported soil/sediment will be determined using flow direction map. However, if the transport capacity of any pixel is less than total soil ready to move out of particular pixel, the tool will assign the difference between transport capacity and the total soil ready to move out, as amount of sediment deposited in that pixel. Batch processing option is given in programme to process temporal data and to save time in repeated operations/processes. Using developed tool, sediment outflow maps for different years (1979-87) were produced. Such maps provide the amount of sediment outflow from the system at every cell and are useful for determination of sediment flowing out of the watershed at any location. Figure 5 depicts the sediment outflow map for the year 1987 as illustration. While cell values of Outlet of Bino watershed from theses maps were read for validation period and compared with observed sediment data, a very low errors have been observed (0.6%, -1.1% and -10.8% for 1985, 86, and 87, respectively). Such low errors in estimation of sediment yield do support the efficacy of the model.

Generation of vulnerability maps of net erosion/deposition: Using Equation 6, sediment deposition maps for various years were obtained. Net soil erosion/deposition maps of various years were produced by superimposing sediment deposition maps over gross erosion map of corresponding years. Such maps are helpful in identifying areas vulnerable to soil erosion and sediment deposition in watershed area. Figure 6 depicts net soil erosion/sediment deposition map for year 1987 as illustration. A significant area (7% of total watershed area) of the Bino watershed is under deposition. As can be seen from Figures 6, most of the deposition of sediment occurred in the sides of the drainage channels when they reach in valleys and also on flatter land areas found in the cultivated valley lands. It is possible to identify the critical areas delivering most of the sediment to the river system. Notably, these areas are not necessarily the same as those producing most erosion, as most of the eroded sediment is deposited within the catchment, before reaching the river system. The net erosion estimated on a cell basis for the watershed is grouped into the following scales of severity of erosion: Slight (0 to 5 t ha^{-1} year^{-1}), moderate (5 to 10 t ha^{-1} year^{-1}), high (10 to 20 t ha^{-1} year^{-1}), very high (20 to 40 t ha^{-1} year^{-1}), severe (40 to 80 t ha^{-1} year^{-1}) and very severe (> 80 t ha^{-1} year^{-1}) as per the guidelines suggested by Singh *et al.* (1992) for Indian conditions.

It was estimetd that soil loss in 10.6% area of Bino watershed is above soil loss tolerence limit . Notable that soil tolerance limit is defined as the acceptable rate of soil erosion at which the quality of a soil as medium for plant growth can be maintained. Mandal and Sharda (2011) found soil tolerance limit 5 t ha^{-1} year^{-1}for this particular region. Bino watershed consists a huge area under agriculture (33.5%). Worth notable that during tillage operations, land is exposed and loosened and become more suspectible for the erosion. The condidition is become more severe in the hilly areas where cultivation is practiced in outward slope terraces. The field verfication confirmed that erosion and associated sediment deposition had indeed occur in these areas. Such categorizations of net soil erosion as illustrated in Figure 6 can be of immense significance in deciding the priority levels for implementation of the suitable measures (biological or engineering) for watershed treatment.

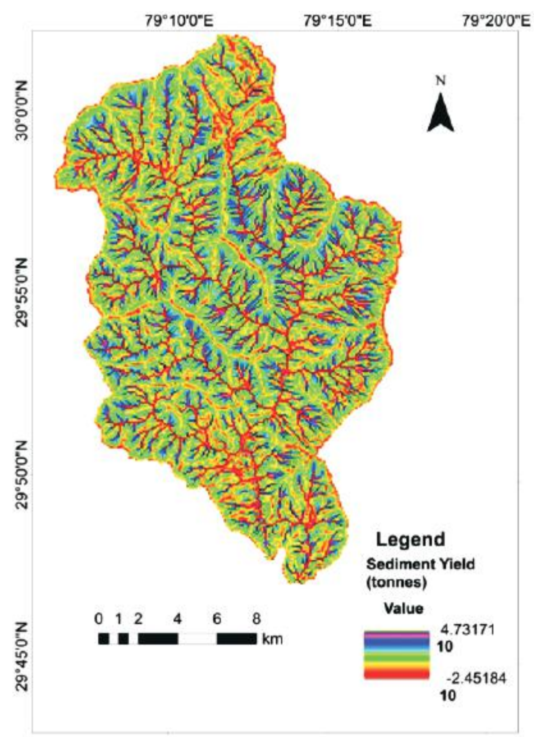

Fig. 5. Sediment outflow map of Bino watershed

On-site erosion reduces the soil quality due to removal of nutrient rich top soil layer and also reduces the water holding capacity of many soils. Therefore, in developing countries like India, where rural population is more than 65% and land is the identity of the people,

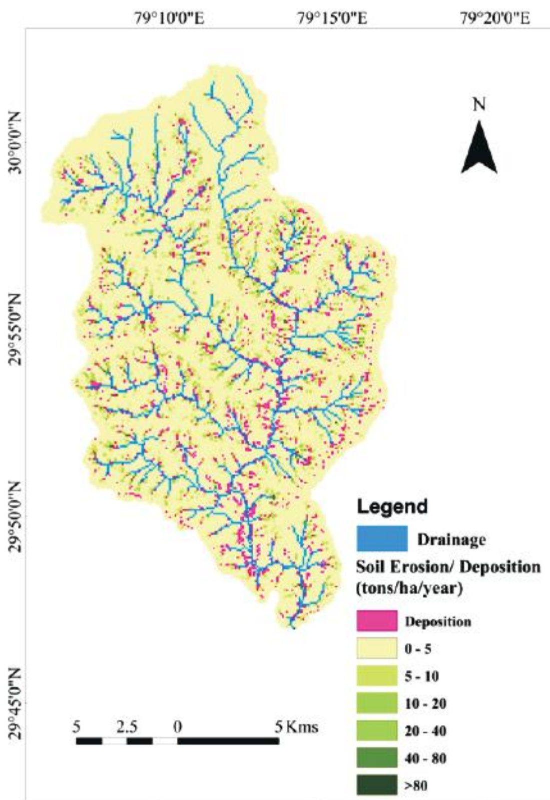

Fig. 6. Net erosion/deposition map of Bino watershed

assessment of erosion focuses mainly on the on-site effects of erosion. It is evident from the literature that productivity can be increased by bringing the soil loss near or below the soil tolerance limit. Therefore, comparison between soil tolerance limit and prevailing soil loss can be the best criteria for deciding the priority areas as well as treatment activities within the watershed. In the present study, the formulated model has potential to identify the areas where soil loss exceeding the permissible/tolerance limit (10.6% area of study watershed has been identified in the present study) and these are the areas where immediate soil conservation measures have to be implemented. In the nutshell, our target should to bring the soil loss within the soil loss tolerance limit which will certainly lead to sustainable agricultural production system.

In the present era of industrialization, more attention is being paid to the society at large, viz., in flood prevention, water reservoir preservation, and water pollution control (Garen *et al.,* 1999). However, it has been observed that sedimentation in the reservoirs have occurred at a much faster rate than anticipated. In view of the stupendous task of construction and the huge cost involved in hydro-power projects, ensuring longevity of the reservoir have become the cause of major concern to the planners and administrators. Nevertheless, sedimentation data from number of projects indicated that the actual sediment production rates (SPR) have been much more than the assumed rates. The erosion/deposition maps derived by the formulated model in the present study exhibit sediment rate at a particular cell in spatial domain, and the value at the outlet cell indicate the sediment outflow from the entire watershed. The sediment outflow at any point may be quite helpful in planning to design sediment production rate (SPR) for a hydro-power project at that location. However, sites identified vulnerable to soil deposition from such maps could be avoided for planning sites for multipurpose projects where huge amount of storage of water is required.

Whether the main concern of soil and water conservation planning is towards prevention of on-site or off-site effects of erosion, there was a growing need for tools that enable to define the spatial distribution of erosion within a catchment i.e. to identify sources of sediment erosion. The formulated model involving only elementary processes responsible for soil erosion and subsequently sediment deposition is capable to capture the spatial patterns of soil erosion as well as lumped sediment load in the entire watershed up to a cell area (90m x 90m). Formulated model is more rational and pragmatic than the lumped Sediment Delivery Ratio (SDR) approach. Worth notable that GIS and remote sensing techniques are capable to access data in tough terrain and adverse climatic conditions. Since, model requires input data in the form of different thematic GIS layers, model has potential to be applied for any watershed, in terms of size and location, throughout the globe. Moreover, the model may be a useful tool in sustainable environmental watershed management planning.

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Analysis of Rainfall and Temperature Trends in Haryana, India

Shaloo, A. Sarangi and R. Kaur
Water Technology Centre, ICAR-Indian Agricultural Research Institute, New Delhi-110 012, India
E-mail: shaloo_eco@iari.res.in

Abstract: Analysis of rainfall trend showed increasing trend for Kaithal and Palwal district of Haryana but for Kaithal, there was significant increase with z-value of 2.59. However, non-significant decreasing trend was observed for other districts of Haryana. Further, trend analysis for maximum temperature showed an increasing trend for all districts except for Kaithal but it was observed that the trend was consistent only for Bhiwani district with z-value of 1.47. Contrastingly, it was observed that the trend of minimum temperature increased for all districts of Haryana. Nonetheless, based on the results of trend analysis, judicious agricultural management activities would be recommended based on regional variations in Haryana State.

Key Words: Haryana, Maximum Temperature, Minimum Temperature, Modified Mann Kendall test, Rainfall

Climate change related investigations assume paramount importance these days due to its impact which is being observed and ascertained to affect the rainfall and temperature at global scale. In recent years, agriculture sector has been adversely affected due to changing climatic conditions. Besides this, scarcity of agricultural facilities, lack of scientific approach in small scale farming, lack of water harvesting and other infrastructures in our Country coupled with changing climate will adversely affect the agricultural production. Kumar *et al.* (2010) analysed the monthly, seasonal and annual trends of rainfall using monthly data series during the period 1871 to 2005 for 30 sub-regions in India. They reported that nearly half of the sub-divisions have shown an increasing trend in annual rainfall and other regions shown the opposite trend. Subash *et al.* (2010) reported rainfall and temperature trends at various locations in India, where different locations showed both decreasing and increasing trends which are critical for sustainability in crop production. The primary concern in yields and agricultural production in India is the rainfall depth and its variability. In Indian, 80% of the total precipitation is mainly due to southwest monsoon that ensures fresh water for various purposes including irrigation.

Darshana *et al.* (2012) examined the variability and trends in annual and seasonal rainfall for the nineteen stations of Haryana. The significant increasing trends of annual rainfall depth was observed for all meteorological stations except for *Kurukshetra* and *Panchkula*. Deshmukh and Lounge (2013) noticed long–term changes in temperature and rainfall in Buldana district in Vidarbha region of Maharashtra, India. The increasing trend in mean of maximum (MMAX) temperature and total mean rainfall (TMRF) is confirmed by Mann-Kendall trend test. They observed that in Vidarbha region, the December MMAX temperature has increased by 2.69°C and annual MMAX temperature has increased by 1.32°C, whereas the highest decrease in TMRF occurs in November, by 25.08 mm, and annual TMRF has increased by 12.14mm, during the last 31 years. Recently, climate change has resulted in unexpected changes in crop production across the world. India is among the highly affected countries where alteration of rainfall patterns and increase in temperature has been noticed (IPCC, 2014; Dash *et al.,* 2011; Jain and Kumar, 2012; Jain *et al*., 2013; Abeysinghe *et al*., 2014; Kundu *et al*., 2015). The objective of this study was to analyse the trends of rainfall and temperature for six districts of Haryana for which the long term daily climatic data for the period from 1969 to 2009 (41 years) was available. Trend analysis was undertaken using Modified Mann-Kendall non-parametric test with Sen's slope estimator for detecting trends and its magnitude for identifying the changing climate at regional scales.

MATERIAL AND METHODS

Climatic parameters *viz.* rainfall depth, maximum and minimum temperature were acquired from IMD (Indian Meteorological Department) for six districts (*viz.* Kaithal, Bhiwani, Fatehabad, Rohtak, Palwal and Sirsa) during the period of 41 years,1969 to 2009. Further, the acquired data were analysed and the average values were estimated. Subsequently, the trend analysis was undertaken using the Modified Mann-Kendall (MMK) test on the time series data of annual rainfall depth, average maximum and minimum temperature and the results were analysed.

Haryana state is located in the northern region of India and enclosed between 27°37' to 30°35' N latitude and 74°28' to 77°36' E longitude comprising of 21 districts. The altitude varies between 200 to 1200 metres above mean sea level (amsl). The land area of this state is 4.42 m ha, which is 1.4 % of the geographical area of the country. The gross cropped area of the state is 6.32 m ha and net cropped area is 3.62 m ha with a cropping intensity of 177%. Temperature fluctuates between 15° C to 5° C in winter and 15 °C to 45 °C during summer. The major part of Haryana State comes under the fertile Indo-Gangetic belt. Crops grown during rabi season are wheat, tobacco, pulses, linseed, sugarcane, sesame and groundnut, whereas during *kharif* the rice, jowar, bajra, maize, cotton, jute, tobacco, pulses, linseed, rapeseed and mustard crops are grown.

Modified Mann Kendall test (MMKT): The basic assumption of the Mann-Kendall test is that the data need to be independent and randomly ordered. However, in many real situations the observed data are auto-correlated. The existence of positive autocorrelation in the data increases the probability of detecting trends. Although this is a well-known fact that autocorrelation in the data is often ignored. A theoretical relationship was derived to calculate the variance of the Mann-Kendall test statistic for auto-correlated data and based on this a modified non-parametric trend test which is suitable for auto-correlated data was incorporated (Hipel and McLeod, 1994). The empirical formula for calculating the variance of S in the case of auto-correlated data is given by eq. 1.

$$V(S) = var(S).\frac{n}{n_s^*} = \frac{n(n-1)(2n+5)}{18}.\frac{n}{n_s^*} \qquad (1)$$

where, $\frac{n}{n_s^*}$ represented a correction due to the autocorrelation in the data. The correction of autocorrelation is given by equation (2).

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} X \sum_{i=1}^{n-1}(n-1)(n-i-1)(n-i-2)\rho_s(i) \quad (2)$$

Where, n is the number of observations and (i) is the autocorrelation function of the ranks of the observations. The advantage of the approximation in equation (2) is that by using the ranks of the observations, the variance of S can be evaluated by equations (1) and (2) without the need for either the normalized data or their autocorrelation function.

The standard normal deviate (Z-statistics) is then computed as below:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & , if\ S > 0 \\ 0 & , if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & , if\ S < 0 \end{cases} \qquad (3)$$

If the computed value of |Z| > zá/2, the null hypothesis (H0) is rejected at á level of significance in a two-sided test. In this analysis, the null hypothesis was tested at 95% confidence level.

A positive value of Z indicates an increasing trend and negative value indicates decreasing trend.

Sen's slope estimator: Slope (*i.e.* change in data per unit time) of a linear trend in time series can be estimated by using a simple nonparametric procedure developed by Sen (1968). The Sen's slope estimator is widely used due to its simplicity in computation, analytical estimates of confidence intervals and robustness to outliers which are prime advantages over the general slope estimation method. This approach involves computing slopes for all the pairs of time points and then using the median of these slopes as an estimate of the overall slope. Sen's method proceeds by calculating the slope of the line using all data pairs, as shown in the following equation:

$$Q_i = \frac{x_j - x_k}{j-k} \qquad (4)$$

where, *j*> *k*. If there are *n* values x_j in the time series, we get as many $N = ((n+1)/2)$ as slope estimate Q_i. Sen's estimator of slope is simply given by the median of these *N* values of Q_i's.

$Q = Q_{[(N+1)/2)]}$ if *N* is odd (5)

$Q = (Q_{[N/2]} + Q_{[(N+2)/2]})/2$ if *N* is even. (6)

Sen's slope estimator is computed as Q_{med}=Q(N+1)/2 if N appears odd and it is considered as Q_{med}=[$Q_{N/2}$+$Q_{(N+2)/2}$]/2, if N appears even. At the end, Q_{med} is computed by a two sided test at 100 (1-á) % confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of Q indicates an upward or increasing trend and a negative value of Q shows a downward or decreasing trend in the time series.

In the present study, an interface in MATLB *viz.* trend test estimator was used to undertake the above analysis pertaining to rainfall depth and temperatures of selected districts of Haryana. Climate Change Trend Analysis interface was developed in MATLAB® environment to analyze the trends in various meteorological variables *e.g.* rainfall, temperature, solar radiation etc. using trend tests. The interface incorporates four trend tests *viz.* MK test and MMK test with Sen's slope estimator, Sen Seasonality Trend Test and Cox Stuart Trend test. It also gives the statistical summary (*i.e.* maximum, minimum, mean, standard deviation and variance) of the input data along with the histogram which shows the distribution of data.

RESULTS AND DISCUSSION

Trend analysis of rainfall depths: Trend analysis of annual rainfall depth values indicated that *Kaithal w*as the only district which showed a significant increasing trend with 95 % confidence level during 41 years. The S statistics, Z-value, Kendall's tau and Sen's slope were 220, 2.6, 0.27 and 5.8, respectively for kaithal district. The positive value of Kendall's tau and S statistics showed an increasing trend in the time series data of rainfall for Kaithal district. Moreover, the Z-value showed that the trend was statistically significant. Similarly, the trend test parameters obtained from MMKT were analysed for all six districts of Haryana. However, for Bhiwani, the trend was decreasing with S-statistic -16 and Sen's slope -0.38, but this decreasing trend was non-significant which was indicated by the Z-value -0.02. It was also observed that there was a decrease in the trend for Fatehabad district with trend test parameters *viz.* S statistics, Z-value, Kendall's tau and Sen's slope -80.00, -0.098, -0.887 and -1.88, respectively. The S statistics, Z-value, Kendall's tau and Sen's slope for Rohtak district were -59.00, -0.072, -0.651 and -1.35 and it was non-significant. Palwal also showed increasing trend with positive value of Sens' slope (0.004) and was statistically non-significant as corroborated by Z-value 0. Moreover, for Sirsa district, the trend was observed to be decreasing with Sen's slope –0.03, but was not significant (Table 1). The rainfall variability during different years was prominent in all districts, but the long term trend for a period of 41 years was different for different districts (Fig. 1). Moreover, the observed trend in the time series data as reflected in the scatter diagram was ascertained through above mentioned trend tests and was observed that Kaithal showed significant increasing trend. The annual rainfall depth indicated two increasing trends at different time scales *viz.* increasing trend during 1969 to 1998 (20 years) and again during 1999 to 2009.. Existence of two trends in the scatter diagram of long term data may be attributable to a sudden decrease in annual rainfall depth during 1999 as compared to the year 1998 (Fig.1a.). Similar result were also reported by Chakraborty *et al.* (2013) for Seonath sub-basin in Chhattisgarh State.

Trend analysis of average maximum and minimum temperature: Trend analysis indicated increasing trend in average maximum temperature for all six districts excluding Kaithal but Bhiwani is the only district which was showing significant increasing trend *with* 95 % confidence level *during the period 1969-2009. The* S statistics, Z-value, Kendall's tau and Sens' slope were 132, 1.47, 0.16 and 0.01, respectively and the positive value of Kendall's tau and S statistics showed an increasing trend of maximum temperature for Bhiwani district. Moreover, the Z-value showed that the trend was statistically significant. Similarly, the trend test parameters obtained from MMKT were analysed for all six districts of Haryana. However, for Kaithal, the trend was decreasing with S-statistic -32 and Sen's slope -0.002, but this decreasing trend was non-significant, which was indicated by the Z-value -0.34. It was also observed that there was an increase in the trend for Fatehabad district with trend test parameters *viz.* S statistics, Z-value, Kendall's tau and Sen's slope 28, 0.3, 0.03 and 0.002, respectively. The S statistics, Z-value, Kendall's tau and Sen's slope for Rohtak district were 101, 1.1, 0.12 and 0.009, respectively. Palwal was also showing increasing trend with positive value of Sen's slope (0.004) and was statistically non-significant as corroborated by Z-value (0.6). Moreover, for Sirsa district, the trend was increasing with Sen's slope 0.001, but was not significant. The maximum temperature variability during different years was prominent in all districts, but the long term trend for a period of 41 years was different for different districts (Table 2, Fig. 2). Moreover, the observed trend in the time series data as reflected in the scatter diagram was ascertained through above mentioned trend tests and was observed that only one district (Bhiwani) showed significant increasing trend. Referring Fig. 2, it was observed that trends were increased upto year 1996 and afterward it decreased in the year 1998 and again it increased upto the year 2009 for all six districts. In case of trend analysis of average minimum temperature, it was observed that all the six districts were showing significant increasing trend with 95 % confidence level during 1969-2009 (41 years). The value of the parameters *viz.* S statistic, Z-value, Sen's slope and Kendall's tau are shown in Table 3. The positive value of Kendall's tau and S statistics showed increasing trend in the time series data of minimum temperature. From Z statistic, it was revealed that trend was statistically significant. As it is indicated in scatter diagram (Fig. 3) trends were increasing significantly for all districts during the period 1969 to 2009.

In the present study, the spatial and temporal

Table 1. Trend test statistics and interpretation of annual rainfall depths in different districts of Haryana using MMKT

Mann-Kendall test (Rainfall)								
Districts (Haryana)	Latitude	Longitude	Mann-Kendall Statistics	Kendall's Tau	Z-value	Sen's slope	Test Interpretation	Significance
Kaithal	76.5	29.5	220.000	0.268	2.59	5.788	Trend increasing	Yes
Bhiwani	75.5	28.5	-16.000	-0.020	-0.168	-0.384	Trend decreasing	No
Fatehabad	75.5	29.5	-80.000	-0.098	-0.887	-1.881	Trend decreasing	No
Rohtak	76.5	28.5	-59.000	-0.072	-0.651	-1.358	Trend decreasing	No
Palwal	77.5	27.5	0.000	0.000	0.000	0.004	Trend increasing	No
Sirsa	74.5	29.5	-4.000	-0.005	-0.033	-0.031	Trend decreasing	No

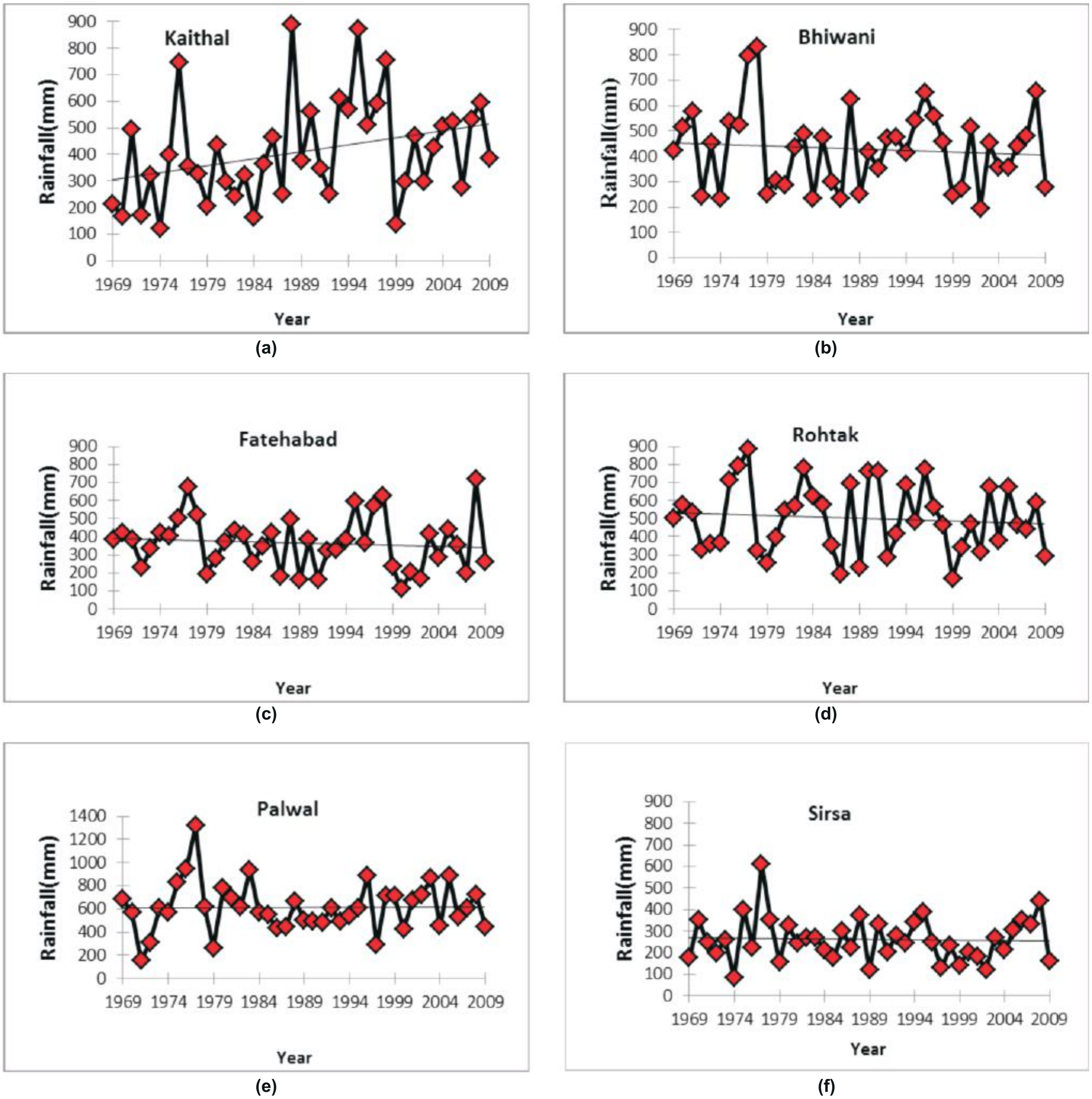
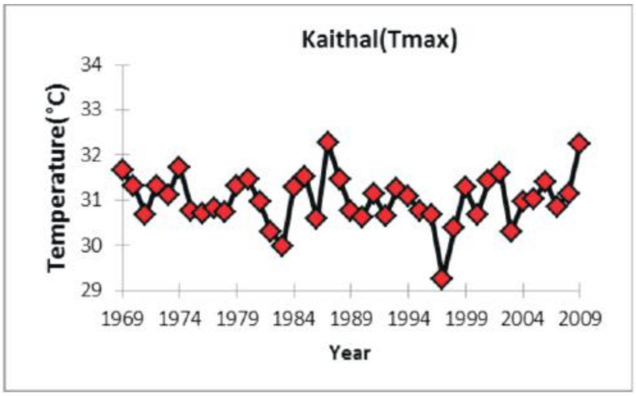


Fig. 1. Trend analysis of annual rainfall at different district, Haryana from 1969-2009

Table 2. Trend test statistics and interpretation of average maximum temperature in different districts of Haryana using MMKT

Mann-Kendall test (Tmax)								
Districts (Haryana)	Latitude	Longitude	Mann-Kendall Statistics	Kendall's Tau	Z-value	Sen's slope	Test Interpretation	Significance
Kaithal	76.5	29.5	-32.000	-0.039	-0.348	-0.002	Trend decreasing	No
Bhiwani	75.5	28.5	132.000	0.161	1.471	0.013	Trend increasing	Yes
Fatehabad	75.5	29.5	28.000	0.034	0.303	0.002	Trend increasing	No
Rohtak	76.5	28.5	101.000	0.123	1.123	0.009	Trend increasing	No
Palwal	77.5	27.5	58.000	0.071	0.640	0.004	Trend increasing	No
Sirsa	74.5	29.5	30.000	0.037	0.326	0.001	Trend increasing	No



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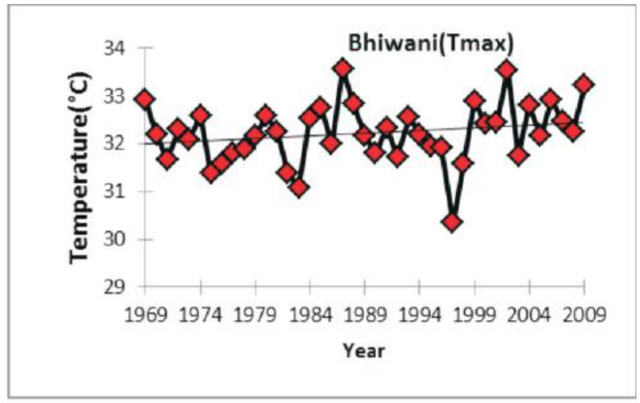

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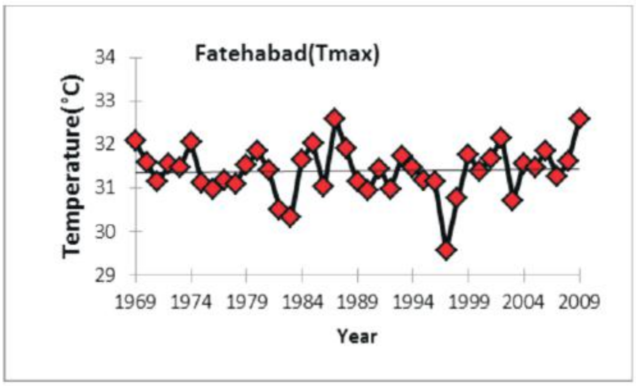

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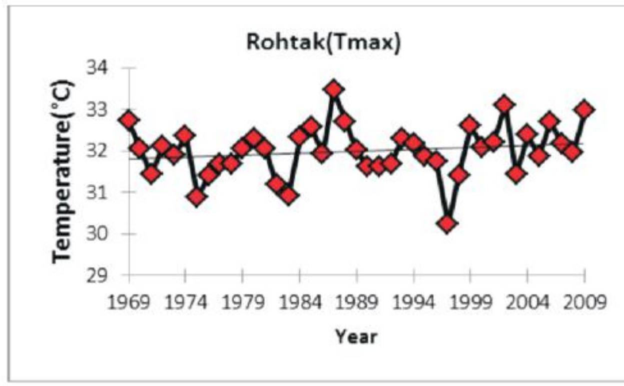

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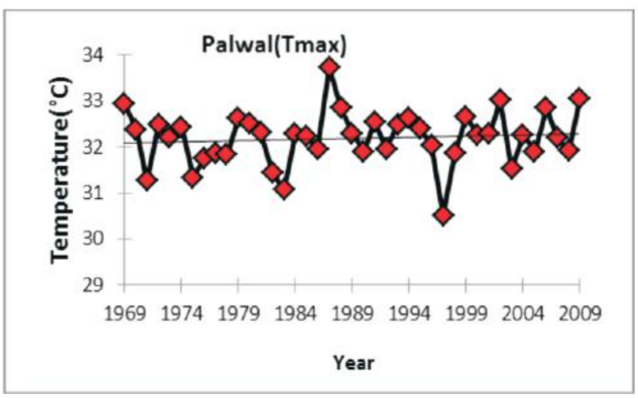

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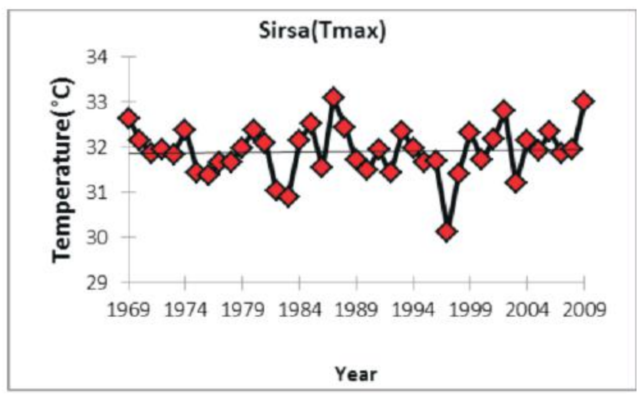

(f)

Fig. 2. Trend analysis of average maximum temperature at different district, Haryana from 1969-2009

Table 3. Trend test statistics and interpretation of average minimum temperature in different districts of Haryana using MMKT

Mann-Kendall test (Tmin)								
Districts (Haryana)	Latitude	Longitude	Mann-Kendall Statistics	Kendall's Tau	Z-value	Sen's slope	Test Interpretation	Significance
Kaithal	76.5	29.5	438.000	0.534	4.91	0.031	Trend increasing	Yes
Bhiwani	75.5	28.5	422.000	0.515	4.73	0.034	Trend increasing	Yes
Fatehabad	75.5	29.5	404.000	0.493	4.53	0.029	Trend increasing	Yes
Rohtak	76.5	28.5	379.000	0.462	4.24	0.029	Trend increasing	Yes
Palwal	77.5	27.5	418.000	0.510	4.68	0.028	Trend increasing	Yes
Sirsa	74.5	29.5	382.000	0.466	4.28	0.032	Trend increasing	Yes

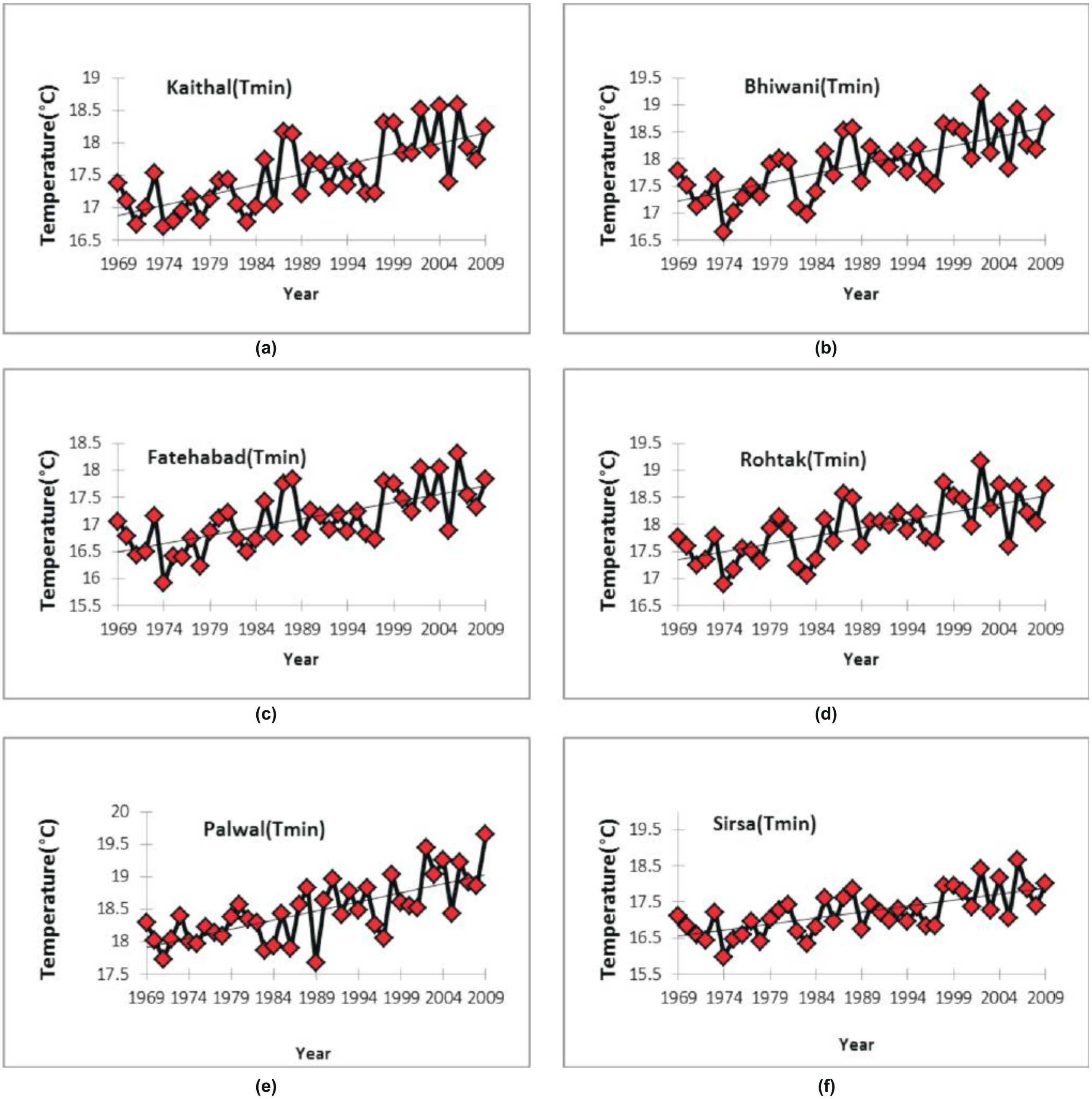

Fig. 3. Trend analysis of average minimum temperature at different district, Haryana from 1969-2009

variability of climatic parameters were investigated for six district of the Haryana using Modified Man Kendall trend test. The trend test assisted in statistical corroboration of increasing or decreasing trend as visualized in the scatter diagram of time series data. It was observed that the rainfall depth, maximum and minimum temperature in six districts of Haryana depicted spatio-temporal variability during 1969 to 2009. Significant increasing trend was observed for only one district each pertaining to rainfall depth (Kaithal) and maximum temperature (Bhiwani), whereas, for minimum temperature, all six district showed significant increasing trend. Therefore, it can be concluded that the trend test need to be undertaken for long term time series data of different climatic parameters to ascertain whether there was climate variability or climate change besides its magnitude at a given level of significance. Nonetheless, such studies would provide an understanding of present and future climate of the region to undertake judicious agricultural water management activities which would assist in attaining sustainability in agriculture.

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Water Quality Index for Sustaining River Ecology: A Case Study of Two Hydropower Projects in Series on Satluj River

Pradeep Kumar, Soban Singh Rawat and P. G. Jose
National Institute of Hydrology, Western Himalayan Regional Centre, Jammu-180 003, India
E-mail: pradeep4uonline@gmail.com

***Abstract*:** In the pre- Nathpa Jhakri Hydroelectric Project (NJHEP) and pre- Rampur Hydroelectric Project (RHEP) conditions, the Satluj water quality index (WQI) is found to be higher than Satluj WQI standard (47 and 55, respectively for rainy and lean seasons) at all the locations (upstream and downstream of Natha dam and Jhakri power house). The water quality parameters were well within acceptable limits. However, in the Post-NJHEP and post-RHEP scenario, the lean season Satluj-WQI at downstream of Rampur just meets the standard. This may be attributed to higher turbidity and higher faecal coliform concentration expected in the post-RHEP situation due to the same pollutant load coming to the river having reduced flows due to flow diversion for power generation. The study also suggests that excessive turbidity due to silt flushing during the post-project condition may have adverse impact on the aquatic life.

***Key Words*:** Dissolved oxygen, Faecal coliform, River ecology, Turbidity, Satluj, Water quality index

The water quantity is determined by a single parameter – the volume or rate of flow during a given time period, the water quality is described in terms of concentration of several constituents (20 odd common constituents to hundreds). Comparison of water quality in terms of a list of constituents is not easy. Water sample containing six components in 5% higher than permissible levels; pH, hardness, chloride, sulphate, iron and sodium may not be as bad for drinking as another sample with just one constituent – mercury at 5% higher than permissible. Water quality indices (WQI) aim at giving a single value to the water quality on the basis of one or the other system which translates the list of constituents and their concentrations present in a sample into a single value. In the present study, two existing indices proposed by National Sanitation Foundation (NSF), USA and Central Pollution Control Board (CPCB), India have been used for assessing the water quality status of Satluj river reach affected by two hydropower projects in series i.e. Nathpa Jhakri Hydropower Project (NJHEP) and Rampur Hydropower Project (RHEP). In addition, a new index is proposed in the context of evaluating the river ecology status by incorporating the turbidity parameter in CPCB-WQI.

MATERIAL AND METHODS

The study area consists of the Satluj river reaches related with the Nathpa Jhakri Hydroelectric Project (NJHEP) and Rampur Hydroelectric Project (RHEP) (Fig. 1). The NJHEP is in operation stage and the diverted water at Nathpa dam is released back into Satluj after power generation at Jhakri. RHEP is under construction. The RHEP will make use of the water released in the tail race pool after power generation at Jhakri. Thus, RHEP will cause reduction in Satluj river flow downstream of Jhakri and up to Bael where the water will be released back into Satluj after power generation. The combined effect of NJHEP and RHEP is that the Satluj river will be deprived of the natural flows to the extent of 405 cumec in the reach from Nathpa to Jhakri (34 km) and then from Jhakri to Bael (23 km).

Nathpa Jhakri hydroelectric project: The 1500 MW Nathpa Jhakri Hydroelectric Project (NJHEP) is a run-of the river project on the river Satluj with a dam near village Nathpa in district Kinnaur and an underground power house near village Jhakri in district Shimla. The project area is on Hindustan Tibet road NH-22 approximately 150 km from Shimla.

About 405 cumecs of water is required to harness the installed capacity of the project. During monsoon season,

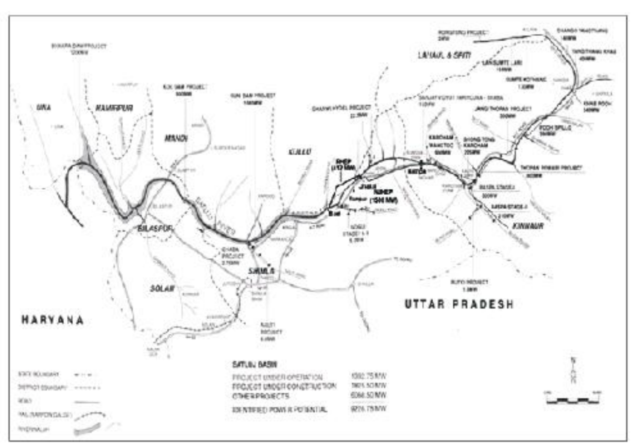

Fig. 1. The study area showing hydropower projects in Satluj basin

the flow of the river varies from 700 to 2500 cumecs, and from 100 to 150 cumecs during the lean months. In the lean period, the entire water in the river at Nathpa is required for power generation. In between Nathpa and Jhakri, there are several small streams locally known as streams. Flow of Sholding stream is also diverted into head race tunnel (HRT) during lean period. The river reach between Nathpa and Jhakri is situated in steep mountain terrain. The study area falls in three tehsils i.e. Rampur tehsil of Shimla district, Nichar tehsil of Kinnaur district and Nirmad tehsil of Kullu district.

There is great variation of altitude with rugged terrains and hard climatic conditions in the study area. Most of the sediment of Satluj river (almost 90%) is contributed by the upper reaches falling in Tibet. Horticulture is almost nil on right bank of Satluj river. There is more forest area on right bank compared to left bank and land holdings are also less. After Jeori, right bank has the green forests. Main face of right bank is overlain by pastures at places, but the back side has dense forests.

Rampur hydroelectric project: The Rampur project is designed to divert 383.88 cumecs of de-silted water of the Satluj from the tailrace pool of NJHEP to the Rampur Intake structure from where the water is conveyed (from left bank to the right bank) through a 484 m HRT and 43.2 m cut and cover conduit. A 10.5 m dia headrace tunnel of 15.08 km conveys the water to a surface power station near Bael. Water is then returned to the Satluj river. The project is under construction stage. On completion, the project would utilise a gross head of 138 m to generate approximately 1969.69 Gwh of design energy in a 90% dependable year. The catchment area of the Satluj upto Nathpa-Jhakri is 49,800 sq. km. and upto Rampur HEP is 50,800 sq. km.

National sanitation foundation (NSF)-Water quality index (WQI): Brown *et al.* (1970) developed an index based on nine parameters (Table 1), developing a common scale, and assigning weights for which elaborate Delphic exercises were performed. This effort was supported by the National Sanitation Foundation (NSF). For this reason, this index is referred as NSF-WQI and also as Brown's Index in literature. In addition, Brown *et al.* (1970) stated that if total content of detected pesticides or toxic elements (of all types) exceeds 0.1 mg L^{-1}, the water quality index will be automatically registered to zero. The index (NSFWQI) is calculated as follows:

$$\mathrm{NSFWQI} \quad \sum_{i=1}^{n} w_i q_i$$

where, q_i is the quantity of the i^{th} parameter (a number between 0 to 100 read from the appropriate sub-index graph) and w_i is weight of the i^{th} parameter. The WQI uses a scale from 0 to 100 to rate the quality of the water. The overall WQI score is compared against the following scale (Table 2) to determine how healthy the water is at a given time.

CPCB-WQI: CPCB-WQI is primarily based on the NSF-WQI (Abbasi, 2002). However, slight modifications were made in terms of assignment of weightages so as to conform to the water quality criteria for different categories of water uses set by the Central Pollution Control Board, India. Four important water quality parameters i.e. dissolved oxygen (DO), biochemical oxygen demand (BOD), pH and faecal coliform were selected through Delphi. A weighted sum aggregation function was used to evaluate the overall water quality index. The index was developed to evaluate the water quality profile of river Ganga in its entire stretch and to identify the reaches where the gap between the desired and the existing water quality is significant enough to warrant urgent pollution control measures (Sarkar and Abbasi, 2006).

The index had the weighted multiplication form:

$$\mathrm{W.Q.I} = \sum_{i=1}^{N} w_i I_i$$

Where I_i is sub index for i th water quality parameter, W_i is weight associated with i th water quality parameter and N is the number of water quality parameters. A list of four parameters was selected through Delphi. Sub-Index values were obtained by using sub index equations as shown in Table 3.

To assign weightages, significance ratings were given to all the selected parameters. A temporary weight of 1 was assigned to the parameter which received highest significance rating. All other temporary weights were obtained by dividing each individual mean rating with the highest. Each temporary weight was then divided by the sum of all weights to arrive at the final weights. These weights were modified to suit the water quality criteria for different categories of uses. The classification of water *vis a vis* the final index values is given in Table 4. The weights and modified weights are illustrated in Table 5.

Table 1. Weights for parameters included in Brown's NSF-WQI

Parameters	Weights
Dissolved oxygen	0.17
Faecal coliform density	0.15
pH	0.12
BOD (5-day)	0.10
Nitrates	0.10
Phosphates	0.10
Temperature	0.10
Turbidity	0.08
Total solids	0.08
Total	1.00

Table 2. NSF-WQI scale

Index value	NSF water quality	Suitability for activities involving direct human contact, recreation, bathing, etc.	Suitability for support of aquatic life
91-100:	Excellent water quality	Suitable	High diversity of aquatic life
71-90:	Good water quality		
51-70:	Medium or average water quality		Less diversity, have increased algae growth
26-50:	Fair water quality	Marginally suitable	Low diversity
0-25:	Poor water quality	Not suitable, abundant quality problems	Limited number of aquatic life forms

Table 3. Sub-index equations of the CPCB-WQI

Parameter	Range applicable	Equation	Correlation
	0–40% saturation	IDO = 0.18 + 0.66 (% sat)	0.99
DO	40–100% saturation	IDO = - 13.5 + 1.17 (% sat)	0.99
	100–140% saturation	IDO = 163.34 - 0.62 (% sat)	–0.99
BOD (mg l^{-1})	0–10	IDO = 96.67 – 7.00 x (BO)	–0.99
	10–30	IBOD = 38.9 – 1.23 x (BOD)	–0.95
	2–5	IpH = 16.1 + 7.35 x (pH)	0.92
pH	5–7.3	IpH = - 47.61 + 20.09 x (pH)	0.99
	7.3–10	IpH = 316.96 – 29.85 x (pH)	–0.98
	10–12	IpH = 96.17–8.00 x (pH)	–0.93
Faecal coliform	$1–10^3$	Icoli = 97.2 – 26.80 x log (coli)	–0.99
	$10^3–10^5$	Icoli = 42.33 – 7.75 x log (coli)	–0.98
	$> 10^5$	Icoli = 2	

Source: Sarkar and Abbasi (2006)

Satluj-WQI : Inclusion of turbidity in CPCB-WQI: Turbidity means the optical condition of waters caused by suspended or dissolved particles or colloids that scatter and absorb light rays instead of transmitting light in straight lines through the water column. Turbidity may be expressed as nephelometric turbidity units (NTUs) measured with a calibrated turbidity meter. NSF-WQI is useful in the context of drinking water supply. CPCB considers four parameters (DO, BOD, pH and faecal coliform) for the purpose of maintaining quality of river water for mass bathing and recreation only. Sediment concentration of flows downstream of dams and barrages is influenced; not only by the releases from the dam but also due to addition of sediments (i) flushing from desilting chambers and (ii) runoff from mined areas and muck disposal sites

Out of 486 cumec flow diverted from Nathpa dam, 81 cumec is returned to Satluj river for flushing out deposited sediments in desilting chambers. Silt load of river Satluj in monsoon months ranges from 15 g L^{-1} to 50 g L^{-1}. In non-monsoon months, it varies from less than 1 g L^{-1} to 5 g L^{-1}. The 81 cumec discharge from desilting chamber has high silt content of the order of 70 to 80 g L^{-1}. Therefore, Satluj river will have high turbidity upto Jhakri (~ 80 g L^{-1}) beyond which it will reduce to 10 g L^{-1} due to return of diverted flow after power generation. However after construction of Rampur Hydroelectric project, silt concentration will continue to be high in the downstream reach upto Bael. Therefore, turbidity

Table 4. Water class as per CPCB-WQI score

WQI	Description	Class
63 – 100	Good to excellent	A
50 – 63	Medium to good	B
38 – 50	Bad	C
38	Bad to very bad	D,E

Table 5. Weights assigned to different water quality parameters in CPCB-WQI and Satluj-WQI

Parameters	Weights assigned		
	NSF-WQI	CPCB-WQI	Satluj-WQI
DO	0.17	0.31	0.27
Faecal coliforms	0.15	0.28	0.24
pH	0.12	0.22	0.19
BOD	0.1	0.19	0.16
Turbidity	0.08	0.00	0.13
Total	0.62	1.00	1.00

is an important parameter which should be considered while assessing the quality of flow. In this context, a new index (Satluj-WQI) has been proposed and the modified weights are given in Table 5.

Permissible limit on turbidity: Background turbidity means turbidity in the immediate vicinity of and outside the area of influence of the discharge or discharges from the source or sources under consideration. For establishing permissible limits, background turbidity may be calculated as the up-stream historical turbidity associated with low flows, excluding episodic run-off events, for the season(s) or period(s) for which the turbidity discharge limit is established. If background data are unavailable, 1 NTU may be used as a default value.

Aquatic life turbidity criteria in fresh water rivers in India are not available. Such criteria have been evolved in some developed countries and are available on websites. For the purpose of this study, the turbidity criteria as followed by Department of Ecology, State of Washington, USA (http://www.ecy.wa.gov/ecyhome.html) have been taken and are given in Table 6.

In case of NJHEP, background turbidity is taken as the turbidity measured at Wangtoo, which is U/S of the Nathpa dam. The average background turbidity measured at Wangtoo are as given below:

Satluj-WQI standard for river ecology: The Satluj WQI standard considering river bathing standards as per CPCB criteria and aquatic life turbidity criteria (for lean season and rainy season) have been calculated and found as below:

Water quality data: Himachal Pradesh State Environment Protection and Pollution Control Board (HPSEPPCB) has carried out water quality sampling at four locations (U/S of Nathpa dam, D/S of Nathpa dam, U/S of Jhakri and D/S of Jhakri) during pre-project and at three locations (Wangtu Bridge U/S of Nathpa dam, U/S of Rampur and D/S of Rampur) during post-project condition.

RESULTS AND DISCUSSION

Water quality data available for pre-commissioning stage have been used to estimate NSF-WQI, CPCB-WQI and Satluj-WQI. The values of CPCB-WQI, NSF-WQI and Satluj-WQI for pre-commissioning stage are given in Table 7. The Satluj-WQI is found to be more consistent with NSF-WQI (better correlation coefficient and lower standard error and

Table 6. Aquatic life turbidity criteria

Use category	Per cent saturation
1. Char spawning and rearing 2. Core summer salmonid habitat 3. Salmonid spawning, rearing, and migration 4. Non-anadromous interior redband trout	Turbidity shall not exceed: 5 NTU over background when the background is 50 NTU or less; or A 10% increase in turbidity when the background turbidity is more than 50 NTU.
1. Salmonid rearing and migration only 2. Indigenous warm water species	Turbidity shall not exceed: 10 NTU over background when the background is 50 NTU or less; or A 20% increase in turbidity when the background turbidity is more than 50 NTU.

Source: http://www.ecy.wa.gov/ecyhome.html

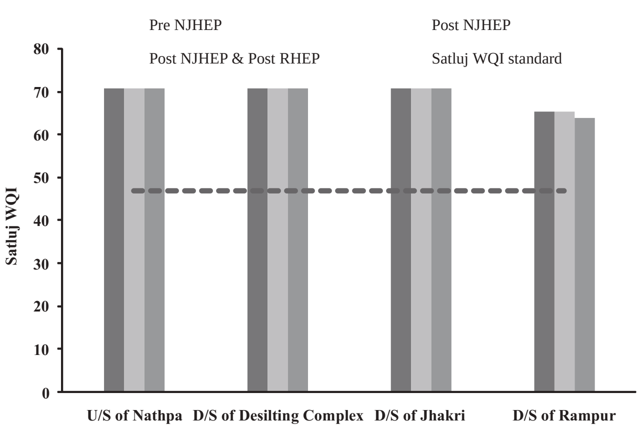

Fig. 2. Satluj WQI at various locations for pre and post-project conditions of NJHEP and RHEP during rainy season

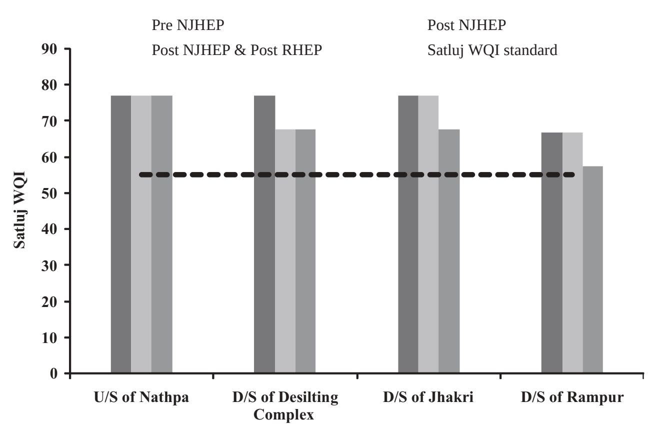

Fig. 3. Satluj WQI at various locations for pre and post-project conditions of NJHEP and RHEP during lean season

Table 7. CPCB-WQI, NSF-WQI and Satluj-WQI for pre-project condition

Source	Location	Period	NSF-WQI	CPCB-WQI	Satluj-WQI
HPPCB	Nathpa U/S	May, 2002	73.62	85.86	77.51
	Nathpa D/S	May, 2002	69.95	81.76	73.88
	Jhakri U/S	May, 2002	72.31	79.38	81.65
	Jhakri D/S	May, 2002	69.60	77.45	73.37
HPPCB	Nathpa U/S	July, 2002	66.58	74.80	68.29
	Nathpa D/S	July, 2002	62.24	72.96	66.97
	Jhakri U/S	July, 2002	66.05	72.70	66.81
	Jhakri D/S	July, 2002	63.85	72.84	66.29
HPPCB	Nathpa U/S	Sep-Oct, 2002	64.96	91.44	62.49
	Nathpa D/S	Sep-Oct, 2002	80.77	89.70	85.55
	Jhakri U/S	Sep-Oct, 2002	70.67	78.55	74.42
	Jhakri D/S	Sep-Oct, 2002	75.41	82.66	78.61
HPPCB	Nathpa U/S	Nov-Dec, 2002	76.49	81.31	82.09
	Nathpa D/S	Nov-Dec, 2002	72.46	73.54	75.34
	Jhakri U/S	Nov-Dec, 2002	73.02	77.24	76.96
	Jhakri D/S	Nov-Dec, 2002	75.00	75.73	75.72
HPPCB	Nathpa U/S	Feb, 2003	73.75	73.36	77.63
	Nathpa D/S	Feb, 2003	71.89	71.70	75.66
	Jhakri U/S	Feb, 2003	78.54	79.94	79.77
	Jhakri D/S	Feb, 2003	76.13	77.25	76.12
HPPCB	Nathpa U/S	Mar, 2003	64.33	74.61	71.14
	Nathpa D/S	Mar, 2003	61.1	74.96	68.54
	Jhakri U/S	Mar, 2003	67.23	80.39	75.65
	Jhakri D/S	Mar, 2003	62.73	67.05	59.63
HPPCB	Nathpa U/S	Apr, 2003	63.27	78.48	73.65
	Nathpa D/S	Apr, 2003	70.52	77.82	73.2
	Jhakri U/S	Apr, 2003	60.74	70.95	66.99
	Jhakri D/S	Apr, 2003	64.82	69.86	69.95
Standard Error				5.032	3.168
Root Mean Square Error (RMSE)				9.550	4.878
Correlation Coefficient between NSF-WQI & CPCB-WQI/Satluj-WQI				0.483	0.858

root mean square error) than CPCB-WQI with NSF-WQI. However, CPCB-WQI and Satluj-WQI values are little higher than NSF-WQI. This is due to the fact that CPCB-WQI and Satluj-WQI consider lesser number of water quality parameters and hence getting relatively higher weightages compared to the weightages assigned to these parameters in NSF-WQI.

Change in Satluj-WQI in the post-project scenario: Observed water quality data for pre and post project conditions at different locations on Satluj river have been used to calculate Satluj WQI. The Satluj WQI at U/S of Nathpa dam, D/S of desilting complex of NJHEP, D/S of Jhakri and D/S of Rampur are compared in Fig. 2 (rainy season) and Fig. 3 (lean season).

The Satluj WQI is higher than Satluj WQI standard at all the locations and also during rainy season and lean season. It is mainly because the water quality parameters (DO, BOD, pH, Faecal coliform) are well within acceptable limits even though turbidity of Satluj river is very high. The excessive turbidity during the post-project condition will have adverse impact on the aquatic life. The lean season Satluj WQI at D/S of Rampur for the post-NJHEP and post-RHEP condition just meets the standard as shown in Fig. 3. This may be attributed to higher turbidity and higher faecal coliform expected in the post-RHEP situation.

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Sustainable Agriculture through Two-Tier Rain Water Management System in Rainfed Agriculture

S. M. Taley, A. N. Mankar[1], K. A. Jadhav[2] and V. P. Ubarhande[2]

Department of Soil & Water Conservation Engineering; [1]Department of Agricultural Engineering
[2]Agro-Ecology and Environment Centre
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola-444 104, India
E-mail: smtaley@rediffmail.com

Abstract: The study was conducted on two tier system rainwater conservation measures in saline tract of Purna river valley with the objective to increase the productivity, profitability and water use efficiency through suitable double cropping system. Double cropping system of green gram-chickpea, the yield of green gram was found significantly higher (i.e. 8.48 q ha^{-1}) under two tier system of rain water management (contour cultivation with protective irrigation) over the yield recorded in other rain water management systems. Chickpea grown after green gram under two tier system gave significantly higher yield of 19.33 q ha^{-1} in comparison to other moisture management practices. Soybean under two tier system recorded significantly higher yield of 23.56 qha^{-1} as compared with yield recorded in mono tier system (contour and across the slope cultivation) and conventional system. Chickpea yield after harvesting of soybean was significantly superior over other practices of soil moisture management. The significantly higher chickpea equivalent yield of 21.53 q ha^{-1} was found in soybean–chickpea cropping system compared with the chickpea equivalent yield of 19.33 q ha^{-1} recorded in green gram–chickpea cropping system under two tier system. The higher net returns of Rs.87076 ha^{-1} was found in soybean-chickpea cropping system under two tier system and the lowest Net return of Rs. 14401 was found in green gram–safflower cropping system under mono-tier system. Double cropping system of green gram-chickpea and soybean-chickpea observed statistically at par in B:C ratio.

Key Words: Cropping system, Conservation, Contour, Rain water management, Two-tier system

The Purna valley of Vidarbha region is an East–West elongated basin with slight convexity to the south and covers parts of Amaravati (1738 km^2), Akola (1939 km^2) and Buldhana (1015 km^2) districts which extends from 20° 45' to 21° 15' N latitude and 75° 15' to 77° 45' E longitude. This tract spreads on both sides of Purna river, affecting about 892 villages, covering an area about 4.69 lakh ha. The river starts from southern slopes of Govilgarh hills of Satpuda range, which is the principal drain joining to Tapi river. The major tributaries are Pedhi, Sarapi, Shahanur, Katepurna, Uma, Morna, Man, Mas, Nirguna, Nalganga and Dnyanganga. Locally it is said that there are about 360 tributaries joining Purna river. Of the 4.69 lakh ha area in the affected tract, very little portion is irrigated. Surface irrigation sources are negligible here. The main crops of the saline tract are cotton, sorghum, pigeon pea, black gram and green gram. In the small double cropped pockets, wheat, gram and safflower are cultivated.

Rainfed area in Purna river valley are highly diverse ranging from resource rich area with good agricultural potential to resource poor area with much more restricted potential with salinity and sodicity. The soil management in the saline tract of Purna valley is difficult due to the severe erosion rate, swelling, cracking and seizing characteristics. In India over 40% of the agricultural land is located in arid region and the farmers are not even able to recover their investments in agriculture. It has been reported that hardly 35% of the rain water is used effectively while the remaining 65% goes as runoff, causing severe soil erosion, flooding of rivers and siltation of water bodies. Hence, this valuable asset has turned out to be a liability.

The erosion hazards are greater under cereals and millets crops cultivation. Jat *et al.* (2008) reported that, the black gram was found effective in controlling run off and soil loss as compare to cereals and millet crops. Hence, the present investigation was carried out to study the productivity, profitability and water use efficiency through suitable double cropping system (two tier system) in saline tract of Purna river valley in Amravati district of Vidarbha.

MATERIAL AND METHODS

The experiment was carried out in Randomized Block Design with five rain water management systems. The treatments comprised A) conventional system, control, B) Mono-tier system cultivation across the slope and Contour cultivation, C) Two-tier system, cultivation across the slope with protective irrigation and contour cultivation with protective irrigation system of rain water management (RWM). The rainfall received during the experimental years was during 2008-09 is 534.80 mm, 2009-10: 727.30 mm, 2010-11: 1076.3 mm, 2011-12: 453.6 mm, 2012-13: 674.0 mm and 2013-14: 894 mm.

Three cropping system i.e. green gram – chickpea, soybean - chickpea and green gram–safflower were followed under each rain water management system. green gram and soybean sown during last week of June to first week of July and harvested after 60 to 110 days, respectively during each seasons. Chickpea and safflower were sown in last week of September to first week of October and harvested after 90 to 110 days, respectively. Crop varieties Nirmal for green gram, Jaki-9218 for chickpea, JS-35 for soybean and Bhîma for safflower were selected. The recommended doses of NPK were applied @ 25:50:20 Kg ha^{-1} to green gram, 25:50:30 Kg ha^{-1} to chickpea, 30:75:30 Kg ha^{-1} to soybean, and 25:25:00 Kg ha^{-1} to safflower. One protective irrigation of 2.5 to 3.0 mm depth was given. The net returns, benefits cost ratio and production efficiency value in terms of Kg ha^{-1} day^{-1} and Rs.ha^{-1}day^{-1} were calculated with standard methods.

Water use efficiency was calculated with the help of following formula.

$$\text{Water use efficiency (kg ha}^{-1}\text{ mm)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Total water applied (mm)}}$$

The individual year's data and pooled data of six years were statistically analysed with the standard methods described by Gomez and Gomez (1984). The results of the study have been discussed year wise and based on mean value of six years.

RESULTS AND DISCUSSION

Productivity of cropping system: The pooled data [Fig. 1 (a & b)] over the period of six years revealed that the double cropping system of green gram–chickpea, green gram gave significantly higher yield of 8.48 qha^{-1} under two tier system of rainwater management i.e. contour cultivation with protection irrigation followed by across the slope cultivation with protective irrigation (8.20 qha^{-1}) over the yield recorded in mono tier systems of rainwater management. Chickpea grown after green gram under two tier system of rainwater harvesting gave significantly higher yield of 19.33 qha^{-1} in

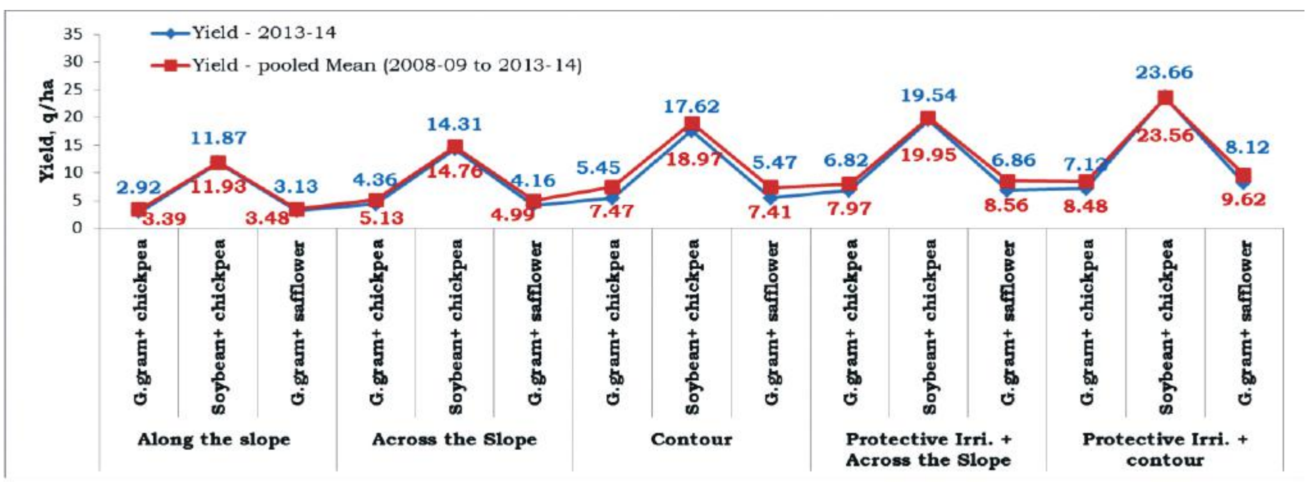

Fig. 1(a). Yield of different cropping system (Kharif) under various system of rain water management (2008-09 to 2013-14)

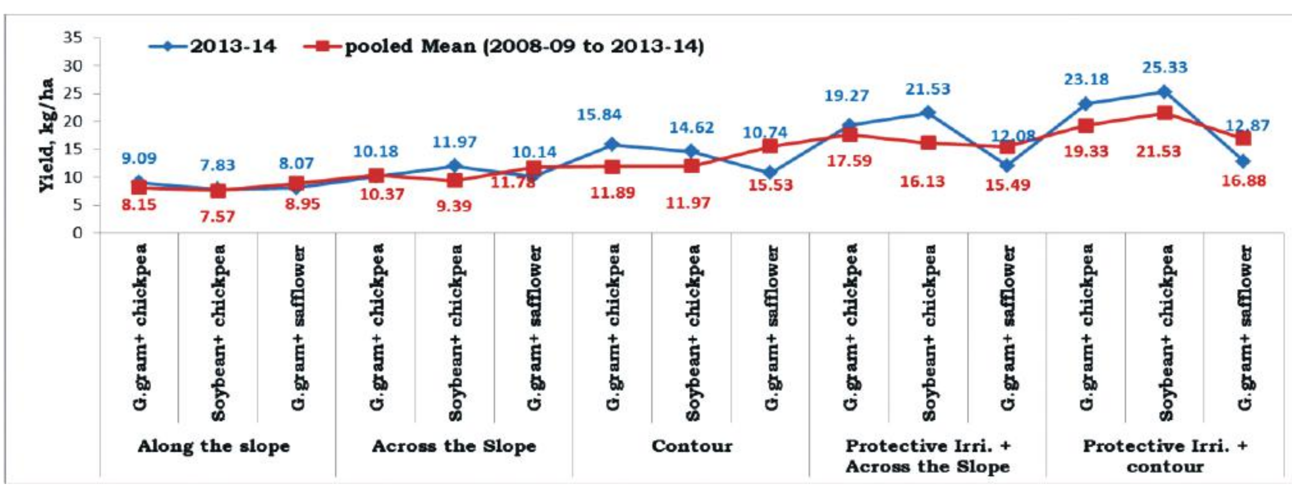

Fig. 1(b). Yield of different cropping system (Rabi) under various system of rain water management (2008-09 to 2013-14) comparison to other moisture management practices. Two tier system of rain water management recorded significantly higher yield of soybean (23.66 qha^{-1}) as compared with yield recorded in mono tier (contour and across the slope cultivation) and conventional system of rain water management. Similarly highest chickpea yield of 21.53 qha^{-1} was recorded in two tier system of rain water management after harvesting of soybean which was significantly superior over other practices of soil moisture management. The double cropping system of soybean-chickpea was found superior followed by green gram-chickpea in mono and two tier system of rainwater management. The highest net return of Rs. 87076 ha^{-1} was obtained from soybean-chickpea cropping system which was highest over to the net returned received from green gram - chickpea (Rs. 68937 ha^{-1}) and green gram - safflower (Rs. 48784 ha^{-1}) under two tier system of rain water management. Double cropping system of green gram + chickpea and soybean + chickpea observed statistically at par in B: C ratio.

The highest production efficiency (19.92 kg ha^{-1} and 14.45 Rs ha^{-1} day^{-1}) was observed in green gram – chickpea cropping system followed by (19.68 kg ha^{-1} and 14.25 Rs ha^{-1} day^{-1}) in soybean - chickpea cropping system under two tier system over mono-tier system of rainwater management. Similarly highest B:C ratio and water use efficiency was recorded in green gram-chickpea cropping system over soybean- chickpea in two tier system followed by mono-tier system of rainwater management, similarly highest rainwater conservation was observed in contour cultivation followed by across the slope cultivation. Studies of Goyal and Sharma (2000) and Goyal *et al*. (2007) also revealed that the variation in amount of moisture conserved, time of moisture depletion and moisture management through life saving irrigations with impounded rain water, maintained the yield levels of Kharif and rabi season. From the result it is observed that the protective irrigation with contour and across the slope cultivation during dry spell in monsoon season and during moisture stress in winter is beneficial over mono-tier system of rain water management.

Economics of cropping system: The expenditure of Rs. 23,888 ha^{-1} was incurred on the cultivation of green gram-chickpea, Rs. 28065 ha^{-1} was incurred on soybean–chickpea and Rs. 24885 ha^{-1} in green gram–safflower cropping system with cultivation across the slope and protective irrigation (Fig.2).

Green gram-chickpea cropping system incurred Rs. 24583, soybean-chickpea Rs. 28789 and green gram–safflower Rs. 25046 on cultivation of contour cultivation with protective irrigation. The highest gross returns of Rs. 115865 and net return of Rs. 87076 was obtained from the soybean–chickpea in two tier system of rain water management. The lowest gross returns of Rs.35424 and net return of Rs. 14401 was found in the green gram-safflower cropping system with conventional system of moisture management (i.e. along the slope cultivation).

Production efficiency: Production efficiency value in terms of kg ha^{-1} day^{-1} was increased with increasing combination of moisture management practices under both the cropping systems. Production efficiency of 19.92 kg ha^{-1} day^{-1} was recorded in green gram-chickpea cropping system and

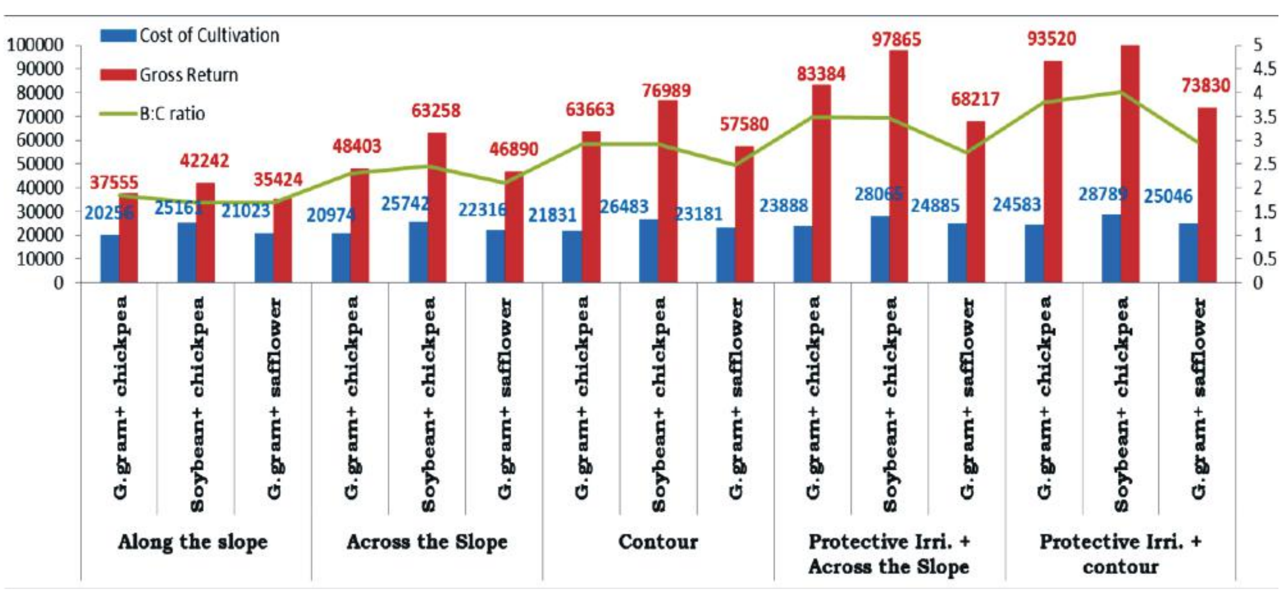

Fig. 2. Economics of different cropping system under various system of rain water management

19.68 kg ha^{-1} day^{-1} in soybean–chickpea cropping system.

Similar trend was also found in production efficiency value in terms of Rs ha^{-1} day^{-1}. The highest production efficiency value was recorded in green gram-chickpea cropping system (14.45 Rs. ha^{-1} day^{-1}) followed by soybean-chickpea (14.25 Rs. ha^{-1} day^{-1}).

B: C ratio: The green gram–chickpea followed by soybean-chickpea double cropping system were best for higher production efficiency and net returns under contour cultivation with protective irrigation followed by across the slope cultivation with protective irrigation in deep black soil (Fig. 2). The benefit cost ratio of green gram-chickpea (1:3.80), soybean-chickpea (1:4.02) and green gram-safflower (1:2.95) double cropping system showed that the

Table 1. Production efficiency value under various moisture conservation practices

	Rain water mang.	Cropping system	Gram equivalent yield (kg ha^{-1})	Crop duration, (days)	Production efficiency value (kg ha^{-1} day^{-1})	Production efficiency value (Rs ha^{-1} day^{-1})
Conventional	Along the	G.gram+chickpea	1384.13	175	7.92	3.47
	slope	Soybean+chickpea	1501.84	205	7.33	2.58
		G.gram+safflower	1325.57	200	6.63	2.59
Mono tier	A/S	G.gram+chickpea	1812.71	175	10.35	5.72
		Soybean+chickpea	1758.19	205	10.81	5.96
		G.gram+safflower	1763.44	200	8.82	4.46
	Contour	G.gram+chickpea	2296.29	175	13.12	8.27
		Soybean+chickpea	2686.44	205	13.11	8.11
		G.gram+safflower	2199.33	200	10.99	6.45
Two tier	P I	G.gram+chickpea	3131.81	175	17.89	12.61
	+	Soybean+chickpea	3426.34	205	16.64	11.44
	A/S	G.gram+safflower	2549.28	200	13.41	7.87
	P I	G.gram+chickpea	3486.03	175	19.92	14.45
	+	Soybean+chickpea	4034.56	205	19.68	14.25
	Contour	G.gram+safflower	2807.21	200	14.04	9.19
CD (p=0.05)			423.36	-	1.68	1.57

Table 2. Season wise avg. soil moisture content at various depths under different system of rain water management and cropping systems (2008-09 to 2013-14)

	Treatment	Cropping system	Kharif				Rabi			
			15 cm	30 cm	45 cm	60 cm	15 cm	30 cm	45 cm	60 cm
Conventional	Along the	G.gram+chickpea	8.29	14.35	19.59	26.38	7.70	9.82	11.52	13.86
	slope	Soybean+chickpea	7.89	12.42	17.72	27.02	7.72	9.78	11.84	13.74
		G.gram+safflower	8.47	16.13	21.83	30.75	7.04	11.24	12.08	14.02
Mono tier	A/S	G.gram+chickpea	11.26	16.52	21.12	28.12	12.16	13.52	13.74	15.16
		Soybean+chickpea	8.68	14.52	19.12	29.34	12.08	12.74	13.97	15.52
		G.gram+safflower	11.72	15.54	23.52	32.14	11.12	14.12	14.12	15.94
	Contour.	G.gram+chickpea	14.10	18.17	22.54	30.08	14.12	15.12	15.76	17.52
		Soybean+chickpea	10.84	16.54	21.12	31.84	13.74	14.12	15.84	17.84
		G.gram+safflower	14.70	17.32	24.08	34.12	13.08	16.74	16.08	17.72
Two tier	PI	G.gram+chickpea	12.75	20.52	24.12	32.12	17.08	22.12	24.12	26.52
	+	Soybean+chickpea	12.07	18.74	23.54	33.44	15.86	23.08	26.16	28.12
	A/S	G.gram+safflower	12.04	19.74	26.12	36.08	16.12	21.12	25.58	28.84
	PI	G.gram+chickpea	13.64	24.12	27.12	34.56	19.12	25.08	32.16	34.12
	+	Soybean+chickpea	13.67	22.14	25.84	36.52	18.16	26.84	33.18	36.58
	Contour	G.gram+safflower	13.94	23.12	28.12	38.12	19.08	26.52	34.12	38.19

Table 3. Water use efficiency (kg ha^{-1}mm) rainfed cropping system (2008-2013)

	RWM	Cropping system	Mean yield kg ha^{-1}	WUE kg ha^{-1} mm	%increase over conventional
Conventional	Along the	G.gram+chickpea	339	0.44	-
	slope		909	1.19	-
		Soybean+chickpea	1193	1.57	-
			783	1.03	-
		G.gram+safflower	348	0.45	-
			807	1.06	-
Mono tier	A/S	G.gram+chickpea	513	0.67	51.33
			1018	1.34	11.99
		Soybean+chickpea	1476	1.94	23.72
			1197	0.57	52.87
		G.gram+safflower	499	0.65	43.39
			1014	1.33	25.65
	Contour	G.gram+chickpea	447	0.58	31.5
			1584	2.08	74.25
		Soybean+chickpea	1897	2.49	59.01
			1462	1.92	86.71
		G.gram+safflower	741	0.97	112.93
			1074	1.41	33.08
Two tier	PI +	G.gram+chickpea	797	0.98	135.10
	A/S		1927	2.38	111.99
		Soybean+chickpea	1995	2.46	67.22
			2153	2.65	174.96
		G.gram+safflower	856	1.05	145.97
			1208	1.49	49.69
	PI +	G.gram+chickpea	848	1.04	150.50
	Contour		2318	2.86	155.00
		Soybean+chickpea	2356	2.91	97.48
			2533	3.12	223.49
		G.gram+safflower	962	1.18	176.43
			1287	1.58	59.47

management of rain water with contour and across the slope cultivation supported with protective irrigation from pond (two tier system) is economically viable in the deep black soil of saline tract Purna river valley.

Soil moisture content: Soil moisture content in both the season's *kharif* and *rabi* were recorded at different depth i.e. 15 cm, 30 cm, 45 cm, and 60 cm (Table 2). Soil moisture content was highest in green gram- safflower cropping system. During *kharif* at 45cm depth soil moisture content was found to the tune of 28.12 and at 60 cm depth 38.12. During *rabi* season at 45 cm depth soil moisture content was found to the tune of 34.12 and at 60 cm depth 38.19.

Water use efficiency: In two tier system the water use efficiency was recorded 2.91 kg ha^{-1} mm^{-1} in soybean and 3.12 kg ha^{-1} mm^{-1} in chickpea under soybean-chickpea cropping system in contour cultivation with protective irrigation (Table 3). The water use efficiency of 2.86 kg ha^{-1} mm^{-1} was in chickpea and 1.04 kg ha^{-1} mm^{-1} was in green gram in green gram-chickpea cropping system. The water use efficiency was recorded in all tested crops under two tier system was higher over other moisture management system. It is concluded that the two-tier system i.e. contour and across the slope cultivation with protective irrigation during dry spell in monsoon and moisture stress in winter is beneficial over mono-tier system of rain water management. Thus, for the sustainable rainfed agriculture the two-tier rain water management system is beneficial in terms of productivity and net returns.

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Flood Prediction Analysis of Wadanepalley Gauging Station

S. Priyadarsini, Kiran Yarakula[1] and Pijush Samui[1]
School of Information Technology and Engineering
[1]Centre for Disaster Mitigation and Management, Vellore Institute of Technology, Vellore-632 014, India
E-mail: priyait46@gmail.com

Abstract: To reduce damage, forecasting of flood events is very useful information. In the present paper, the daily discharge data for 2009 of Krishna River at Wadanepalley gauging station is used for prediction. To analyze the pattern of the discharge, Auto Regressive Integrated Moving Average (ARIMA), Back Propagation Artificial Neural Network (BPNN) with normalized data to predict the flood values. Apart from the work, machine learning techniques called Relevance Vector Machine (RVM) and Gaussian Process Regression (GPR) are also applied for the prediction of discharge data. With the help of correlation co-efficient (r) and Root Mean Square Error (RMSE), the accuracy of prediction of various models is examined. A comparative analysis is also performed between ARIMA, BPNN, RVM and GPR. From the results it is observed that RVM provides better results than that of ARIMA, BPNN and GPR.

***Key Words*:** Correlation coefficient, Flood prediction, Feed forward back propagation neural network, Relevance vector machine, RMSE, Regression models

Water is the most precious and replenishes available natural resource on the nature. The development and management of water resources are the major concern for any country or region. To reduce damage due to flood, forecasting of flood events is very useful information. Large numbers of severe and devastating floods, endangering both life and property have been recorded in Andhra Pradesh. According to the data compiled by the XII plan working group on flood management and regional specific issues of central water commission (CWC), 9.040 Mha area of Andhra Pradesh is affected by flood during 1953-2010 (CWC, 2011).

The prediction of flood will be helpful for reducing the damages. The prediction is possible by using a statistical model based on historical data and past events. Time series forecasting model is applied to predict and forecast the future events based on the known old values before happening and measuring to avoid damages due to natural hazards like, rainfall, flood, and drought. For time series analysis, the mathematical statistical models like Auto Regression (AR) and Auto Regressive Integrated Moving Average (ARIMA) have been widely used in the water resources problems. Compared to physical based mathematical models, the advantage of artificial neural networks is the fact that the ANN simulates processes without the incorporation of physical laws in the mathematical form.

Relevance vector machine (RVM) is another kernel based approach widely used for classification and regression within the last few years. Huang *et al.* (2008) examined the use of RVM to predict stock indices. Combined the RVM algorithm with wavelet techniques to build the model, using wavelets to extract patterns from the variable time series and the extracted features have been used as the RVM input to make predictions. GPR is a probabilistic and non-parametric model. In GPR, the output is a normal distribution. There are lots of applications of GPR in the literature (Ruiz and Binefa, 2012; Nearing *et al.,* 2014; Chen *et al.,* 2014).

In the present research work, Andhra Pradesh is considered as the study area for the prediction of daily discharge. In Andhra Pradesh, Krishna, Godavari, Palar and Penner are the main rivers used to sustain agriculture, industrial power generation and for domestic purpose. Simultaneously more number of floods has been recorded on Krishna and Godavari rivers. Hence historical data about the Wadanepalley gauging station of Krishna River is used to analyze the predicted data.

The machine learning technique, Relevance Vector Machine (RVM) and Gaussian Process Regression (GPR) have been used in this study for prediction of daily data. Finally the predicted value of all the models like ARIMA, BPNN, RVM and GPR are analyzed and identified the best model. The best model is acknowledged based on the correlation co-efficient and Root Mean Square Error (RMSE).

MATERIAL AND METHODS

Auto Regressive Integrated Moving Average (ARIMA)

Auto-regressive (AR) Model: For the predicted values of the models like auto regressive integrated moving average (ARIMA), back propagation feed forward neural network (BPNN), relevance vector machine (RVM) and gaussian process regression (GPR) are analyzed and identified the best fitted model for the above said data based on the correlation coefficient and RMSE values.

The AR model is applied to the time series data in which the event outcome of (t+1)th period is dependent on the presence t period magnitude and those preceding values observed sequence $X_1, X_2, \ldots X_t$ is used to fit the AR model.

$$X_t \quad {}_1(X_{t\ 1} \quad) \quad {}_2(X_{t\ 2} \quad) \ \ldots\ldots\ {}_k(X_{t\ k} \quad) \quad {}_i \ldots(1)$$

Where, is mean of the observed values. ^{2} is the variance of the observed values.

${}_i$ is the random variate with mean zero and ${}_i \quad N(0, \frac{r}{})$

^{2} is the variance of the observed values. First order AR is denoted by AR (1) and defined as,

$$y_t \quad {}_1(y_{t\ 1} \quad) \quad {}_i \ldots..(2)$$

The second order AR model is denoted by AR (2) and represented as,

$$y_t \quad {}_1(y_{t\ 1} \quad) \quad {}_2(y_{t\ 2} \quad) \quad {}_i \ldots.(3)$$

Moving Average (MA) Model: The equation for moving average model for generating the values X_t at any instant in the series is as,

$$X_t \quad {}_t \quad {}_1\ {}_{t\ 1} \quad {}_2\ {}_{t\ 2} \ \ldots..\ {}_k\ {}_{t\ k} \ldots.(4)$$

Where *k* denotes the order of moving average and

$$y_t \quad {}_0 \quad \sum_{i\ 1}^{p} \ {}_i y_{t\ 1} \quad \sum_{i\ 0}^{q} \ {}_i\ {}_{i\ 1} \ldots.(5)$$

By the convention of normalizing units, where

$$y_t \quad {}_0 \quad {}_1 y_{t\ 1} \quad {}_2 y_{t\ 2} \ \ldots\ldots..\ {}_p y_{t\ p} \quad {}_t \quad {}_1\ {}_{t\ 1} \ \ldots\ldots\ {}_q\ {}_{t\ q}$$

Back Propagation Feed Forward Neural Network (BPNN) Model: A neural network is a powerful data modeling tool to capture and represent complex input/output relationships. Neural Network acquires knowledge about the input through learning. ANN is the mathematical model is biological neurons. The feed forward neural network is widely used ANN in hydrology and water resource engineering. This consists of three layers namely input layer, hidden layer and output layer. The data are introduced to the network by using input layer; the input layer data are processed in the hidden layer. Finally output layer produces output. The basic model of the feed forward network is shown in Fig 1.

Mathematically three layer feed forward neural network with a input nodes, b hidden layers and one output node can be represented as

$$q_t \quad g(\sum_{j\ 1}^{b} w_j f(\sum_{i\ 1}^{a} w_i p_{t\ i})) \ldots.(7)$$

Where q_t is the output layer, p_{t-1} is the input of the network, w_i is the connection weights between the input and hidden nodes, w_j is the connection weight between hidden and output nodes. The most common g(9) function is sigmoid function and f(8) is the linear function. The equation for sigmoid and linear function is given as follows:

Linear: $f(x) \quad purelin(x) \quad x_i \ldots.(8)$

Log-sigmoid: $g(x) \quad \log sig(x) \quad \dfrac{1}{1 \quad \exp(\quad x)} \ldots.(9)$

The back propagation neural network (BPNN) is the most popular supervised learning model of artificial neural networks, which is developed by (Rumelhart *et al.,* 1986). In the training phase, each layer's weight and biases are initialized. By using the trained network, the simulation is done to predict data using the model. BPNN continuously adjust the weights and biases so that the error between target output and estimated output is minimized. This parameter modification stops when the performance error goal is achieved (Karunanithi *et al*., 1994). Post processing is used to forecast the model to predict future data value.

Relevance Vector Machine (RVM): The Relevance vector machine is another kernel based approach being explored for classification and regression within the last few years. Artificial neural network and SVM requires a large set of data whereas RVM is characterized to observe the relationship among variables with small observations. The selection of kernel, kernel specific parameters, regularization parameters and the interpretation of model is the major challenge in SVM (Cannas *et al*., 2006).

The RVM adopts a Bayesian approach to learn the observations in a data set, *x*, are key to reproducing the patterns represented by those observations, and seeking sparsity by using only those observations that contain independent useful information about the process being modeled (Kitandis and Brar, 1980). RVM predicts output by maximizing a marginal likelihood. In RVM, the relation between x and y is given below.

$$y \quad \sum_{i\ 1}^{N} a_i K \ x, x_i \quad a_0 \ldots.(10)$$

where N is the number of datasets, $K(x,x_i)$ is a kernel function, a_0 and a_i are weights.

The expression of the likelihood from the training datasets is given below.

$$p\ y/a, \ ^2 \quad 2 \quad ^{2\ n/2} \exp \quad \frac{1}{2\ ^2} \| y \quad a \ \|^2 \ \ldots.(11)$$

The value of *a* is determined by maximizing the above expression (11). To avoid over fitting, the following zero-mean Gaussian prior distribution is assigned to a.

$$p\ a/\ \quad \prod_{i\ 0}^{n} N\ a_i/0,\ _i^{1} \quad \prod_{i\ 0}^{n} \frac{_i}{\sqrt{2}} \exp \quad \frac{a_i\ _i^{\ 2}}{2} \text{ ....(12)}$$

posterior distribution of a is given below.

$$p\ a/y,\ \ ,\ ^2 \quad 2 \quad ^{-\frac{n\ 1}{2}} \left|\ \right|^{\frac{1}{2}} \exp \quad \frac{1}{2}\ a \qquad ^1\ a$$

here is mean and is variance. The expression of and is given below.

$$^2 \qquad A^{\ 1}$$

$$^2 \qquad y\text{....(15)} \quad \text{where } A \quad diag \quad _0,\ _1,...,\ _n$$

and $x_1\ ,\ \ x_2\ ,...,\ \ x_n$

The marginal likelihood is given below.

$$p\ y/\ \ ,\ ^2 \quad \begin{matrix} p\ y/a,\ ^2\ p\ a/\ \ da \quad 2 \quad ^{n/2} \left|\ ^2 I \quad A^{\ 1}\ \right|^{1/2} \\ \exp \quad \frac{1}{2} y \quad ^2 I \quad A^{\ 1} \quad ^1 y \end{matrix} \text{ ....(16)}$$

Gaussian Process Regression (GPR): Let us consider the following sample (L)

$$L \qquad x_i, y_i \ \ _{i\ 1}^{N} \text{....(17)}$$

Where *x* is input, *y* is output and *N* is the number of datasets. In the present research work, L_x and L_y have been taken as inputs for the GPR. The output of GPR is d_w

So, $x \quad L_x, L_y$ and $y \quad d_w$

In GPR, the relation between *x* and *y* is given below.

$$y_i \quad f\ x_i \qquad _i\text{....(18)}$$

Where f is latent real-valued function and åis the observation error.

For a new input (x_{N+1}), the expression of the output (y_{N+1}) is given below.

$$\begin{matrix} y \\ y_{N\ 1} \end{matrix} \sim N\ \ 0, \begin{matrix} K\ \ x,x \qquad _n^2 I & k\ \ x, x_{N\ 1} \\ k\ \ x, x_{N\ 1} & k\ \ x,x \end{matrix} \text{ ....(19)}$$

Where $_n^2$ is variance, K and k denote covariance matrix. The distribution of Y_{N+1} is Gaussian. The mean () and variance (^{2}) of Y_{N+1} is given below.

$$k\ \ x_{N\ 1}\ \ K^{\ 1} y\text{....(20)}$$

$$^2 \quad k\ \ x_{N\ 1} \quad k\ \ x_{N\ 1}\ ^T K^{\ 1} k\ \ x_{N\ 1}\text{ ....(21)}$$

Data analysis: The ANN is trained and tested and the optimal number of neurons in the hidden layer has been identified using some guidelines. To avoid the problem of over-fitting, and to select the appropriate architecture with optimal number of neurons in the hidden layers for "I" input layers, some guidelines have been proposed by researchers. (Kang *et al*., 1991) proposed I/2as hidden layer neurons, "I" proposed by (Tang and Fishwick, 1993), "2I" proposed by (Wong, 1991) and "2I+1" proposed by (Hecht-Nielsen, 1990). Table 1 shows the performance of ANN varying with the number of nodes in the hidden layer. It is observed that ANN with 2I neurons in hidden layer provides better performance with r close to 1 and with lowest RMSE value. The bolded value specifies the best result.

Evaluation of performance: In this work Root Mean Square Error (RMSE) has been used as performance evaluation measure as this is a very sensitive to even small errors, it is better to compare the small differences in the model's performance.

The RMSE is defined as follows:

$$RMSE \quad \sqrt{\frac{\sum_{i\ 1}^{n} (O_i \quad P_i)^2}{n}}\text{....(22)}$$

Where O_i is the observed frequency and P_i is the predicted frequency. *n* is the number of observations. In the present work 365 discharge frequencies have been used to model the predicted and observed data. Along with RMSE, correlation coefficient (*r*) also used as performance measurement.

$$r \quad \frac{\frac{1}{n}\sum_{i\ 1}^{n} (O_i \quad \overline{O})(P_i \quad \overline{P})}{\sqrt{\frac{1}{n}\sum_{i\ 1}^{n} (O_i \quad \overline{O})^2}\sqrt{\frac{1}{n}\sum_{i\ 1}^{n} (P_i \quad \overline{P})^2}}\text{....(23)}$$

The *r* value close to unity implies that the results are satisfactorily accepted otherwise it is inadequate.

RESULTS AND DISCUSSION

The various methods discussed in the present work are implemented using MATLAB 2009b. The daily discharge data of Wadanepalley gauging station for the year 2009 are used for the present research work.

Auto Regressive Integrated Moving Average (ARIMA): The result of ARIMA is depicted in figure 2(a) with correlation co-efficient. From the figure it shows that the observed and predicted discharge data follow the same pattern with no more deviations.

Back Propagation Neural Network (BPNN): In this method, three layer ANN model with log sigmoid transfer function from the input layer to the hidden layer, and a linear function from the hidden layer to output layer is used for forecasting. The input data and target data are normalized in the range [0, 1] because the sigmoid function has been used as a transfer function. The network is trained for 1000 epochs using back propagation algorithm with learning rate 0.001. The model is trained with various input structures and tested to identify the optimal number of neurons in the hidden layers. The input data are divided into 70% training data and 30% testing data for the proposed experiment purpose. The performance of BPNN is given in terms of RMSE and *r* in Table 2.

Relevance Vector Machine (RVM): Here to implement RVM the input data of BPNN have been used for this procedure. The radial basic function (RBF) is used as the kernel function. The objective function of RVM is,

$$y \quad \sum_{i\ 1}^{33} w_i e^{\frac{(x_i\ \ x)(x_i\ \ x)^T}{1.62.}} \quad ....(24)$$

Where *n* is the number of training samples. In this study, 33 samples have been used as training samples. *w* is weight and is width. Here the width is assigned with 0.9.

Gaussian Process Regression (GPR): The performance of GPR depends on the proper choice of and. In this article, trial and error approach has been used to determine the design values of and. The developed GPR gives the best performance at = 0.001 and = 0.4. Figure 1 shows the performance of training and testing data sets. The performance of GPR has been assessed in terms of Coefficient of Correlation(R) value. For a good model, the value of R should be close to one. It can be seen from Table 2 that the value R is close to one for training as well as testing datasets and the RMSE value is having lesser value.

Comparative study: The performance of predicted models like ARIMA, BPNN, RVM and GPR for Krishna river is compared. The RMSE and Correlation Co-efficient (*r*) are the performance measures for these models and the results of the models are summarized in the table 2. It is observed that the RVM model shows the best performance with the lowest RMSE and highest Correlation co-efficient for both training and testing data (Table 2). The BPNN is the second best model, followed by GPR. As specified in table ARIMA is having moderate prediction accuracy with less correlation co-efficient.

The RVM model performance is improved by 21.25% in correlation co-efficient and reduce in RMSE by 85.71% as compared to the performance of ARIMA. RVM also produced some improvement over GPR with about a 10.2% improvement in *r* and RMSE value of RVM is reduced

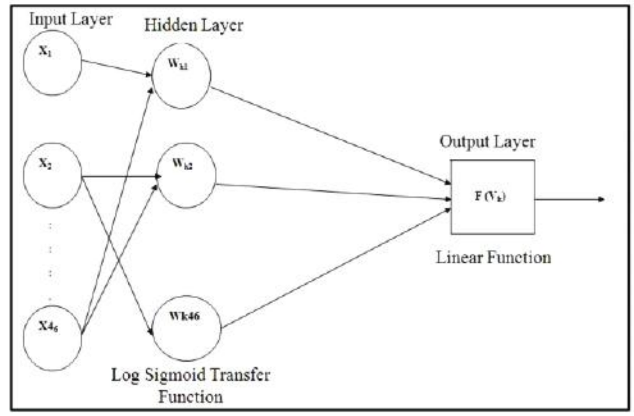

Fig. 1. Structure of feed forward neural network

Table 1. The result of ANN with different hidden neurons

Hidden neurons	RMSE	Correlation Coefficient(r)
I	0.004	0.812
2I	0.001	0.892
2I+1	0.008	0.743
I/2	0.008	0.671

Table 2. Performance measurements of models

Method	Correlation co-efficient	RMSE
ARIMA	0.78	0.42
BPNN	Train: 0.94, Test: 0.88	0.06
RVM	Train: 0.99, Test: 0.98	0.08
GPR	Train:0.89, Test:0.81	0.10

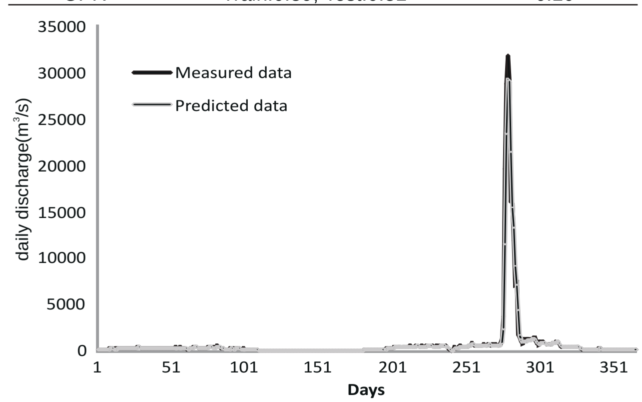

Fig. 2(a). Performance of auto regressive integrated moving average

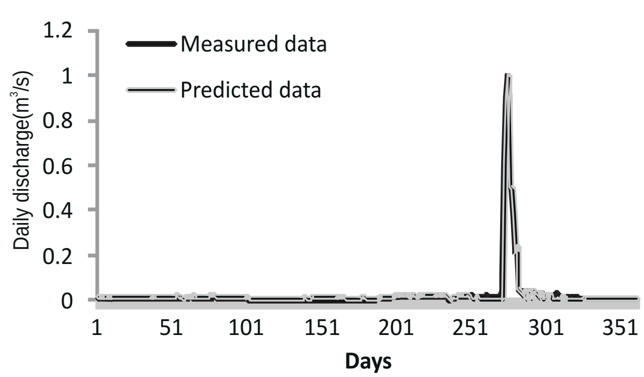

Fig. 2(b). Performance of back propagation neural network model

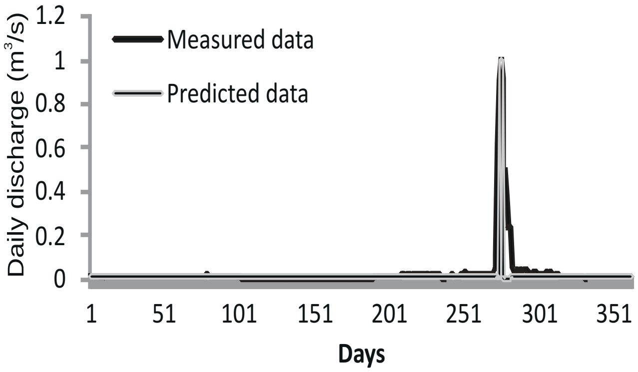

Fig. 2(c). Performance of regression vector machine

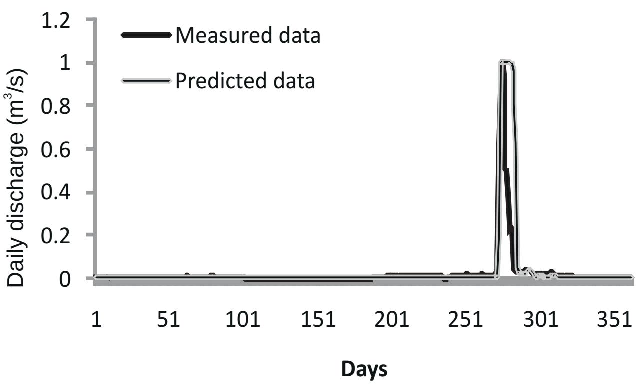

Fig. 2(d). Performance of gaussian process regression

by 0.2% when compared to GPR. As with, the RVM model resulted in improvement with about 0.5% over BPNN for *r* as well, and 0.25% reduction in RMSE as compared to BPNN.

Figure 2(a), 2(b), 2(c) and 2(d) show the results obtained with four model ARIMA, BPNN, RVM and GPR compared with measured daily discharge data of Krishna river at the wadanepalley gauging site for the year 2009. It indicates that ARIMA, BPNN, GPR and RVM fit the daily discharge better and these models are applicable for river flow forecasting. It is observed that RVM results are closer to the actual data than those of ARIMA, GPR and BPNN. It is also observed that form the results, RVM gives a better prediction performance with *r* value very closer to unity than other time series analysis models.

In the present study, Wadanepalley gauging site of Krishna River is used to perform the analysis. Auto Regressive Integrated Moving Average (ARIMA), Back Propagation Neural Network (BPNN), Gaussian Process Regression (GPR) and the Relevance Vector Machine (RVM) methods are used to identify the predicted daily discharge values for the year 2009. The performances of all the models are evaluated based on correlation co-efficient (r), Root Mean Square Error (RMSE). It is observed that the *r* values for ARIMA, BPNN, RVM and GPR are 0.78, 0.94, 0.99, and 0.89 respectively. The RMSE value shows very high value of 0.42 for ARIMA model and fewer values for BPNN (0.065623) and RVM (0.08). Based on the *r* values and RMSE, it is concluded that RVM depicts accurate results as compared to all the models.

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Species Selection for Enhancing Productivity of Freshwater Carps in Inland Saline Water of Punjab-A Field Study

Meera D. Ansal, Asha Dhawan, Gurmeet Singh and Kulwinder Kaur

Department of Aquaculture, College of Fisheries
Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141 004, India
E-mail: ansalmd@gmail.com

Abstract: Experiment was conducted to assess the possibility of enhancing productivity of freshwater carps in inland saline water of Punjab, through species selection in a semi-intensive poly-culture system. Freshwater carps were stocked (@ 15,000 fingerlings ha^{-1}) in three combinations viz; 5 species [*Catla catla* Ham. (catla), *Labeo rohita* Ham. (rohu), *Cirrhinus mrigala* Ham. (mrigal), *Cyprinus carpio* Linn. (common carp) and *Ctenopharyngodon idella* Val. (grass carp)], 4 species (catla, rohu, common carp and grass carp) and 3 species (catla, rohu, and common carp), in earthen ponds constructed in salt affected waterlogged area. Species selection did not has any undesirable effect on the overall survival of fish and among all the species, rohu registered highest percent survival (87.03 to 95.42%), while lowest survival was in grass carp (74.13 to 80.77%). An average fish productivity of 2.07, 2.18 and 2.38 tonne ha^{-1}, with an apparent feed conversion ratio of 2.24, 2.19 and 2.11 was recorded after 6 months of rearing from 5, 4 and 3 species rearing ponds, respectively. As compared to 5 species rearing, 15% higher productivity of freshwater carps was achieved in inland saline water (salinity 4-8 ppt), through 3 species rearing at a stocking density of 15,000 fingerlings ha^{-1}.

Key Words: Carps, Inland saline water, Productivity, Survival, Water logging

South-west districts of Punjab, comprising Mukatsar, Ferozepur, Faridkot, Fazilka, Bathinda and Mansa (Fig. 1) are affected by problems of underground salinity and water logging due to rising water table, which has been reported to have risen at an alarming rate (@ 15-20 cm $annum^{-1}$) during the last decade (Shakya and Singh, 2010). The twin problem of water logging and salinization in south-west Punjab is broadly attributed to the low lying topography of the affected areas coupled with lack of proper drainage system, poor percolation because of impervious clay strata and constant seepage from the Rajasthan and Sirhind feeder canal (Government of India, Planning Commission Report, 2013). Non-extraction of underground saline water, intensive irrigation network and land leveling, leading to major obliteration of the natural topography and drainage, and major shifts in cropping patterns in last 50 years have collectively contributed and compounded the dual problem of water logging and salinity in the south west region of the State.

In such inland salt affected waterlogged areas, where agriculture has very less or no scope and water although saline is abundantly available, aquaculture is the most suitable option. There is voluminous scope of utilizing these waste lands for rearing brackish water finfish and shellfish species like mullets, pearl spot, milk fish, sea bass, tiger prawn, vannamei shrimp, etc. (Jain, 2007; Pathak *et al.,* 2013), but it could not be developed due to the fact that all these species are cold sensitive and do not survive in the northern states during winters and further, seed of these species has to be airlifted from far off coastal states like Andhra Pradesh, West Bengal, Gujarat etc., which offers limited rearing period and does not fascinate the resource deficient farmers to take the initiative. In view of the mentioned limitations associated with brackish water species, substantial efforts have been made by Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana (Punjab) to work out the possibilities of rearing freshwater carps in inland saline water, which are the only species reared in the fresh water zone of the State. Freshwater carps

Fig. 1. Salt affected South-West districts of Punjab (map source: www.travelindia-guide.com)

were reared successfully in inland salt affected areas of Punjab, with an average productivity of 2.48 tonnes ha^{-1} yr^{-1} at stocking density of 10,000 fingerlings ha^{-1} under a semi-intensive poly culture system, which was later enhanced by 37.5% (3.40 t ha^{-1} yr^{-1}) through stocking density enhancement to 15,000 fingerlings ha^{-1} (Dhawan *et al.,* 2009, 2010; Ansal *et al.,* 2013), where survival and growth in freshwater carps in inland saline water was found to vary with species. Hence, the present study was taken up to work out the possibility of further enhancing the productivity of freshwater carps in inland saline water, through species selection at a stocking density of 15,000 fingerlings ha^{-1}.

MATERIAL AND METHODS

An outdoor 6-month semi intensive poly-culture trial of freshwater carps was conducted (in duplicate) in inland salt affected waterlogged waste land in village Shajrana (District Fazilka) Punjab, for productivity enhancement through species selection. Raised ponds (630-680m^2) with underground seepage water (salinity 15 parts per thousand or ppt), were filled with canal water (150 cm water depth and 60 cm free board). Ponds were manured with cow dung @ 20,000 kg $ha^{-1}yr^{-1}$ to boost natural fish food (plankton) production, where 1/4th of the dose was added 20 days before stocking of fish and rest in equal fortnight installments, after stocking fish. Fingerlings of surface, column and bottom feeding freshwater carps were stocked @ 15,000 fingerlings ha^{-1} in 3 different combinations viz; 5 species [*Catla catla* Ham. (catla), *Labeo rohita* Ham. (rohu), *Cirrhinus mrigala* Ham. (mrigal), *Cyprinus carpio* Linn. (common carp) and *Ctenopharyngodon idella* Val. (grass carp)], 4 species (catla, rohu, common carp and grass carp) and 3 species (catla, rohu, and common carp). The surface (catla), column (rohu and grass carp) and bottom (mrigal and common carp) feeding fish were stocked as per standard stocking ratio of 3:4:3, respectively (CIFRI, 1985). Fish were fed with farm made feed (rice bran and mustard meal in the ratio of 1:1) @ 2% fish body weight daily. Feed was applied in the form of dough every day after sunrise at a fixed time and place. During the culture period, canal water was used to compensate for evaporation and seepage losses for maintaining 150cm (5 feet) water depth and salinity levels below 8 ppt, as salinity levels above 8 ppt adversely affect survival and growth of freshwater species, including carps (Jain *et al.,* 2008; Dhawan *et al.,* 2009, 2010). Water quality analysis was carried out at fortnight intervals with respect to electric conductivity (EC), pH, total alkalinity (TA), total hardness (TH), chlorides (Cl^-), calcium (Ca^{++}), magnesium (Mg^{++}), Sodium (Na^+), potassium (K^+) and sulphate (SO_4^{2-}) concentration, following methods of APHA (1991). Salinity of water was tested by using ATAGO-Hand Refractometer, while sodium and potassium were estimated with flame photometer. Fish sampling was carried out at monthly intervals to record growth of each species (n=10) in terms of body weight and amount of supplementary feed was adjusted accordingly. Nylon threads and reflecting tape were tied over the experimental ponds for protection against predation by fish eating birds like cormorants and herons inhabiting the surrounding waterlogged area.

At the end of the rearing period, whole fish was harvested by draining out the pond completely with the help of a water pump to assess comparative fish survival and productivity in 5, 4 and 3 species rearing ponds. Net weight gain (NWG) of individual species and apparent feed conversion ratio (FCR) in different ponds were calculated by the following formulae

NWG = Average final body weight - Average initial body weight

$$\text{FCR} = \frac{\text{Feed given (kg)}}{\text{Fish biomass harvested (kg)}}$$

The data was analyzed with a Statgraphic statistical package (Statgraphics version 2.6). One way ANOVA and Duncan's multiple range tests was applied to work out the effect of different species combinations on growth of freshwater carps in inland saline water ($P \leq 0.05$).

RESULTS AND DISCUSSION

The salinity of water in 5, 4 and 3 species rearing ponds varied between 3.5-8 ppt during the culture period of 6 months (Fig. 2), where salinity of water declined after rainfall and addition of canal water in the pond for compensating evaporation and seepage losses. Range of different water quality parameters (EC, pH, TA, TH, Cl^-, Ca^{++}, Mg^{++}, Na^+, K^+ and SO_4^{-2}) in the different treatments during the experiment are presented in Table 1.

Overall survival of fresh water carps was 85.88, 86.13 and 85.67% in 5, 4 and 3 species rearing ponds, respectively (Table 2) and species selection did not has any undesirable

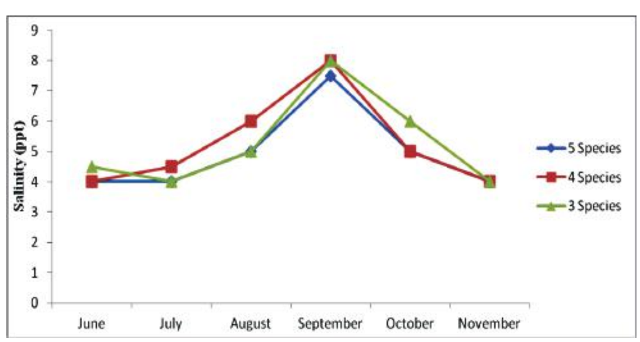

Fig. 2. Salinity (ppt) changes in 5, 4 and 3 species rearing ponds during the culture period

effect on the overall survival of fish. However, among all the species, rohu registered highest survival (87.03 – 95.42%) followed by mrigal, catla, common carp and grass carp, indicating better adaptability of rohu to inland saline water as compared to other species.

In 5 species rearing, rohu recorded the maximum body weight (186.67g) with NWG of 117.17g, while in case of 4 and 3 species rearing ponds, the bottom feeder common carp registered maximum body weight (210.67 and 219.00 g, respectively). It can be attributed to absence of mrigal in the

Table 1. Range of different water quality parameters in 5, 4 and 3 species rearing ponds

Species combination	Salinity (ppt)	EC (mS cm^{-1})	pH	TA $CaCO_3$ (mg l^{-1})	TH $CaCO_3$ (mg l^{-1})	Ca^{++} (mg l^{-1})	Mg^{++} (mg l^{-1})	Na^{+} (mg l^{-1})	K^{+} (mg l^{-1})	Cl^{-} (mg l^{-1})	SO_4^{2-} (mg l^{-1})
5 species *	4.0-7.5	5.87-9.67	7.49-8.27	102-180	1256-1880	134-345	165-243	730-1410	330-450	709-1528	86-142
4 species *	3.5-8.0	5.69-9.30	7.47-8.24	98-132	1224-2290	151-381	156-322	790-1250	340-480	813-1936	69-298
3 species *	4.0-8.0	5.71-9.70	7.81-8.57	84-112	1390-2320	101-402	136-237	820-1260	340-460	839-1929	98-152

* 5 species = Catla, rohu, mrigal, common carp and grass carp; 4 species = Catla, rohu, common carp and grass carp
3 species = Catla, rohu and common carp

Table 2. Survival and growth of freshwater carps in 5, 4 and 3 species rearing ponds

Parameter	Catla	Rohu	Mrigal	Common carp	Grass carp
	5 species combination (catla, rohu, mrigal, common carp and grass carp)				
% Survival	80.40	95.42	87.33	78.20	74.13
Initial BW (g)	19.50 ± 0.62	15.33 ± 0.84	10.50 ± 0.43	23.83 ± 0.87	9.50 ± 0.42
Final BW (g)	136.67 ± 4.28	186.67 ± 4.33	176.83 ± 4.42	150.50 ± 5.04	84.67 ± 2.46
NWG (g)	117.17	171.34	166.33	126.67	75.17
Overall fish survival = 85.88%					
Fish biomass harvested m^{-2} = 207 g					
Apparent FCR = 2.24					
Anticipated productivity ha^{-1} 6-$months^{-1}$ = 2.07 t					
Parameter	4 species combination (catla, rohu, common carp and grass carp)				
	Catla	Rohu	Mrigal	Common carp	Grass carp
% Survival	85.00	89.43	-	84.33	80.77
Initial BW (g)	19.17 ± 0.83	16.33 ± 0.80	-	23.84 ± 0.87	9.00 ± 0.57
Final BW (g)	137.17 ± 3.77	174.17 ± 3.95	-	210.67 ± 5.80	81.00 ± 1.32
NWG (g)	118.00	157.84	-	186.83	72.00
Overall fish survival = 86.13%					
Fish biomass harvested m^{-2} = 218 g					
Apparent FCR = 2.19					
Anticipated productivity ha^{-1} 6-$months^{-1}$ = 2.18 t					
Parameter	3 species combination (catla, rohu and common carp)				
	Catla	Rohu	Mrigal	Common carp	Grass carp
% Survival	86.40	87.03	-	83.50	-
Initial BW (g)	19.33 ± 0.84	15.17 ± 0.87	-	23.50 ± 1.09	-
Final BW (g)	142.17 ± 3.01	195.67 ± 2.74	-	219.00 ± 5.29	-
NWG (g)	122.84	180.50	-	195.50	-
Overall fish survival = 85.67%					
Fish biomass harvested m^{-2} = 238 g					
Apparent FCR = 2.11					
Anticipated productivity ha^{-1} 6-$months^{-1}$= 2.38 t					

[1] Values for initial and final BW are mean ± S.E. (n=10)
[2] Natural food not taken into account for calculating FCR

rearing system, which otherwise competes with common carp for food and space, being a bottom feeder. The results reveal that excluding mrigal from the rearing system enabled common carp to grow at 40 and 45% higher growth rate in 4 and 3 species rearing system, respectively. In contrast, Chandra and Joshi (2015) reared 4 species of freshwater carps (catla, rohu, mrigal and common carp) in a salt affected farm (stocking density 8000 advance fry ha^{-1}) and found common carp to grow faster than mrigal, which can be ascribed to lower stocking density and hence, reduced competition pressure on common carp in comparison to the present study. Among all the species, lowest NWG was recorded in grass carp, which can be attributed to feeding of fish with formulated dry diets instead of green vegetation, which is otherwise required for faster somatic growth in grass carp (Jena and Das, 2011). Besides climatic suitability, availability of seed and feed are the key factors in species selection and since there is scarcity of green vegetation in inland salt affected waterlogged areas, grass carp holds little scope for inclusion in the freshwater carp culture package for inland saline water.

On an average, 207, 218 and 238 g fish was harvested m^{-2} from 5, 4 and 3 species rearing ponds after 6 months, with an apparent FCR of 2.24, 2.19 and 2.11 (with respect to supplementary feed only) and an anticipated productivity of 2.07, 2.18 and 2.38 t ha^{-1}, respectively (Table 2). The productivity of freshwater carps in inland saline water can be enhanced by 15% through species selection. Although, freshwater carps can be reared in inland saline water and help in utilizing inland salt affected waterlogged waste lands for economic gains, but not much attention has been paid in this direction so far. Earlier, productivity of freshwater carps in inland saline water (salinity 3.5-7.0 ppt, EC 5.16- 9.66 mS cm^{-1}) was increased from 2.48 to 3.40 t ha^{-1} yr^{-1} through stocking density enhancement from 10,000 to 15,000 fingerlings ha^{-1} in a 5 species (catla, rohu, mrigal, common carp and grass carp) rearing system (Dhawan *et al.,* 2010; Ansal *et al.,* 2013). In the present study, the fish was reared for a shorter period (6 months) and the anticipated annual productivity is expected to exceed the earlier reported productivity of 3.40 t ha^{-1} yr^{-1} by a significant margin. Singh (2002) harvested 1,068 kg of freshwater carps (catla, rohu, mrigal, common carp and grass carp) and 108 kg fresh water prawn (*Macrobrachium rosenbergii*) from 0.4 ha inland saline water pond, having salinity range of 4.5 -7.0 ppt, after culture period of eight months, which corresponds to an anticipated productivity of 2.94 t ha^{-1}. Chughtai and Mahmood (2012) recorded net fresh water carp productivity ranging from 1.19–1.4.1 t ha^{-1} yr^{-1} from in inland saline water ponds (EC 1.80 – 3.93 dS m^{-1}), where Indian major carps (catla, rohu and mrigal) and Chinese carps (common carp, grass carp and silver carp) were stocked in different combinations of 5 or 6 species. Most recently, Chandra and Joshi (2015) achieved freshwater carp productivity of 4.24 t ha^{-1} yr^{-1} with 4 species (catla, rohu, mrigal and common carp at stocking density of 8000 fry ha^{-1}) rearing in inland saline water farm (EC 1191- 1386 µmhos cm^{-1}) in salt affected area of village Pawari (U.P.), which is higher than the productivity reported in Punjab earlier (Dhawan *et al.,* 2010; Ansal *et al.,* 2013) as well as achieved in the present study and is majorly attributed to significant differences in salinity, species combinations and culture period in the said findings.

In view of above discussion, it is hereby concluded that 3 species fresh water crap culture (catla, rohu and common carp at a stocking density 15,000 fingerlings ha^{-1}) can be taken up in inland saline waters (4-8 ppt) of Punjab, for better FCR and higher productivity. However, there is need to conduct more trials for identifying more ideal combinations for developing an ideal package of practice for inland saline water aquaculture, in terms of productivity with respect to freshwater carps.

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Drought Investigation for Crop Planning in Badri Gad Watershed of Uttarakhand

R. K. Srivastava and H. C. Sharma[1]

Division of Agricultural Engineering
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Jammu-180 009, India
[1] College of Technology, G.B. Pant University of Agriculture & Technology, Pantnagar-263 145, India
E-mail: rksrivastava74@yahoo.co.in

Abstract: Daily rainfall data of 24 years (1985-2008) was analysed to estimate the long term averages of weekly, monthly, seasonal and annual rainfall, drought analysis and possible storage in water storage structure within Badri Gad Watershed of Uttarakhand. The rainfall starts from 23rd week and it continues till 39th week with decreasing trend from 33rd week. Total annual rainfall of the area was erratic in nature with the minimum value of 719.10 mm in 2001 and the maximum value of 1840.20 mm in 1998. The average value of annual rainfall for area was 1234.76 mm. The maximum rainfall occurred during June to September months (about 64 % of the annual rainfall). Poor rainfall was observed during remaining months, particularly October, November and December. The maximum months during the period of study which were categorized as drought month, normal month and surplus month, were November, June and September, July, respectively. Thus, excess water can be stored in water harvesting structures during surplus months and same may be utilized during drought months.

Key Words: Drought month, Normal month and surplus month, Rainfall analysis, Water storage structure

Water scarcity rises a great threat on environment, quality of life since water is an important supply for daily life in maintaining the stability of environment. Drought planning is necessary as a process that concentrates on enhancing abilities in monitoring drought vulnerability and mitigation drought effects. Rainfall analysis plays important role for crop planning, water harvesting and drought management particularly in rainfed area of hilly region (Raina *et al.,* 2007) The amount and distribution of rainfall in any particular area are very helpful in sound crop planning (Singh and Sharma, 2003). The average rainfall of the region is generally considered as the basis for deciding the irrigation management and cropping pattern. But it has been observed that the knowledge of mean annual rainfall may not be that much useful to decide irrigation and water management activities for crop planning. Several workers viz., Bhakar *et al.* (2006), Sheoran *et al.* (2008), Rai and Singh (2009), Srivastava and Shukla (2009), Singh *et al*. (2009), Upadhyaya and Upadhyaya (2009) have studied rainfall analysis for crop planning drought estimation. Further, in view of deepening water crises almost across the globe, water harvesting much sought after aspect of offering at least life saving irrigation to crop plants. In this context drought analysis using rainfall data becomes extremely important to know the months in which excess water is available for storage structure and in which months irrigation is required using stored water. Therefore, a study was carried out to analyze the pattern of rainfall in Badri Gad watershed of Uttarakhand. Monthly estimation of rainfall data for assessment of normal years, abnormal years and drought years, normal months, abnormal months and drought months has been made which is expected to be useful for deciding the cropping pattern, irrigation planning and management. .

MATERIAL AND METHODS

The study area was located in Narendra Nagar block of Tehri Garhwal district of Uttrakhand (Fig. 1). The outlet of the watershed is located near the Yamuna bridge on the Dehradun-Yamunotri National Highway, which is about 55 km away from Dehradun. The watershed is located in between the longitudes of 78^{o} 00' 21.02”E and 78^{o} 10' 21.43” E, and latitudes of 30^{o} 32' 23” and 30^{o} 38' 19.63” N. The total area of the watershed is 11,668.2 ha (116.68 km^{2}) with a perimeter of 51.82 km. The climate of the study area is humid temperate with an average rainfall of 1234.76 mm (1985-2008) of which about 70 to 80% is received during June to September. The average temperature in this area varies from 3^{o}C to 30^{o}C. Forest is the dominating land cover which mainly lies above 1600 m AMSL. However, a major part of the agricultural area is found at the elevations of about 1200 to 1600 m AMSL.

Rainfall and drought analysis: The rainfall data were collected, for a period of 24 years (1985 to 2008) from Agro-metorological Observatory, College of Forestry, Hill Campus, Ranichauri of G.B. Pant University, Pantnagar. The data were analysed for rainfall behaviour, weekly, monthly and annual rainfalls, drought analysis, determination of normal,

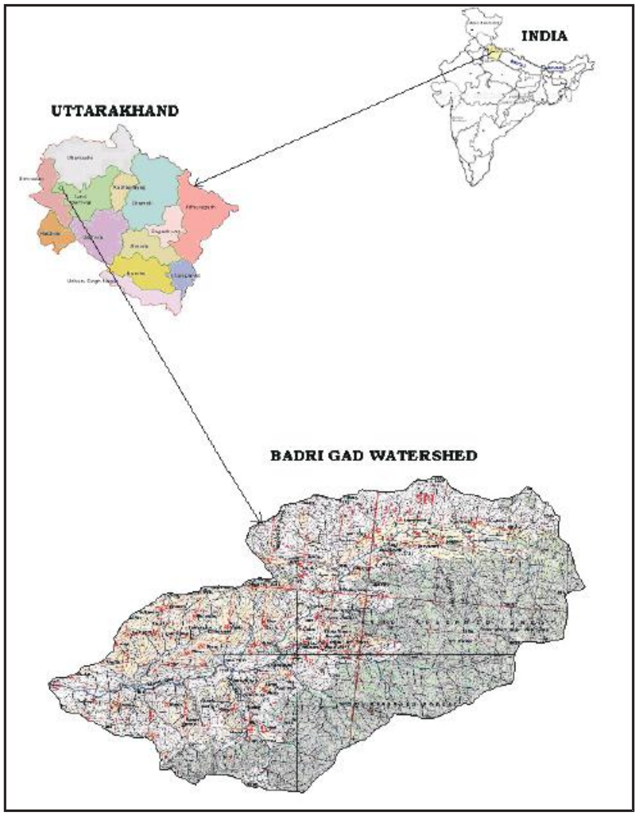

Fig. 1. Index map of Badri Gad watershed

drought and surplus months in the year, determination of normal, drought and surplus years. Daily rainfall data were arranged in years, months and standard meteorological weeks and the average values of the same were worked out for weekly rainfall**.** The monthly and yearly total rainfall was determined for each year. The criteria as used by Sharma *et al*. (1979) were adopted for computing drought.

Drought month: The month was classified as drought month in which precipitation received was less than 50% of average monthly rainfall.

Surplus month: The month was classified as surplus month in which precipitation received was more than twice of average monthly rainfall.

Normal month: The month was classified as normal month in which precipitation received was in between 50% and 200 per cent of average monthly rainfall.

Drought year: The year was classified as drought year in which precipitation received was less than or equal $\bar{x}$ -   to, where $\bar{x}$ is mean annual precipitation and   is standard deviation.

Surplus year: The year was classified as surplus year in which precipitation received was more than or equal to $\bar{x}$ -

Normal year: The year was classified as normal year in which precipitation received was $\bar{x}$ -,   i.e. in between $\bar{x}$ - and $\bar{x}$ -   .

RESULTS AND DISCUSSION

Rainfall Analysis

Weekly rainfall: The weekly rainfall distribution at Badri Gad watershed was more than 20 mm occurred during 23rd week followed by subsequent weeks, which continued upto 39th week (Fig. 2). The uniform rainfall was observed from 23rd to 39th week with the minimum value of 23.26 mm during 24th week. Duration from 40th to 22nd week, which fall in non-monsoon seasons, the rainfall showed poor and erratic behaviour. It was revealed that the uniformity of rainfall was pronounced from 23rd to 39th week (4th June to 24th September).

Monthly rainfall: The rainfall started from April with its

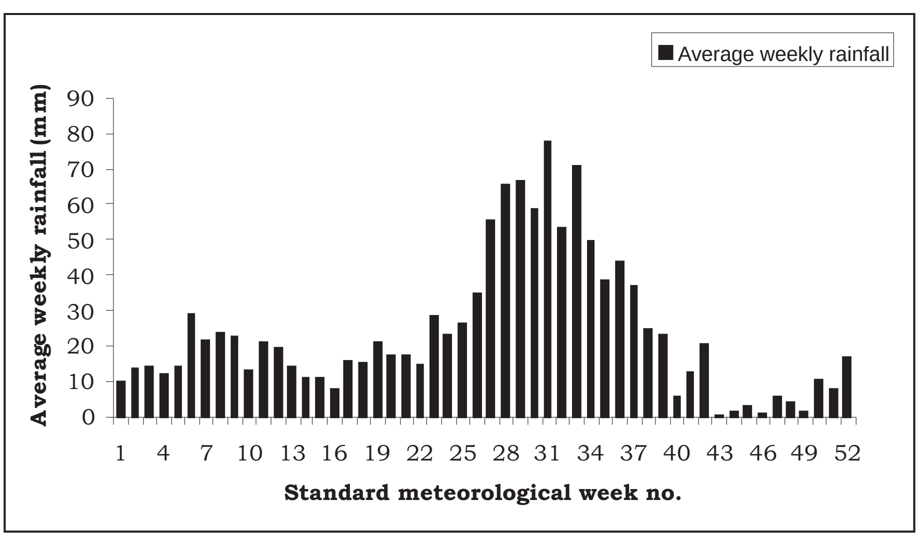

Fig. 2. Mean weekly rainfall distribution at Badri Gad watershed

increasing trend as the days progressed up to July (Fig. 2). Rainfall was maximum (272.98 mm) during July, after which rainfall started to decline till November. The maximum rainfall occurred during June-September months (about 64 % of the annual rainfall). Poor rainfall was observed during remaining months, particularly October, November and December. Minimum rainfall was observed in the month of November (13.67 mm).

Annual rainfall: The total annual rainfall for the study period was erratic in nature with the minimum value of 719.10 mm in 2001 and the maximum value of 1840.20 mm in 1998 (Fig 4). The average value of annual rainfall for Badri Gad watershed, during 24 years of analysis, was 1234.76 mm. The peak values of annual rainfall were observed during the year 1998 followed by 1990, 1986, 1988,1993, and 1995, whereas, troughs were observed during the year 2001 followed by 1992, 1987, 1999, 1991, 2006, 1991, 2008, 2003, 2004, 1994, 1989 and 1996 for which annual rainfall was less than mean annual rainfall (1234.76 mm).

Drought Analysis

Drought, normal and surplus months: The maximum months during the period of study which were categorised as drought month, normal month and surplus month, were November, June and September, July, respectively. In year-wise analysis, it was observed that years 1999, 2007 and 2008 were having maximum i.e. 6 months as drought months, years 1990 and 1997 were having maximum i.e. 8 months as normal months and years 1999, 2000, 2003 and 2008 had maximum three months as surplus months (Tables 1,2 and 3).

From the Table 2, it can be observed that about 17.01 per cent of the total numbers of months were surplus months, 46.43 per cent normal months and 36.46 per cent were drought months, which indicates the erratic distribution of rainfall. It was also observed that out of total period of 24 years, most of the drought months had occurred in the post and pre-monsoon periods i.e. October to May having highest frequency for November (21 drought months out of 24 months). It was also observed that from January to June there was maximum number of surplus months with minimum 54 per cent of probability. Maximum number months were found in July and August with minimum probability of 75 per cent.

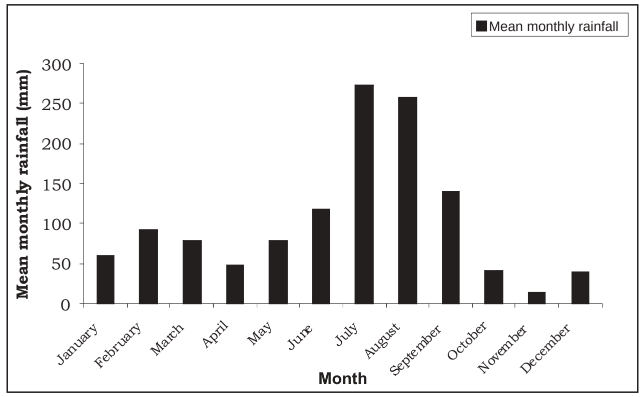

Fig. 3. Mean monthly rainfall distribution at Badri Gad watershed

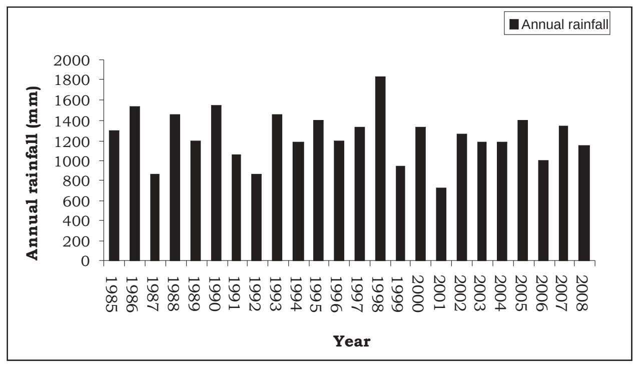

Fig. 4. Annual rainfall distribution at Badri Gad watershed

Table 1. Month wise yearly rainfall (1985-2008) to be drought, surplus and normal month at Badri Gad watershed

Month	Average rainfall, mm	Drought (less than)	Surplus (more that)	Normal (in between)
January	59.23	29.61	118.46	29.61 to 118.46
February	92.63	46.31	185.26	46.31 to 185.26
March	77.26	38.63	154.52	38.63 to 154.52
April	52.41	26.21	104.83	26.21 to 104.83
May	77.24	38.62	154.48	38.62 to 154.48
June	117.78	58.89	235.57	58.89 to 235.57
July	272.98	136.49	545.95	136.49 to 545.95
August	255.70	127.85	511.41	127.85 to 511.41
September	138.99	69.50	277.98	69.50 to 277.98
October	40.24	20.12	80.48	20.12 to 40.24
November	13.67	6.83	27.33	6.83 to 27.33
December	39.26	19.63	78.52	19.63 to 78.52

Table 2. Month wise distribution of number of months to be drought, surplus and normal at Badri Gad watershed

Year	Drought month	Normal month	Surplus month
1985	3	7	2
1986	3	7	2
1987	3	7	2
1988	5	5	2
1989	4	6	2
1990	3	8	1
1991	4	6	2
1992	5	5	2
1993	5	5	2
1994	4	6	2
1995	5	5	2
1996	3	7	2
1997	3	8	1
1998	4	6	2
1999	6	3	3
2000	5	4	3
2001	5	5	2
2002	5	5	2
2003	4	5	3
2004	5	5	2
2005	5	5	2
2006	4	7	1
2007	6	4	2
2008	6	3	3
Total	105	134	49

Table 3. Year wise distribution of number of months to be drought, surplus and normal at Badri Gad watershed

Month	Drought month	Normal month	Surplus month
January	9	15	0
February	8	15	1
March	8	16	0
April	11	13	0
May	9	13	2
June	2	19	3
July	1	3	20
August	1	5	18
September	1	19	4
October	18	5	1
November	21	3	0
December	16	8	0
Total	105	134	49
Per cent of total study period	36.46	46.53	17.01

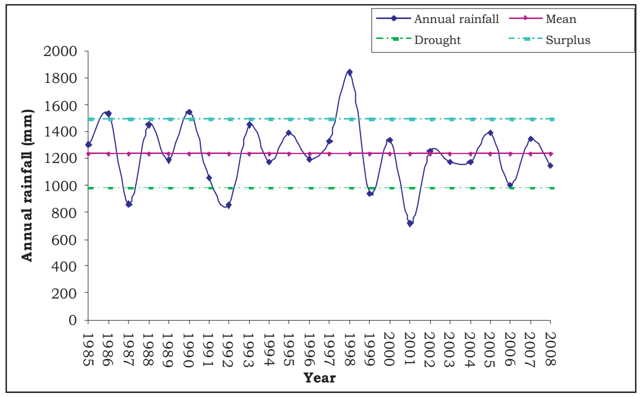

Fig. 5. Rainfall distribution at Badri Gad watershed

Table 3 revealed that about 50 per cent of the years had five or more number of drought months. Maximum number of normal months in a year was found to be 8, which accounted for only 8.33 per cent of total years. Analysis indicates that there was maximum chances of failure *rabi* crops under rainfed condition.

Drought, normal and surplus years: The mean annual rainfall was 1234.76 mm and standard deviation was 253.20 mm. Thus, 16.66 per cent of years received rainfall less than 981.57 mm, were drought years, 12.50 per cent of the years which received rainfall equal to or more than 1487.96 mm were surplus years and 70.84 per cent of years received rainfall between 981.57 mm and 1487.96 mm were normal years for the period of analysis (Fig. 5)

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Monitoring of Soils and Water for Pesticide Contamination in Apple Growing Regions of Himachal Pradesh, India

I. D. Sharma, R. S. Chandel[1*] S. S. Brar and Joginder Singh[1]

Department of Entomology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan-173 230, Solan, India
[1]Regional Horticultural Research & Training Station and KVK, Sharbo, Kinnaur-172 107, India
**E-mai: rs_c@rediffmail.com*

Abstract: Pesticide residues were determined in soil and water samples collected from two apple growing agro-climatic zones (Zone III, wet temperate high hills and Zone IV, dry temperate cold desert) of Himachal Pradesh, India. Residues of organochlorine, synthetic pyrethroid and organophosphate insecticides were estimated by GC equipped with ECD and NPD systems, whereas, carbendazim and mancozeb by spectrophotometric method. Among the commonly used pesticides, HCH isomers (0.01-0.08 $mgkg^{-1}$), chlorpyrifos methyl (0.03 $mgkg^{-1}$), endosulfan sulphate (0.12 $mgkg^{-1}$), â-endosulfan (0.01-0.1 $mgkg^{-1}$), p,p'-DDE (0.01-0.06 $mgkg^{-1}$), p,p'-DDT (BDL-0.02 $mgkg^{-1}$). á-endosulfan (0.01-0.02 $mgkg^{-1}$) and Dicofol (0.02-0.05 $mgkg^{-1}$) were the predominant soil contaminants estimated above their limit of quantification (0.01 $mgkg^{-1}$). None of the samples were contaminated with synthetic pyrethroides, carbamates, dithiocarmamate fungicides and carbendazim. No water sample was found to carry pesticide residues above the limit of quantification.

Key Words: Apple orchard, Extraction in plant and soil, Pesticide residue

Apple is the dominant fruit provides livelihood to a large rural population residing in the interiors of Shimla, Kullu, Kinnaur, and Lahaul & Spiti districts of the Himachal Pradesh. Intensive agricultural practices often include the use of pesticides to enhance crop yields. However, the improvement in yield is sometimes concomitant with the occurrence and persistence of pesticide residues in soil and water (Ware and Whitacre, 2004), thus contributing to the risk of environmental contamination. The appreciable quantity of pesticides and their degraded products have been reported to accumulate in the soil ecosystem, adversely affecting soil health and productivity. The persistence of toxic pesticides in water affecting aquatic life and quality of drinking water has also been reported by various workers. Earlier reports from several mountain areas indicated a large scale switching of mountain farmers to the cultivation of income generating fruit crops, and thus resulting in indiscriminate use of pesticides (Partap, 2010). Study was planned to monitor the environmental risk through soil and water contamination by pesticides in the apple ecosystem of Himachal Pradesh, India.

MATERIAL AND METHODS

The locations selected to undertake present studies in Himachal Pradesh were Bajaura (District Kullu), Mashobra (District Shimla) falling in Zone III (high hills wet temperate; 1524-2742m amsl); Kukumseri (District Lahaul & Spiti) and Rekong Peo (District Kinnaur) in Zone IV (high hills dry temperate; above 2742 m amsl. The composite soil samples were collected at two stages i.e. before flowering and at crop harvest from two identical locations of each zone having apple orchards. A total of 60 soil samples were collected from each agro climatic zone along with their history. One of the 5 samples collected at each site was obtained from an uncultivated field as a control. Twenty four water samples were also collected each from underground and surface water sources in and around the study locations. Soil and water samples were screened for a total of 23 pesticides. Calibration curves of working standards were used to evaluate the linearity of the gas chromatograph response each day of analysis and pesticide residues were quantified based on these external standards.

Extraction and cleanup: Soil samples were extracted using a soil-packed sintered column. Each sub-sample (15g) was blended with 0.3g Florisil and 0.3mg charcoal in mortar until free flowing. The sample mixture was transferred to a 250 mL sintered column followed by elution with 100 mL of acetone: hexane (1:9 v/v). The eluate was evaporated to dryness using a rotary evaporator (Heidolph) at 40-50^{0}C. Residues were re-dissolved in 5 ml hexane and subjected to additional cleanup steps.

The n-hexane containing pesticide residues was loaded on 1g activated silica gel column. The column was eluted with 15 mL of acetone: hexane (1:9 v/v) and eluate was evaporated to dryness using a rotary evaporator at 40-50^{0}C. The residues were dissolved in 5 mL hexane for GC analysis. Water samples were extracted using liquid-liquid extraction (LLE). Each sample (500 mL) was extracted with dichloromethane (3 x 100 mL). The combined dichloromethane layers were evaporated on a rotary evaporator (Heidolph) to dryness and finally residues were dissolved in 5 mL hexane for GC analysis.

Residue analysis: A Gas Chromatograph (Agilent 6890N) equipped with a ^{63}Ni electron capture detector (ECD), nitrogen phosphorus detector (NPD) was used for residue estimation. Injector and detector temperature was kept at 250°C and 300°C, respectively. Oven temperature programme was ramped as 100C for 1 minute, 30C minute^{-1} up to 150C for 2 minutes, 3C minute^{-1} up to 205C and finally it was increased at the rate of 10C minute^{-1} up to 260C and kept for 10 minutes. Gases used were Nitrogen, hydrogen and zero air. The confirmation of residues was done on GC-MS using same column as used in GC. Helium was used as the carrier gas in GC-MS at a constant column flow rate of 1.1 mL min^{-1}. Samples were injected in the split less mode with the purge flow to split vent set at 35 mL min^{-1}, pressure at 15 psi and total flow at 39 mL min^{-1}. The respective temperature of injector and detector was 250°C and 350°C. For confirmation runs, the temperature program on the column was as follows: 100°C for 2.0 min, 15°C min^{-1} to 160°C, 5°C min^{-1} to 270°C held for 5 min.

The mancozeb residues were analysed as per the method described for dithiocarbamate fungicides estimation (Schwack and Nyanzi, 1995) and the carbendazim residues were determined as per the method of Nath *et al.* (1993).

RESULTS AND DISCUSSION

The analytical method employed to estimate residues was validated by spiking the control soil and water samples at three different concentrations viz., 0.01, 0.05, 0.1 for Ocs and chlorpyrifos; and 0.05, 0.1, 0.5 mg kg^{-1} for Ops, SPs, carbendazim and mancozeb. The average recoveries obtained were 88.25, 85.70, 88.40, 90.35, 88.80, 84.60, 85.28, 87.00, 85.86 and 86.26 per cent for Ó-HCH, Ó-DDT, Ó-endosulfan, chlorpyriphos, dicofol, Ó-pyrethroids, malathion, methyl demeton, carbendazim and mancozeb, respectively (table1). The limit of determination (LOD) was 0.01 mgkg^{-1} for Ocs and chlorpyrifos, whereas, 0.05 mgkg^{-1} for Ops and SPs.

Soil textural classification: In Zone III, at location Bajaura the soil was silt- loam (Sand 40%, Silt 38.9-43.6%, clay 12-17.5%) with pH 6.7 and organic carbon 0.9 per cent, whereas, at Mashobra it was silt clay loam (Sand 19%, Silt 45%, clay 30%) with pH 6.9 and organic carbon 1.5 per cent. In Zone IV having locations Kukumseri and Rekong Peo the soil texture was sandy loam (Sand 59-60%, Silt 14-25.2%, clay 7.5-15%) with pH 6.9-8.4 and organic carbon 0.7-0.9 per cent. The soils of the dry temperate zone of Himachal Pradesh were found neutral to alkaline (pH, 6.2-10.3) in reaction and sandy loam to sandy clay loam in texture (Sharma and Kanwar, 2010). The occurrence of most of the pesticides at lower concentrations in our studies is attributed to the rapid degradation of these pesticides under neutral to alkaline pH conditions of the soil.

Pesticide usage pattern: The insecticides viz; chlorpyrifos, cypermethrin, chlorpyrifos + carbendazim, deltamethrin, dicofol, endosulfan, fenvalerate, malathion, methyl demeton, carbendazim, hexaconazole+methyl demeton, and mancozeb were identified as the common pesticides used by most of the farmers in the study.

Residue estimation: The quantity of pesticide residues detected in the samples collected from different locations is given in Table 2 and 3. In Kukumseri, HCH isomers viz., á-HCH (0.01mgkg^{-1}), â-HCH (0.02 mgkg^{-1}) and ã-HCH (0.08 mgkg^{-1}) were detected before flowering whereas, only â-endosulfan (0.1 mgkg^{-1}) was found at harvest stage. At Rekong Peo, only chlorpyrifos (0.02 mgkg^{-1}) was detected before flowering, whereas, at harvest, maximum concentration of endosulfan sulphate (0.9 mgkg^{-1}) followed

Table 1. Recovery of pesticides at different fortification levels

Pesticides	Fortification levels (mg kg^{-1})	Recovery (%)
Ó-HCH (á, â, ã, ä HCH)	0.01, 0.05, 0.1	88.25 (82.50-93.80)
Ó-DDT (p,p'-DDE, o,p'-DDD, p,p'-DDD, p,p'-DDT,)	0.01, 0.05, 0.1	85.70 (80.10-94.20)
Dicofol	0.01, 0.05, 0.1	88.80 (84.84-90.23)
Ó-Pyretrhroids (ë-cyhalothrin, permethrin, fenvalerate, cypermethrin, deltamethrin)	0.05, 0.1, 0.5	84.60 (81.40-91.44)
Ó-Endosulfan (á-endosulfan, â-endosulfan, endosulfan sulphate)	0.01, 0.05, 0.1	88.40 (81.92-93.60)
Chlorpyrifos-methyl	0.01, 0.05, 0.1	88.50 (83.25-92.25)
Chlorpyrifos	0.01, 0.05, 0.1	90.35 (86.72-94.16)
Mancozeb	0.05, 0.1, 0.5	86.26 (83.73-89.69)
Carbendazim	0.05, 0.1, 0.5	85.86 (82.79-88.38)
Malathion	0.05, 0.1, 0.5	85.28 (83.96-89.15)
Mmethyl demeton	0.05, 0.1, 0.5	87.00 (84.76-90.21)

Table 2. Pesticide residues in apple orchard soils

Location (Zone)	Sampling time	Residues mg kg^{-1}										
		á- HCH	â- HCH	ã-HCH	á-endosulfan	p,p'-DDE	â-endosulfan	endosulfan sulphate	p,p'-DDT	Chlorpyrifos-methyl	Chlorpyrifos	Fenvalerate
Kukumseri (IV)	Before flowering	0.01	0.02	0.08	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	At harvest	BDL	BDL	BDL	BDL	BDL	0.10	BDL	BDL	BDL	BDL	BDL
Reckong Peo (IV)	Before flowering	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.02	BDL
	At harvest	0.01	BDL	0.02	BDL	0.03	0.04	0.90	BDL	BDL	BDL	BDL
Bajaura (III)	Before flowering	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	At harvest	BDL	BDL	BDL	BDL	0.01	0.03	BDL	0.02	0.03	0.02	BDL
Mashobra (III)	Before flowering	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	At harvest	0.02	0.01	0.02	0.01	0.01	0.06	0.12	0.02	BDL	0.03	0.06

Table 3. Pesticide residues in uncultivated soils around orchard soils

Location (Zone)	Residues mg kg^{-1}										
	á- HCH	â- HCH	ã-HCH	ä-HCH	Dicofol	á-endosulfan	â-endosulfan	Endo.sulphate	p,p'-DDE	p,p'-DDT	Chlorpyrifos-methyl	Chlorpyrifos
Kukumseri (IV)	0.01	0.04	0.01	BDL	0.05	0.02	BDL	BDL	0.01	BDL	BDL	BDL
Reckong Peo (IV)	BDL	BDL	0.01	0.01	0.03	0.02	0.04	0.06	BDL	BDL	BDL	BDL
Bajaura (III)	BDL	BDL	BDL	BDL	0.02	0.01	0.01	BDL	0.06	BDL	BDL	BDL
Mashobra (III)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

by â-endosulfan (0.04 mgkg^{-1}), p,p'-DDE (0.03 mgkg^{-1}),á-HCH (0.02 mgkg^{-1}) and ã-HCH (0.01 mgkg^{-1}) was observed. In zone III, the samples collected from both the locations i.e. Bajaura and Mashobra contained no residue before flowering. However, at harvest the residues (0.01-0.03 mg kg^{-1}) of p,p'-DDE, p,p'-DDT, â-endosulfan, chlorpyrifos and chlorpyrifos- methyl were recorded in samples of Bajaura. Whereas at Mashobra , the residues of insecticides viz., á-HCH, â- HCH, ã- HCH, p,p'-DDE, p,p'-DDT, á-endosulfan, â-endosulfan, endosulfan sulphate, chlorpyrifos and fenvalerate detected in samples (at harvest) were 0.02, 0.01, 0.02, 0.01, 0.02, 0.01, 0.06, 0.12, 0.03 and 0.06 mgkg^{-1}, respectively.

Organochlorine pesticides were found in the uncultivated soils in and around the apple growing zones. Table 3 indicates the number of pesticides detected in soils of Zone III especially in Bajaura with maximum contamination of p-p DDE (0.06 mg kg^{-1}) followed by dicofol (0.02 mg kg^{-1}) á&â-endosulfan (0.01 mg kg^{-1}) samples. At location Kukumseri of Zone IV, dicofol, á, â & ã-HCH, á- endosulfan and p-p DDE were estimated as soil residues in the range varied from 0.01-0.05 mg kg^{-1}. In Reckong Peo, endosulfan sulphate (0.06 mg kg^{-1}) was estimated as the major contaminant followed by â-endosulfan, Dicofol, á-endosulfan and ã&ä- HCH.

Pesticide residues in water: Endosulfan (á-, â- & endosulfan sulphate), HCH (á, â, ã & ä), DDT (p,p'-DDE, o,p'-DDD, p,p'-DDD, p,p'-DDT, dicofol), dicofol, Pyretrhroids (ë-cyhalothrin, permethrin, fenvalerate, cypermethrin, deltamethrin), chlorpyrifos and chlorpyrifos methyl were estimated in surface as well as underground water in and around apple growing areas. However, out of total 48 samples (surface as well as ground water); none was found to carry pesticide insecticide residues above limit of quantification.

The integrated spray schedule comprising of chlorpyrifos, dicofol, carbendazim and mancozeb recommended for the management of apple pests and the farmer's survey revealed the application of around 15 pesticides during the past one decade in the apple orchards. Technical endosulfan is a mixture of two stereo- isomers having 64-67 per cent á- and 29-32 per cent â-endosulfan (MacBean, 2012). After entering the soil, its isomers are vulnerable to different degradation processes. The high soil sorption co-efficient of isomers reduce the potential of volatilization and leaching. In both the zones of study, endosulfan sulphate and â-endosulfan were more prevalent than á-endosulfan due to the tendency of the endosulfan to persist for several months or years after application (Mullins *et al*., 1971). Similar observation of soil contamination with chlorpyrifos has also been reported from northern India (Kumari *et al*., 2008). The occurrence of ã-HCH in higher concentration in apple orchard soils reflected the regular use of lindane on apple. The relatively high concentration of DDE than DDT in the study area owe to maximum degradation of DDT either by volatilization or conversion due to UV radiations after prolonged exposure in the environment (Atlas and Giam, 1988). The HCH isomers, DDT isomers/metabolites and endosulfan isomers/metabolites were also reported as frequently prevalent soil contaminants in the state of Haryana and north Indo- Gangetic alluvial plains (Kumari *et al*., 2008 and Singh *et al*., 2007). Non occurrence of other used pesticides might be related to their low soil persistence (MacBean, 2012) and rapid degradation under neutral to alkaline soil pH conditions more particularly OCs in Zone IV as compared to Zone III. The degradation of fungicide prochloraz was reported faster at higher pH value of 9.2 than 4.0 and 7.0 (Sengupta *et al*., 2009).

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Spatial Variation of Groundwater Quality of IARI Farm, New Delhi

D. S. Gurjar and R. Kaur
Water Technology Centre, ICAR-Indian Agricultural Research Institute, New Delhi-111 012, India
E-mail: dsgurjar79@gmail.com

Abstract: A study was carried out at Indian Agricultural Research Institute (IARI) farm, New Delhi, India to assess the spatial variation in quality of groundwater of IARI farm during 2010-11. The groundwater samples were analysed for the major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}) besides some physico- chemical parameters (pH, electrical conductivity and total dissolved solids). Also, geographic information system-based groundwater quality mapping in the form of visually communicating contour/iso-concentration maps were developed to delineate the spatial variation of physico-chemical characteristics of groundwater samples. Results indicated that pH of all the groundwater samples was within the permissible limit (6.5-8.5) for irrigation. Salinity in terms of electrical conductivity (EC) was also within limit (3 dS/m) except in 2 tube wells located in the top block of the farm. The mean concentrations of cations (Ca^{2+}, Mg^{2+}, Na^{+}) and anions CO_3^{2-}, HCO_3^{-} and Cl^{-}) were safe for irrigation. The over all groundwater quality of IARI farm area was found safe for irrigation except in the tube wells of top block area where higher salinity was observed.

Key Words: Anions, Cations, Groundwater, Quality, Spatial variation, Water

Ground water plays an important role in agriculture for sustaining high productivity. About 43 million hectare areas is irrigated by the groundwater out of the net irrigated area (57 m ha) in India. With rapid increase in population and growth of industrialization, ground water quality is being increasingly threatened by agricultural chemicals and disposal of urban and industrial wastes. Once pollutants enters the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of ground water aquifer and rendering ground water supplies unsuitable for consumption and other uses. The rate of depletion of ground water levels and deterioration of ground water quality is of immediate concern in major cities and towns of the country. In the farm of Indian Agricultural Research Institute (IARI), large numbers of experiments were carried out by the different Division of IARI with the cultivation of different crops using different dose of fertilizers and pesticides. The intensive cultivation practices may deteoriate the quality of groundwater, which is the major source of irrigation at IARI farm. Keeping this in view, the present study was planned to assess the groundwater quality of Indian Agricultural Research Institute farm, New Delhi, India.

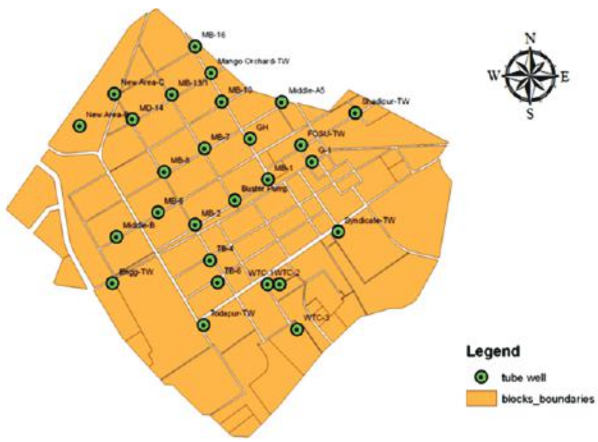
MATERIAL AND METHODS

The Indian Agricultural Research Institute (IARI) farm is situated between 28°37' 22'' N and 28°39' 00'' N, and 77°8' 45'' E and 77°10' 24'' E at an average elevation of 230 m above mean sea level. Out of 473 ha farm area, about 280 ha is under extensive agriculture. The climate of the area is semi-arid with an average annual temperature of 24°C and average annual rainfall of 710mm. The soil varies from sandy loam to clay loam. Most of the irrigation at farm is being carried out through tube wells and subsequent storage and underground pipeline distribution systems. Unconfined, shallow aquifer is found in sand, fine sand with clay and boulder layers. The twenty two groundwater samples were collected with their GPS location from the different tube wells located at IARI farm (Fig. 1) during post-monsoon season in November, 2010. The groundwater samples were collected in 500 ml capacity clean plastic bottles and every bottle was rinsed 2 to 3 times with sampled water. The water samples were properly filtered with Whatsman No.1 filter paper and added some drop of toluene for checking the microbial growth in water sampling bottles. The EC, pH, cations (Na^{+}, K^{+}, Ca^{2+} and Mg^{2+}) and anions (Cl^{-}, CO_3^{-} and HCO_3^{-}) in groundwater samples were determined with standard methods described in APHA (2005). The minimum, maximum, and mean concentrations of physico-chemical parameters of groundwater quality of IARI farm are presented in Table 1.

RESULTS AND DISCUSSION

pH: The pH of the groundwater in the study area lies in the ranges between 6.85 and 8.15 with a mean value of 7.47 (Fig. 2a) indicating alkaline nature of the groundwater. It also indicates that the pH of all the groundwater samples were within the optimum range value for irrigation. The higher groundwater pH was observed in the WTC farm area whereas lower values were found in the Todapur area.

Electrical conductivity: In the present study, the EC varied from 0.87 to 3.88 dS/cm with a mean value of 2.07 (Fig. 2b)



SN	1	2	3	4	5	6	7	8	9	10	11
TW	MB1	MB2	MidB	EnggT	Mid A5	MB-7	GH	MB-10	G-1	MB-13	MB-14
SN	12	13	14	15	16	17	18	19	20	21	22
TW	MB16	MB17	NA-B	Todapur	SyndT	TB4	TB6	FOSU	WTC1	WTC2	WTC3

Fig.1. Map of the study area and location of the sampling points

indicating higher mineralization in the region. As the electrical conductivity is temperature dependent, its variability in a given water. The higher salinity in terms of EC was found in the Top block area whereas lower salinity was found in new area of IARI farm.

Total dissolved solids: TDS values varied between 560 and 2,485 mg/l indicating sufficient input of ionic matter into groundwater samples, even though local geological settings, soil characteristics, and even lithology of the study area may also contributed to total dissolved solids content in groundwater

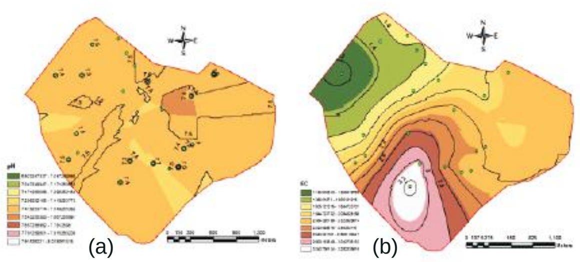


Fig. 2. Spatial variation in (a) pH and (b) EC of the groundwater of IARI farm

Major Cationic and Anionic Chemistry with Their Spatial Variation

Calcium and magnesium*:* Calcium and magnesium) contents range between 4.80 and 21.40 me L^{-1} (Fig. 3) with a mean value of 10.93 me L^{-1}. It indicates that calcium and magnesium content in groundwater was below the maximum permissible limits of 25 me L^{-1}, respectively. Sewage and industrial wastes are the important sources of calcium and magnesium (Subrahmanyam and Yadaiah, 2001). The higher concentration of Ca+Mg was observed in Top block area and lower values were found syndicate bank area.

Sodium: Sodium values ranged from 3.10 to 17.20 me L^{-1} (Fig. 3b) with a mean value of 10.25. It indicated that the sodium content in the groundwater of IARI farm was below maximum permissible limit of 40 me L^{-1} for irrigation.

Potassium: The potassium content in groundwater was ranged from 0.09 to 0.34 me L^{-1} (Fig. 4a). Two factors are responsible for the scarcity of potassium in groundwater, one being the resistance to potassium minerals to decomposition by weathering and the other is fixation of potassium in clay minerals formed due to weathering.

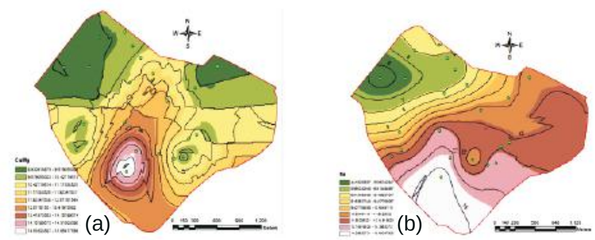


Fig. 3. Spatial variation in (a) calcium+magnesium and (b) sodium content in groundwater

Chloride: The chloride concentrations in the groundwater ranged from 4.0 to 30.40 me L^{-1} (Fig. 4b) with mean value of 12.88 me L^{-1}. The higher chloride concentrations were observed in the groundwater of top block area whereas lower concentrations were found in the groundwater of new area of IARI farm.

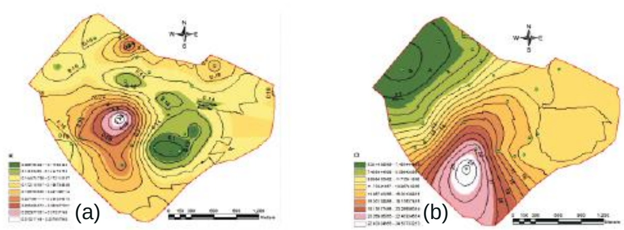


Fig. 4. Spatial variation in (a) potassium and (b) chloride content in groundwater

Carbonate: The carbonate concentrations in the groundwater ranged from 0.00 to 2.40 me L^{-1} (Fig. 5a) with mean value of 1.43 me L^{-1}. The carbonate concentration was not detected in most of the tube wells of IARI farm. Out of 22 groundwater samples, it was present in 5 groundwater samples indicating the less problem of carbonate in groundwater. The maximum concentration of carbonate was observed in the genetics area of IARI farm.

Bicarbonate: The bicarbonate concentrations in the groundwater ranged from 5.80 to 10.0 me L^{-1} (Fig. 5b) with mean value of 7.70 me L^{-1}. The higher bicarbonate concentrations were observed in the groundwater of Main

Table 1. Minimum, maximum, and mean values of physico-chemical parameters

Category	Characteristics	Unit	Min.	Max.	Mean	Maximum permissible limits*
General Parameter	pH	0-14	6.85	8.15	7.47	6.5-8.4
	Electrical conductivity	dS/m	0.87	3.88	2.07	3
	Total dissolved solids	mg/L	560	2485	1295	2000
Major Cations	Calcium (as Ca^{2+}) + Magnesium (as Mg^{2+})	me/L	4.80	21.40	10.93	25
	Sodium (as Na^{+})	me/L	3.10	17.20	10.25	40
	Potassium (as K^{+})	me/L	0.09	0.34	0.18	2
Major Anions	Carbonates (as CO_3^{2-})	me/L	0.00	2.4	0.30	0.1
	Bicarbonates (as HCO_3^{-})	me/L	5.80	10.00	7.70	10
	Chlorides (as Cl^{-})	mg/L	4.00	30.40	12.88	30

*Source: Ayers and Westcot (1985)

block-16 (MB-16) area whereas lower concentrations were found in the groundwater of Main block-14 (MB-14) of IARI farm.

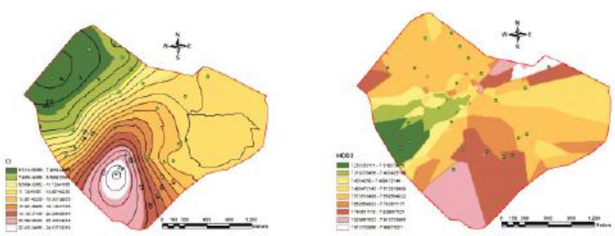


Fig. 5. Spatial variation in (a) carbonate and (b) bicarbonate content in groundwater

The quality of groundwater resources of IARI farm was found almost safe for irrigation, except in few location. However, a periodical monitoring of groundwater quality of IARI farm with more quality parameters including nutrients and heavy metals concentration is also needed for sustainable safe use of the groundwater resources.

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Changes In ISSR Patterns and Correlations among Yield and Yield Contributing Traits in Chickpea Grown under Rainfed and Irrigated Conditions

Geetika Mehta, P. K. Verma[1] and Shikha Yashveer[2]

Department of Genetics and Plant Breeding; [1]Department of Dry Land
[2]Department of Molecular Biology and Biotechnology, CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: drgeetika1326@gmail.com

Abstract: The experiment comprising of 21 genotypes (including local & national checks) indicated that days to maturity, plant height and Primary branches per plant recorded positive significant correlations with seed yield per plant under normal sown conditions which were changed in the rainfed areas. The genetic diversity of the material under study is quite evident from the morphological data. Out of fifty six primers used, one primer namely UBC-841 produced 14 bands. Out of 14 bands produced, two bands of low molecular weight *i.e.* 43 and 60 bp were present only in high yielding genotypes irrespective of presence or absence of remaining 12 bands. These bands need revalidation in chickpea genotypes differing for heat tolerance before they are finally used in MAS programmes. This might prove a boon to the breeders to select for drought tolerant/heat tolerant genotypes in chickpea.

Key Words: Drought tolerance, ISSR in chickpea, Rainfed

Among different legumes, chickpea is a highly acceptable crop during winter season in drought prone areas of India as well as in world on receding moisture. More than 85 per cent chickpea is grown as rainfed mostly on residual soil moisture after harvest of *kharif* crops. In India, the area under chickpea was 8.32 million hectare with productivity of 912 kg ha^{-1} and production of 7.70 million tonnes, whereas, Haryana with an area of 80,000 ha; production of 70,000 tonnes; and productivity of 911 kg ha^{-1} during 2011-12. Despite significant gains in irrigation potential during last three decades, chickpea continued to be a rainfed crop in major parts of the country. Future estimates also indicate that not more than 25 per cent of total chickpea area is expected to be under irrigation. Thus drought is the single most important abiotic constraint limiting the chickpea production. Soil moisture stress reduces the productivity by delay or prevention of crop establishment, destruction of established crop, predisposition of crop to insects and diseases, alteration of physiological and biochemical metabolism in plant. Moisture deficit also affects seed germination and its establishment in the field, photosynthetic ability of the plants and osmotic behavior of cells. However, species and genotypes vary in their capacity to tolerate water stress. The improvement in the genotypes is the only alternative for yield stability under water stress environment. Therefore, the improved chickpea genotypes with better water use efficiency and high yield will be suitable for cultivation in drought prone areas and can prove a boon to improve the economic status of poor farmers. To achieve this, an understanding of physiological processes associated with drought tolerance is pre-requisite. Currently available drought tolerant chickpea genotypes are very few. Considering that a large number of traits are collectively needed to confer yield under drought, there is a need to identify more genotypes to introduce diversity in drought tolerance breeding programs. Root traits, such as depth and root biomass, have been identified as the most promising plant traits in chickpea for terminal drought tolerance (Neeraj *et al*., 2012). Therefore, the present study was undertaken with the objective to find out indirect selection criterion for drought tolerant genotypes in chickpea.

The experiment was carried out at CCS HAU, Hisar during *rabi* season of 2013-14 and 2014-15 comprising 21 chickpea genotypes(including checks) in three replications, 4m row length and row to row spacing of 45 cm. The observations on various traits including morphological parameters viz., days to 50 per cent flowering , days to maturity, plant height at 30, 60 ,90 DAS and physiological maturity (cm), primary branches $plant^{-1}$, pods $plant^{-1}$, 100-seed weight (g), seed yield per plant (g), seed yield (kg ha^{-1}), biological yield (kg ha^{-1}), rain water use efficiency ($kgha^{-1}$-mm) and physiological parameters viz., relative leaf water content (%), membrane injury index of leaf, specific leaf weight (gm), leaf water potential (-bars) and osmotic potential (-bars) were recorded. Moisture content at different depth (0-15, 15-30, 30-60, 60-90 and 90-120 cm) was also recorded from sowing till maturity of the crop at an intervals of 30 days.

ANOVA was performed using standard procedure as explained by Panse and Sukhatme (1989). Correlation analysis was carried out following Pearson correlation coefficient.

ISSR-PCR amplifications: DNA isolation was done as per Saghai Maroof *et al.* (1984). PCR amplifications were carried out using a Perkin Elmer Cetus thermocycler. Amplifications were performed for 30 cycles with denaturation at 91°C for 1 min, annealing at 48°C for 49 s and extension at 72°C for 2 min. Initial denaturation was done at 91°C for 3 min and a final extension step of 5 min at 72°C was also included. The reaction mixture (10 ì l (microlitre) contained 1 ì l of DNA template, 0.5 ì l MgCl2, 1 ì l dNTP mix, 1 ul primer, 1 ì l 10x Buffer, 6 ì l Sterile distilled water and 0.8 units of *Taq* DNA polymerase. ISSR amplified PCR products were resolved on 2.5% agarose gel in 10X TBE buffer (950ml distilled water and 50 ml 1X TBE Buffer) at a constant voltage of 80 V for 3h. The bands were scored quantitatively for presence (1) or absence (0) in each genotype.

1X TBE = for 1000 ml: Tris = 108 gm, Boric acid = 55 gm, 0.5 Molar EDTA = 40 ml, Distilled water. The sequence of UBC841 (48.c) was GAGAGAGAGAGAGAGAYC (length 18 h) where Y may be C or T.

Analysis of variance: Analysis of variance for all the morphological and physiological traits indicated existence of ample variability for all the traits under study. In general, PCV and GCV values were high for all the traits. the heritability (BS) ranged from 68 (days to flowering) to 87% (membrane injury index). The genetic advance under selection also ranged from 22 (branches per plant) to 86% (membrane injury index). All these results indicate importance of membrane injury index as the most appropriate parameter to incorporate drought tolerance in chickpea genotypes. Parameshwarappa *et al.* (2010) showed wide range of genetic variability, moderate to high heritability and high genetic advance for yield and its component traits in drought tolerant accessions evaluated under moisture stress and irrigated situations.

Correlation studies: Correlations were calculated using Pearson correlation coefficient. The correlations were calculated in two seasons *i.e. rabi* 2013-14 and *rabi* 2014-15 under normal irrigated and rainfed conditions. The correlations with seed yield per plant changed under rainfed conditions. The important correlations which were observed were between branches per plant and seed yield (0.847), relative water content and seed yield (0.541), leaf water potential and seed yield (0.466) and negative correlation between membrane injury index and seed yield per plant (0.694) (Table 1). These correlations indicate that seed yield increases with the increase in number of branches per plant, relative water content and leaf water potential. However, negative correlation between seed yield per plant and membrane injury index clearly indicated that more the injury due to drought, more susceptible is the genotype. Therefore, these four parameters can very effectively be utilised for identification of chickpea genotypes suitable for drought conditions provided the genotypes are screened under drought. This is because these correlations hold true only under rainfed conditions.The survey of literature depicts the corollary between various studies and the present study. Gupta *et al.* (2000) observed that genotypes, RSG-44, RSG-143-1 and ICC-4958, which were more tolerant to moisture stress, had lower membrane injury, retain imbibitions and higher seedling growth, osmotic regulation and water use

Table 1. Pearson Correlation Matrix between different morphological and physiological parameters

	DF	DM	PH	B/P	P/P	100SW	HI	RWC	MII	SLW	LWP	SY/P
DF	1.000	0.530*	0.057^{NS}	-0.209^{NS}	-0.203^{NS}	0.518*	0.030^{NS}	-0.144^{NS}	0.110^{NS}	-0.274^{NS}	-0.268^{NS}	-0.221^{NS}
DM	0.530*	1.000	0.268^{NS}	-0.323^{NS}	-0.449*	0.241^{NS}	-0.026^{NS}	0.048^{NS}	0.069^{NS}	-0.261^{NS}	-0.204^{NS}	-0.093^{NS}
PH	0.057^{NS}	0.268^{NS}	1.000	0.308^{NS}	0.166^{NS}	0.248^{NS}	0.113^{NS}	0.438*	-0.328^{NS}	-0.034^{NS}	0.111^{NS}	0.400^{NS}
B/P	-0.209^{NS}	-0.323^{NS}	0.308^{NS}	1.000	0.301^{NS}	0.034^{NS}	0.106^{NS}	0.387^{NS}	-0.600**	0.141^{NS}	0.561**	0.847**
P/P	-0.203^{NS}	-0.449*	0.166^{NS}	0.301^{NS}	1.000	0.130^{NS}	0.466*	0.340^{NS}	-0.264^{NS}	-0.231^{NS}	0.184^{NS}	0.390^{NS}
100SW	0.518*	0.241^{NS}	0.248^{NS}	0.034^{NS}	0.130^{NS}	1.000	0.240^{NS}	-0.102^{NS}	-0.332^{NS}	-0.059^{NS}	-0.198^{NS}	0.150^{NS}
HI	0.030^{NS}	-0.026^{NS}	0.113^{NS}	0.106^{NS}	0.466*	0.240^{NS}	1.000	0.553**	-0.335^{NS}	-0.321^{NS}	-0.043^{NS}	0.389^{NS}
RWC	-0.144^{NS}	0.048^{NS}	0.438*	0.387^{NS}	0.340^{NS}	-0.102^{NS}	0.553**	1.000	-0.408^{NS}	-0.140^{NS}	0.319^{NS}	0.541*
MII	0.110^{NS}	0.069^{NS}	-0.328^{NS}	-0.600**	-0.264^{NS}	-0.332^{NS}	-0.335^{NS}	-0.408^{NS}	1.000	-0.297^{NS}	-0.614**	-0.694**
SLW	-0.274^{NS}	-0.261^{NS}	-0.034^{NS}	0.141^{NS}	-0.231^{NS}	-0.059^{NS}	-0.321^{NS}	-0.140^{NS}	-0.297^{NS}	1.000	0.238^{NS}	0.091^{NS}
LWP	-0.268^{NS}	-0.204^{NS}	0.111^{NS}	0.561**	0.184^{NS}	-0.198^{NS}	-0.043^{NS}	0.319^{NS}	-0.614**	0.238^{NS}	1.000	0.466*
SY/P	-0.221^{NS}	-0.093^{NS}	0.400^{NS}	0.847**	0.390^{NS}	0.150^{NS}	0.389^{NS}	0.541*	-0.694**	0.091^{NS}	0.466*	1.000

DF = days to flowering, DM = days to maturity, PH= plant height, B/P= branches plant^{-1}, P/P= pods plant^{-1}, 100SW= 10 seed weight, HI =harvest index, RWC=relative water content, MII = , SLW = , LWP=leaf water potential, and SY/P=seed yield plant^{-1}

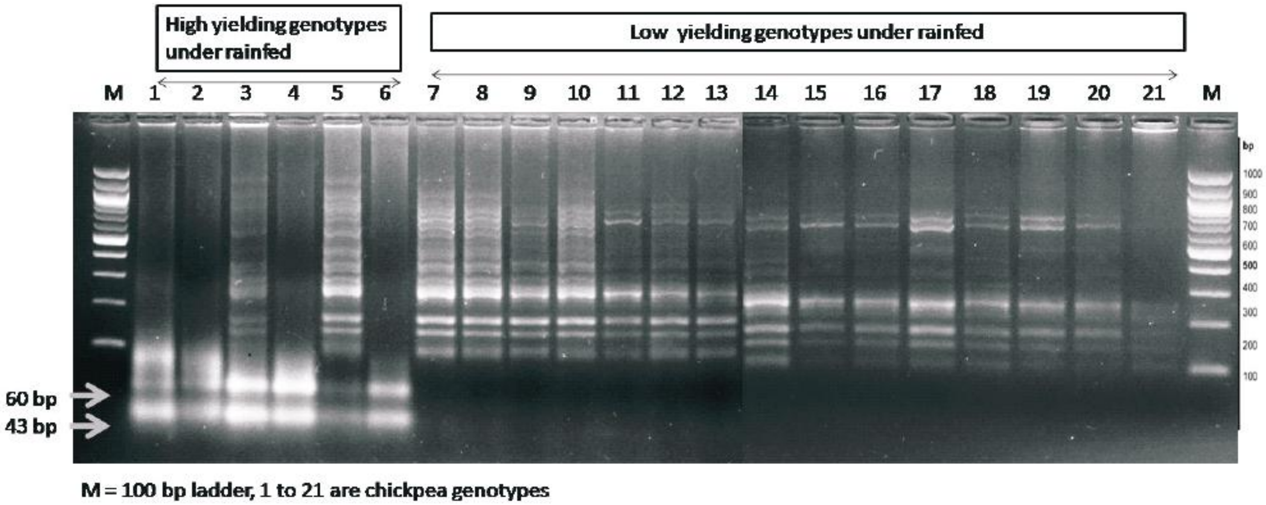

Fig. 1. ISSR bandling profile of 21 chickpea genotypes using UBC-841 primers

efficiency. These metabolic adjustments resulted in lower drought susceptibility index in these genotypes. Deshmukh and Kushwaha (2002) also reported that relative water content and membrane injury index (RWC and MII) of a genotype measured during early phase were found to provide an indication of its relative MII during reproductive stages. The genotypes were grouped into different categories on the basis of MII. They concluded that these traits were relatively simple and, therefore, can be used to screen large number of population for stress tolerance. Yadav *et al.* (2005) observed that at flowering stage, branches/plant, relative water content (RWC), leaf water potential, seeds/plant, seeds/pod and harvest index coupled with the higher leaf water potential were identified as important parameters for drought tolerance.

However few contradictory reports are also available. Neeraj *et al.* (2012) evaluated chickpea genotypes for root characteristics, plant water status and membrane integrity. Root traits, such as depth and root biomass, have been identified as the most promising plant traits in chickpea for terminal drought tolerance. These traits are directly associated with maximum seed yield per plant. ISSR Analysis Out of fifty six primers used, one primer namely UBC-841 gave very encouraging results. Based upon mean values and CD(5%) for grain yield per plot under rainfed conditions, 21 genotypes were grouped in two categories *i.e.* high yielding (6 genotypes) and low yielding (15 genotypes). Assuming that high yield under rainfed condition is due to heat tolerance/drought tolerance, ISSR banding patterns were analysed. Amazingly, out of 14 bands produced, two bands of low molecular weight *i.e.* 43 and 60

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Effect of Growing Environments and Chlorophyll Meter Based N Management on Productivity and Profitability of Maize Cultivars in Alluvial Plains of North-India

Arka Prabha Ghosh, Anchal Dass* and Ramanjit Kaur

Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi - 110 012, India

**E-mail: anchal_iari@rediffmail.com*

Abstract **:** A field experiment was conducted at New Delhi during rainy (*kharif*) season of 2014-15, to determine the influence of growing environments and chlorophyll meter (SPAD meter) guided nitrogen management on growth, productivity and profitability of two maize genotypes in sandy loam textured alluvial soils of north Indian plains. The experimental treatments included 2 maize cultivars *viz.* Pusa Extra Early Hybrid Makka 5 (PEEHM 5) and Pusa Composite 3 (PC 3) and 3 planting dates, July 9, July 24, August 7 and 4 N-rates, control, chlorophyll meter based N application up to silking (CMB) *i.e.,* 30 kg ha^{-1} N basal + 30 kg ha^{-1} N top-dressed each time SPAD value reaches $\leq$ 37.5, chlorophyll meter based N application stage-wise (CMBSW) *i.e.* 30 kg ha^{-1} N basal + 30 kg ha^{-1} N top-dressed each at knee-high, pre-tasseling and silking stage at SPAD value $\leq$37.5, and soil test crop response based (STCRB) N application. PEEHM 5 produced 5% higher grain yield, whereas biological yield was 5.4% higher in PC 3. Both grain and biological yields of both the cultivars decreased with successive 15-day delay in planting from July 9 to August 7, but the decrease was more drastic in PEEHM 5. CMB N application increased grain yield by 8.5% and biological yield by 7.63% and also saved 10 kg N ha^{-1} compared to STCRB N application. The highest gross return, net return and B: C ratio, were recorded with the earliest planting (July 9) and CMB N application. PEEHM 5 was more profitable for early planting (July 9) condition and for later planting dates (August 7), PC 3 showed greater promise.

Key Words**:** PEEHM 5, Planting dates, Pusa composite 3, Precision nitrogen, SPAD meter

Maize (*Zea mays* L.) is the third major cereal crop in the world after wheat and rice. It is the main staple food for hundred millions of people in developing countries especially in Sub Saharan Africa (Lukeba, 2013). The crop has adapted to a wide range of environmental and climatic conditions, ranging from 60°N to 40°S latitude, from below sea-level to an altitude of >4,000 m with rainfall varying from < 25 cm to >1,000 cm (Sharma and Dass, 2012). World-over it is grown on 177 m ha area producing 989 m t grain with a productivity of 5.5 t ha^{-1}. In India, the crop is cultivated on 9.4 m ha with a total production of 22.97 m t and average yield of 2.56 t ha^{-1} (Economic Survey, 2014-15). Maize grain is used as human food, animal feed and also used as raw material for deriving industrial products. Despite its immense economic importance, the yield of maize is still much lower in many countries of the world including India and Pakistan than the yields realized in other parts of the world (Mukhtar *et al.,* 2011). There is stagnation in crop yield particularly in intensive cropping regions where due to imbalanced use of fertilizers and continuous growing of crops (exhaustive) have rendered several nutrients deficient. N being an important component of chlorophyll, protein and nucleic acid is the major yield determining factor in maize. Maize is a nutrient exhaustive crop and its heavy requirement for N poses stiff challenge to the producers because N-fertilizers are becoming increasingly costly and are highly susceptible to losses due to leaching and volatilization, limiting nitrogen-use efficiency below 50%. Ground water contamination and global warming are the other issues related to the use N fertilizers. In this context, a new and mostly technology driven approach of precision N management using chlorophyll meter may be adopted (Dass *et al*., 2015) to address the issues of low N-use efficiency and environmental pollution. Dass *et al.* (2012, 2014) found that applying N based on SPAD value $\leq$37.5 resulted in the highest maize grain yield (5.2 t ha^{-1}) and saved 30–45 kg N ha^{-1}.

Growing environments and climates exert strong influences on the maize crop's physiological and yield performance. Several workers have reported variable growth and yield responses of maize hybrids and other cultivars to planting dates (Berzsenyi and Lap, 2001, Karthikeyan and Balasubramaniam, 2006; Rastegar *et al.,* 2011). Response of maize cultivars to nitrogen management may differ with cultivars and growing environments. Hence, genotypes, planting date and environmental condition interactions need to be studied for arriving at valid recommendations of precise N management in maize. Thus it is important to study the responses of maize cultivars to precise N management approaches and different planting dates to have an understanding of genotype, planting date and environmental condition interactions. With this backdrop, the current investigation was carried out to assess the effect of planting dates and chlorophyll meter based N application on growth, productivity, economics and agronomic efficiency of two maize cultivars, and study the interaction effects of these management variables on maize crop.

MATERIAL AND METHODS

The field experiment was carried out at ICAR-Indian Agricultural Research Institute, New Delhi (28°40' N, 77°12'E and 228.6 m above mean sea level) during *rainy season* of 2014-15. The climate of New Delhi is of sub-tropical and semi-arid type with hot and dry summer and cold winter. During the crop growth period, mean weekly maximum temperature was 34.2°C, while the mean minimum 22.8°C. Mean weekly maximum and minimum relative humidity, sun shine hours day^{-1} and evaporation during the growing season were 84.8%, 53.2%, 5.6 and 6 mm day^{-1}, respectively. Crop season received rainfall of 56.4 mm with a weekly average of 3.13 mm. The experimental field soil was sandy loam in texture, medium in organic carbon (0.58%) low in available N (224 kg ha^{-1}) and medium in available phosphorus (18.7 kg ha^{-1}) and potassium (262 kg ha^{-1}) contents. Soil reaction was neutral (pH 7.4). Field capacity, permanent wilting point and bulk density were 19.5%, 5.8% and 1.54 Mg m^{-3}, respectively.

The experiment had 24 treatment combinations of 2 maize cultivars (Hybrid PEEHM 5 and Composite PC 3), 3 planting dates (July 9 , July 24 and August 7) in the main-plots, and 4 N-rates, control (no N), chlorophyll meter based N application up to silking (CMB) i.e., 30 kg ha^{-1} N basal + 30 kg ha^{-1} N top-dressed each time SPAD value falls to $\leq$37.5 (total quantity of N 150 kg ha^{-1}), chlorophyll meter based N application stage-wise (CMBSW) i.e. 30 kg ha^{-1} N basal + 30 kg N ha^{-1} top-dressed each at knee high, pre-tasseling and silking stages when SPAD value falls to $\leq$37.5 (total quantity of N 120 kg ha^{-1}), and soil test crop response based (STCRB) application (total quantity of N 160 kg ha^{-1}), in sub-plots. The experiment was laid-out in a split-plot design replicated three times. In all there were 72 experimental plots of size 4.8 × 3 m each.

After all land preparation and layout, maize seeds were dibbled at planting interval of 60 × 20 cm using 20 kg seed/ha. As per treatment, for STCRB plots, 56 kg N + 60 kg P_2O_5 + 40 kg K_2O + 25 kg $ZnSO_4$ ha^{-1}, for CMBSW and CMB plots, 30 kg N + 60 kg P_2O_5 + 40 kg K_2O + 25 kg $ZnSO_4$ ha^{-1}, and for control plots, 0 kg N + 60 kg P_2O_5 + 40 kg K_2O + 25 kg $ZnSO_4$ ha^{-1} was applied at the time of sowing. Subsequent N fertilizer was band placed in two splits in STCR, whereas in CMB and CMBSW the N was top-dressed as indicated in the treatments. Based on initial soil test value of N, the fertilizer recommendation for maize for a targeted yield of 4.2 t ha^{-1} was calculated using STCR equation at the beginning of the experiment and computed values were rounded of to 160 kg N ha^{-1}

$$F_N = 6.61\,T - 0.52\,SN$$

Where, T is yield target (4.2 t ha^{-1}), SN is soil N status before sowing

All recommended package of practices (barring treatments) were followed to raise a healthy maize crop. The height of five tagged plants was measured from base of the stem to tip of the terminal leaf at knee-high stage, and form base of the stem to tip of the tassel at tasseling and maturity stages. To determine grain yield and biological yield, maize cobs from the net plots, leaving two border rows from both sides of the plots and half meter on opposite directions of the plots were harvested and sun-dried for 6 days and weighed. Thee cobs were dehusked, shelled, cleaned, dried in sun, weighed again and grain yield was adjusted at 14% moisture. The weight of husk and rachis (cob after removal of grains) were also recorded separately. After cob harvesting, maize stalks were cut at ground level from the net-plot and were sun-dried for 7 days. After proper sun drying, the stalk weight was taken and reported as straw yield. Grain yield, straw yield and other biomass yields are summed up to get total biological yield.

Cost of cultivation for all treatments was worked out taking into account the prevailing market prices of inputs and labour costs, used in raising the crop on hectare basis. The gross and net return, and B: C ratio were calculated taking into account the prevailing market prices for grain and straw of maize. Agronomic efficiency (AE) for different treatments was computed using the following expression.

$$\text{Agronomic efficiency (kg kg}^{-1}) = \frac{\text{Grain yield (kg ha}^{-1}\text{) in N fertilized plot} - \text{Grain yield (kg ha}^{-1}\text{) in control}}{\text{N fertilizer applied (kg ha}^{-1})}$$

RESULTS AND DISCUSSION

Plant height was significantly affected by maize cultivars, planting dates and N rates at knee-high, tasseling and maturity stages. On an average, hybrid variety PEEHM 5 recorded 9.4% higher plant height than PC 3 at knee-high stage but the latter recorded 7.3% and 7.0% greater plant height than PEEHM 5 at tasseling and maturity stages, respectively. Earlier planting on July 9 significantly increased plant height at KH, tasseling and maturity stages compared to late planting on August 7 (Table 1). These differences in planting dates for plant height could have been caused by the difference in irradiative and thermal conditions during growth. Below optimum environmental conditions limit the growth and yield of maize (Anderson *et al*., 2004). The amount of incident radiation and the proportion of this radiation that is intercepted by the crop directly determine the crop growth rate. Moreover, delay in planting causes reduction in amount of incident radiation accumulated from emergence to silking and at grain filling stage, as plants of delayed plantings are, in general, exposed to low temperature and low radiations compared to early plantings and produce lower dry matter yield, hence lower plant height. Several authors have reported similar temperature effects on leaf emergence rate and on leaf expansion in maize and thus affecting net photosynthesis and plant height.

STCRB N treatment produced 0.09 m and 0.58 m taller plants compared to CMB N treatment and control (without N), respectively at knee-high stage. CMB N treatment increased plant height from 2.8–1.8 m and 2.8–2.7 m compared to control (without N treatment) and STCR based N treatment, respectively at tasseling stage and from 2.92–1.88 m and 2.92–2.82 m compared to control (without N) and STCR based N treatment, respectively at maturity stage. Interaction effects of variety and planting dates were significant for plant height at all three stages. PEEHM 5 attained greater height when planted on July 9 at knee-high stage than the plants of other variety sown on other dates. But at tasseling and maturity stages, plants of variety PC 3 sown on July 9 were taller than other treatment combinations (Table 2). These findings may be explained by the report that maximum growth potential is obtained when a crop is grown in an environment for which it has been adapted, and when sufficient water and inputs have been provided in the absence of abiotic and biotic stress (Evans and Fisher, 1999), hence variations between cultivars for plant height could largely be due to difference in their genetic make-up (Dass and Chandra, 2013). Greater plant height under CMB N application could be due to small but regular supply of N synchronized with plant demand.

Corn grain and biological yield: There was significant influence of cultivars, planting dates and N rates on grain and biological yields. Grain yield increased from 4.39-4.62 t ha^{-1} in PEEHM 5 compared to PC 3. On the contrast, the performance in terms of biological yield was superior in the variety PC 3 with an average biological yield of 13.73 t ha^{-1} against 12.99 t ha^{-1} in PEEHM 5. Several researchers, Sharifi

Table 1. Effect of cultivars, planting dates and chlorophyll meter based N application on stage-wise plant height, yield and economics of maize

Treatment	Plant height (m)			Yield (t ha^{-1})		Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B: C ratio
	Knee- high	Tasseling	Maturity	Grain	Biological			
Cultivars								
PEEHM 5	1.28	2.43	2.51	4.62	12.99	73,045	46,014	1.69
Pusa composite 3	1.16	2.62	2.70	4.39	13.73	71,539	45,408	1.72
CD (p=0.05)	0.05	0.10	0.09	0.21	0.57	NS	NS	0.12
Planting dates								
July 9	1.33	2.70	2.74	4.87	14.32	78,013	51,432	1.92
July 24	1.22	2.50	2.61	4.58	13.55	73,492	46,911	1.75
August 7	1.12	2.40	2.47	4.06	12.21	65,371	38,790	1.45
CD (p=0.05)	0.06	0.13	0.12	0.26	0.69	3870	3870	0.15
Nitrogen management								
Control	0.83	1.80	1.88	3.03	9.22	48,957	24,132	0.97
CMB	1.32	2.80	2.92	5.31	15.58	84,951	57,698	2.12
CMBSW	1.32	2.70	2.80	4.82	14.24	77,319	50,454	1.88
STCRB	1.41	2.70	2.82	4.86	14.39	77,941	50,558	1.85
CD (p=0.05)	0.04	0.10	0.09	0.21	0.57	3212	3212	0.12

CMB: Chlorophyll meter based N application up to silking i.e. 30 kg ha^{-1} N basal + 30 kg ha^{-1} N top-dressed each time leaf SPAD value falls to $\leq$37.5

CMBSW: Chlorophyll meter based N application stage-wise i.e. 30 kg ha^{-1} N basal + 30 kg N top-dressed each at knee high, pre-tasseling and silking stages when SPAD value falls to $\leq$37.5

STCRB: Soil test crop response based N application *et al.* (2009), Hokmalipour and Darbandi (2011) and Dolijanovic *et al.* (2007) also reported significant differences among different maize cultivars (including hybrids) in terms of grain yield and total biological yield. Yield differences in maize cultivars are due to stomata conductance value and to differences between genotypes in partitioning of photosynthetic materials towards economic yield.

The economic yield as well as biological yield decreased as planting was delayed. Maize grain yield significantly decreased from 4.87 t ha^{-1} in July 9– 4.58 t ha^{-1} in July 24 and 4.06 t ha^{-1} in August 7. Similarly, the performance of the sowing dates remained same in terms biological yield also where July 9 sown plants were significantly higher yielder compared to other planting dates. Meteorological data recorded and analyzed for the duration of crop growth, revealed that August 7 sown plants experienced considerably low relative humidity, sunshine and temperatures in comparison to July 9 and July 24 sown plants at the time of tasseling which could be the probable reasons for lower growth and grain yield of maize under August 7 planting.

Among N-application rates, chlorophyll meter based nitrogen application up to silking (CMB) produced significantly higher amount of grain and biological yields than other N treatments. Gehl *et al.* (2005) found that grain and biological yields in maize increased with split N-fertilization compared to one single application which are consistent with our findings. Dass *et al.* (2014), in line with our findings, reported that SPAD meter instantly measures chlorophyll content of plants to reduce the risk of yield limiting N deficiencies or costly over fertilizations and also concluded that chlorophyll meter based N gives higher yield than STCR based N application, with considerable saving on fertilizer N.

Interaction effects of varieties and planting dates on grain yield and biological yield of maize were found to be significant. Among the variety and planting date combinations, the plants of variety PEEHM 5 sown on July 9 registered a grain yield of 5.06 t /ha and a biological yield of 14.15 tha^{-1}, both of which were significantly higher than all other combinations. Variety PEEHM 5 when planted on August 7 registered the lowest grain yield and biological yield among all treatment combinations (Table 3). These results demonstrate the better stability of PC 3 across the growing environments; however under early or timely sowing conditions, PEEHM 5 could be a better option.

Agronomic efficiency: Chlorophyll meter based (CMB) N application resulted in higher agronomic efficiency (AE) over STCRB N application, across the both cultivars and planting dates due to higher yield with less input of N (Fig. 1). Between planting dates, AE was considerably higher in July 24 planted crop despite the fact that grain yield was higher in July 9 planted crop. This is because the grain yield from control plots (no- N) was considerably higher in July 9 (3.72) than July 24 (3.29 t/ha) planted crop, restricting the rate of increase in yield due to N applications leading to 18.5% lower AE in July 9 planted crop.

In the sandy loam soil of North India, maize hybrid PEEHM 5 and composite variety PC 3 performed best in

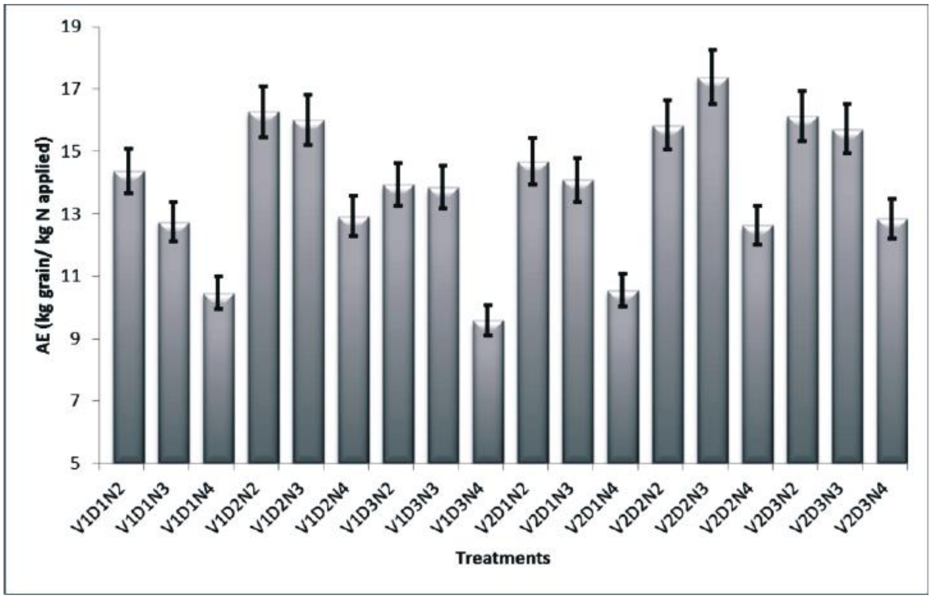
Table 2. Interaction effects of cultivars and planting dates on maize plant height (m) at different growth stages

Planting date	Variety					
	Knee-high		Tasseling		Maturity	
	PEEHM 5	Pusa composite 3	PEEHM 5	Pusa composite 3	PEEHM 5	Pusa composite 3
July 9	1.41	1.24	2.61	2.73	2.68	2.80
July 24	1.32	1.12	2.51	2.55	2.59	2.63
August 7	1.11	1.12	2.17	2.59	2.26	2.68
CD (p=0.05)	0.08		0.18			0.16

Table 3. Interaction effects of cultivars and planting dates on yield and economics of maize

Treatment	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
$V_1 \times D_1$	5.06	14.15	79,879	52,848	1.94
$V_1 \times D_2$	4.85	13.60	76,601	49,570	1.82
$V_1 \times D_3$	3.95	11.22	62,655	35,623	1.30
$V_2 \times D_1$	4.69	14.50	76,147	50,016	1.90
$V_2 \times D_2$	4.32	13.50	70,383	44,251	1.67
$V_2 \times D_3$	4.16	13.19	68,088	41,956	1.59
CD (p=0.05)	0.37	0.98	5,473	5,473	0.21

See table 1 for details



V_1: PEEHM 5, V_2: Pusa Composite 3, D_1, D_2 and D_3 are the planting dates, July 9, July 24, and August 7, respectively.

N_2 :CMB: Chlorophyll meter based N application up to silking i.e. 30 kg/ ha N basal + 30 kg/ha N top-dressed each time leaf SPAD value falls to ≤37.5

N_3:CMBSW: Chlorophyll meter based N application stage-wise i.e. 30 kg/ha N basal + 30 kg N top-dressed each at knee high, pre-tasseling and silking stages when SPAD value falls to ≤37.5

N_4:STCRB: Soil test crop response based N application

Fig. 1. Effect of cultivars, planting dates and chlorophyll meter based N application on agronomic efficiency (AE) of maize

terms of growth characteristics, grain and total biological yields and profitability (gross and net returns, net B:C ratio) when planted on 9th July. Delayed sowing caused significant yield reductions and hence returns in both varieties, but yield reduction was greater in PEEHM 5. Although PEEHM 5 produced higher grain yield, but PC 3 demonstrated higher biological yields as well as better yield stability across growing environments. Scheduling N application as per SPAD value ≤37.5 resulted in significantly higher growth, grain and biological yields, and profitability. Thus, in northern plain zone of India, sowing of maize should not be delayed beyond second week of July; however, if sowing gets delayed use cultivars like Pusa composite 3 and N application scheduling may be done using a chlorophyll meter.

Gross return, net return and net B: C ratio: Gross returns and net returns were not influenced significantly by the varieties, although variety PEEHM 5 fetched marginally higher gross returns and net returns over variety PC 3. Net B: C ratio was also not affected significantly by the varieties. Different planting dates influenced gross returns, net returns as well as net B: C ratio significantly. July 9 planted maize crop proved to be more profitable fetching significantly higher gross returns (Rs.78,013 ha^{-1}), net returns (Rs.51,432 ha^{-1}) as well as net B: C (1.92) ratio over July 24 and August 7 planted crops. CMB N treatment was more profitable producing significantly higher gross returns, net returns and net B: C ratio compared to control and other nitrogen application treatments. Interaction effects of varieties and planting dates on gross returns, net returns and net B: C ratio of maize was significant. PEEHM 5 when planted on July 9 ($V_1 \times D_1$) gave significantly higher gross returns, net returns and net B:C ratio than other combinations, whereas, PC 3 when sown on August 7 ($V_2 \times D_3$) exhibited the lowest gross returns, net returns and net B:C ratio. These economic parameters more or less followed the trend of grain and straw yields.

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Association of Morpho-Physiological Traits in Recombinant Inbred Population of Wheat Under Rainfed Environments

Ashutosh Srivastava, Puja Srivastava, Rinki Khobra[1], Achla Sharma, R. S. Sarlach, Anil Dogra and N. S. Bains

Punjab Agricultural University, Ludhiana-141004, India
[1]Crop Improvement, ICAR-IIWBR, Karnal-132001, India
E-mail: aksri_du@yahoo.com

Abstracts: The present study was carried out to understand the association of morpho-physiological traits with drought tolerance in recombinant inbred population of wheat. In present investigation, 175 RILs along with parents and checks were evaluated for various morpho-physiological traits involving grain filling period, canopy temperature, chlorophyll content, peduncle length, relative water contents, stomatal density, water soluble carbohydrates, number of grains per spike, 1000-grain weight and grain yield. Significant differences were observed for genotypes in respect to all the traits studied under both environments. Correlation analysis for above-mentioned traits in both environments estimated and results revealed that grain filling period, water soluble carbohydrates, number of grains per spike and 1000-grain weight were positively correlated with yield in both concerned environments. Besides, peduncle length, stomatal density, relative water contents and canopy temperature were significantly correlated with traits under rainfed conditions.

Key Words: Canopy temperature, Correlation analysis, Recombinant inbred lines, Relative water content

Wheat is one of the most important cereal and a staple food for more than one third of the world population. The climatic fluctuation in present scenario influences the wheat productivity, in which drought is one the most common environmental stress affecting about 32% of 99 million hectares under wheat cultivation in developing countries and at least 60 million hectares under wheat cultivation in developed countries (Shamsi *et al.,* 2011). The insufficiency of water utilization is the principal environmental stress that causes fluctuation in wheat productivity. Morphological and physiological traits of wheat have a special role in determining the importance of each trait in increasing yield, so these traits were used in breeding programs which at least led to improving yield and introducing commercial varieties that can withstand seasonal drought stress condition (Mollasadeghi *et al.,* 2011). Moreover, grain yield is a complex trait that is influenced by many physiological and biochemical traits both in positive and negative direction. The effectiveness of any breeding or selection programme depends upon the nature and association between yield and other component characters, as more directly and positively a character is associated with grain yield, the more will be the success of the selection programme.

Prior to advent of present day semi-dwarf wheat in the 1960s, tall traditional cultivars were grown under rainfed conditions in the state. These cultivars (C306, C273, C518 and C591) were derived from landraces materials of NWPZ region. After the adaption of semi-dwarf, the tall traditional cultivars were of little use even as donors of traits in wheat breeding programme. Presently these materials have come under focus as a result of greater emphasis on breeding for abiotic stress tolerance and their potential utility in context of drought tolerance when introgressed in to a modern day wheat variety (PBW 343). These two cultivars belonging to distinct adaptation groups, offer several morpho-physiological and biochemical contrasts. C518 is tall and adapted to low input rainfed conditions whereas PBW 343 is semi-dwarf and input responsive. The aim of the present study was to estimate the association of various morphological and physio-biochemical traits of recombinant inbred lines under rainfed conditions along with the type and extent of their contribution to yield.

MATERIAL AND METHODS

The experiment was conducted during *Rabi* seasons of 2012-13 and 2013-14 in Punjab Agricultural University, Ludhiana. The experimental material consisted of 175 recombinant inbred lines (RILs) along with parents (PBW 343 and C 518) and 19 checks viz; commercial cultivars for timely sown irrigated (PBW 621 and HD 2967), rainfed cultivars (PBW 644, PBW 527, PBW 175), traditional tall cultivars (C306, C273, C591, C286, C281, C285), advance breeding lines (PBW 706, PBW 691, BWL 1856) and Australian drought cultivars (Kirchauff, Babax, Excalibur, Gladius, Drysdale). The experimental design was 14x14 square lattice having $1m^2$ plot with three replications. The drought environment was created by withholding of irrigation. Standard agronomical practices for growing normal sown wheat crop were followed. Data recorded for various physio-biochemical under both irrigated and rainfed environments. Meteorological data on weekly were recorded from Agrometerological station, PAU (Fig. 1). The analysis of variance of the data for physio-biochemical and yield related parameters were done using a simple lattice designs by PROC LATTICE and adjusted mean square of treatments were computed by using PROC GLM, SAS (version 9.2). Least significant differences (LSD) were computed at 1% and 5% probability level. Pearson's correlation coefficient among all characters studied was analyzed by statistical software JMP (version 12.0).

RESULTS AND DISCUSSIONS

Analysis of variance for all the physio-biochemical and yield components characters was highly significant (P<0.01) among the RILs under both irrigated and rainfed conditions, indicating the existence of sufficient genetic variability among the population. The mean sum of square due to treatments (adj) were highly significant for all the characters studied viz; grain filling period, peduncle length, water soluble carbohydrates, canopy temperature, chlorophyll content, stomatal density, relative water content, grain number, thousand grain weight, grain yield and harvest index under both irrigated and rainfed environments (Table 1 and 2). Earlier Salem et *al.* (1996) have also reported significant differences among bread wheat genotypes for different traits under both drought and irrigated conditions. Khamssi and Najaphy (2012) showed significant genotypic differences for peduncle length, grain filling period, grains per spike and grain yield in irrigated conditions. However, significant variation among genotypes was observed for grain yield, grains/spike and harvest index in the stress conditions. In another study, Jatoi *et al.* (2012) reported that mean squares due to treatments under irrigated and rainfed environments differed significantly in their performance for all physiological traits and yield component parameters. Hasheminasab *et al.* (2012) also reported significant differences among genotypes for RWC under drought stress conditions. A wide range of variation was observed among population with regard to different characters studied.

The maximum decline in mean value was recorded in relative water content (16.9 %) followed by chlorophyll content (6.9 %), grain filling period (6.0 %) and water soluble carbohydrates (5.55 %). The minimum decline was in mean value for peduncle length (0.27 %). The average value of canopy temperature, chlorophyll content, relative water content and water soluble carbohydrates were exhibited as 28.0, 20.2, 67.4, 30.6 which ranged from 25.4 to 29.8, 11.2 to 34.5, 50.6 to 81.8 and 17.1 to 51.6, respectively, under irrigated conditions. In rainfed conditions, the mean value of canopy temperature, chlorophyll content, relative water content and water soluble carbohydrates were 28.2, 18.8, 56.0 and 28.9 which ranged between 26.3 to 30.8, 10.9 to 30.4, 49.1 to 80.1 and 14.2 to 57.9, respectively (Table 3).

Correlations coefficient among various physio-biochemical and yield component traits was carried out and results obtained are presented in the Table 4. Under irrigated conditions, grain filling period was found positively correlated with peduncle length (r_i = 0.288), stomatal density (r_i = 0.155), mobilized water soluble carbohydrates (r_i = 0.212), 1000 grain weight (r_i = 0.238) and grain yield (r_i = 0.193). In rainfed

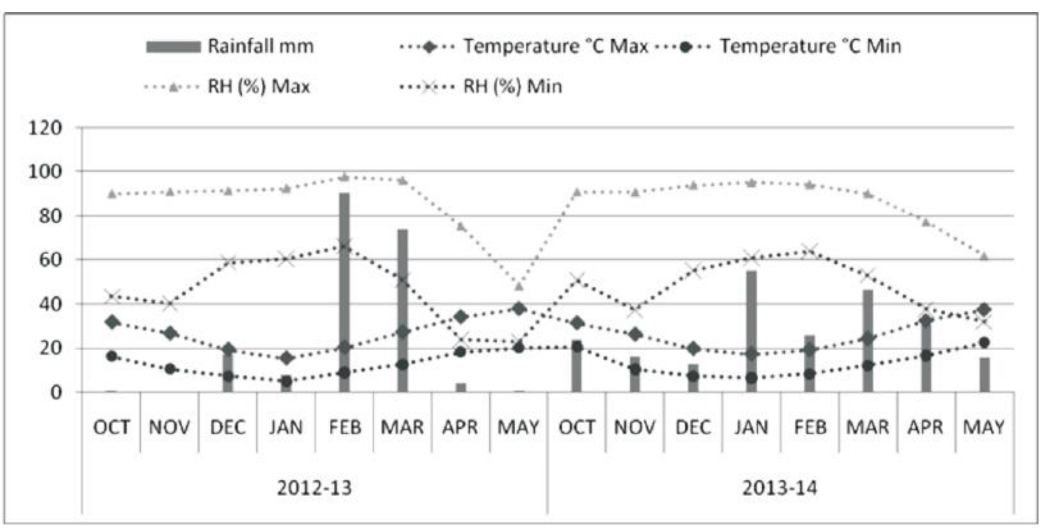

Fig. 1. Agrometerological data during crop season 2012-13 and 2013-14

Table 1. Analysis of variance for morpho-physiological and biochemical traits in 175 RILs along with parents and checks under irrigated conditions

Irrigated		Mean square of characters										
Source of variation	DF	GFP	CTA	CC	PL	RWC	SD	MWSC	GN	TGW	GY	HI
Replication	2	0.86	0.13	1.35	11.66	2086.5**	94.9**	5.21	18.92	73.2877	87.24	0.00952
Block within rep (adj)	39	3.05	0.11	2.92	3.23	47.11	8.62*	1.68	15.34	6.7077	1388.89	0.00669*
Treatment (unadj)	195	33.74	1.74	64.65	110.45	75.57	12.16	169.29	84.95	101.93	18100	0.01391
Treatment (adj)	195	31.19**	1.58**	56.43**	105.57**	71.30**	12.78**	153.09**	76.91**	95.45**	16809.2**	0.0129**
Intra block error	351	3.045	0.163	3.723	2.698	23.44	4.029	1.627	12.71	8.3056	919.64	0.00317
Randomized complete block error	390	3.046	0.158	3.644	2.752	25.80	4.489	1.633	12.97	8.1458	966.56	0.00352
Total	587	13.23	0.68	23.9	38.56	49.36	7.34	57.34	36.91	39.5236	6655.27	0.00699
Efficiency relative to RCBD		100	96.89	97.86	100.32	104.83	105.76	100.01	100.35	98.06	101.67	105.5
R^2		0.862	0.857	0.907	0.958	0.716	0.672	0.983	0.794	0.874	0.917	0.729
CV (%)		5.29	1.45	9.95	4.44	7.17	6.75	4.09	9.72	8.04	12.92	23.21

Abbreviations: GFP-grain filling period, CTA- canopy temperature at anthesis, PL- peduncle length, RWC-relative water content, STD- stomatal density, MWSC-mobilized water soluble carbohydrates, GN-grains per spike, TGW-1000 grain weight, GY- grain yield, HI- harvest index

Table 2. Analysis of variance for morpho-physiological and biochemical traits in 175 RILs along with parents and checks checks under rainfed conditions

Rainfed		Mean square of characters										
Source of variation	DF	GFP	CTA	CC	PL	RWC	SD	MWSC	GN	TGW	GY	HI
Replication	2	10.281	0.269	3.471	0.288	719.44**	6.495	2.002	219.90*	24.302	123.26	0.129**
Block within rep (adj)	39	3.290	0.260	2.243	2.275	37.506	5.949	2.147	8.96	5.901	992.59	0.0022
Treatment (unadj)	195	37.307	2.132	63.273	112.680	80.405	14.985	217.870	95.58	85.030	16636.0	0.0063
Treatment (adj)	195	34.32**	2.00**	56.36**	104.64**	78.65**	13.61**	204.81**	88.02**	80.79**	15645.9**	0.011 **
Intra block error	351	3.481	0.156	2.862	2.921	28.430	3.824	1.092	10.48	6.612	751.45	0.0011
Randomized complete block error	390	3.462	0.166	2.801	2.857	29.338	4.037	1.197	10.33	6.541	775.56	0.0012
Total	587	14.729	0.820	22.892	39.330	48.653	7.682	73.177	39.367	32.676	6042.0	0.0033
Efficiency relative to RCBD		99.44	102.57	97.83	97.78	100.75	101.91	104.53	98.54	98.92	100.76	104.36
R^2		0.859	0.886	0.925	0.956	0.651	0.702	0.991	0.841	0.879	0.926	0.798
CV (%)		5.88	1.40	8.19	4.65	8.21	6.82	3.53	9.23	7.26	13.39	21.17

Abbreviations: GFP-grain filling period, CTA- canopy temperature at anthesis, PL- peduncle length, RWC-relative water content, STD- stomatal density, MWSC-mobilized water soluble carbohydrates, GN-grains per spike, TGW-1000 grain weight, GY- grain yield, HI- harvest index

Table 3. Mean and range of different characters under irrigated and rainfed conditions

Characters	Irrigated				Rainfed			
	Mean	SE	Min	Max	Mean	SE	Min	Max
GFP (days)	33	0.26	25	42	31	0.27	22	41
CTA (°C)	28	0.06	25.4	29.8	28.2	0.06	26.3	30.8
CCI value	20.2	0.31	11.2	34.5	18.8	0.33	10.9	30.4
PL (cm)	36.8	0.43	24	54.4	36.7	0.47	24.5	56.5
RWC (%)	67.4	0.39	50.6	81.8	56	0.40	49.1	80.1
STD	29.6	0.16	24.3	35.5	28.7	0.18	23	34.7
WSC (mg $^{-9}$)	30.6	0.55	17.1	51.6	28.9	0.63	14.2	57.9
Grain spike^{-1}	36.5	0.40	23.6	49	34.9	0.42	20.4	48.5
TGW (g)	35.2	0.44	13.1	42.8	34.9	0.41	21.02	42.8
GY (g m^{-2})	226.4	5.05	76.7	403.3	198.8	5.01	50	383.3
Harvest index	0.24	0.005	0.12	0.53	0.17	0.003	0.07	0.36

See Table 1 for foot note

conditions, grain filling period had significant positive correlation with chlorophyll content, peduncle length, 1000 grain weight and grain yield (r_r = 0.149, 0.296, 0.294, 0.219, respectively). Pireivatlou *et al.* (2011) reported that grain filling rate was correlated with grain weight and grain number per spike in the irrigated and drought stressed environments. Furthermore, positive correlations between grain filling rate and grain yield were obtained in the irrigated and drought stressed environments. They have also reported that the accumulation of pre-anthesis assimilates (mainly under drought stress), short effective grain filling period and high grain filling rate were the major factors for producing higher grain yield in wheat under both irrigated and drought stress conditions. Mojaddam and Lack (2012) suggested that grain filling rate and grain filling period were two main factors affecting grain weight, which was the most important component of grain yield.

Under rainfed conditions, canopy temperature had significant negative correlation with stomatal density, grain number per spike and 1000 grain weight (r_r = -0.196, -0.232, -0.186, respectively). While canopy temperature had non-significant correlation with grain yield under irrigated conditions. Similar finding was also reported by Olivares-Villegas *et al.* (2007). They suggested that canopy temperature measured under irrigated was not associated with yield but under drought condition it had significant negative correlation with yield. Chlorophyll content was observed to be associated positively with relative water content (r_i = 0.181) and grains number per spike (r_i= 0.282) under irrigated conditions. In rainfed conditions, chlorophyll content had positive correlation with relative water content (r_r = 0.288), stomatal density (r_r = 0.180) and grains number per spike (r_r = 0.204).

A significant and positive correlation of peduncle length with grain filling period (r_i = 0.710), grains number per spike (r_i = 0.195) and 1000 grain weight (r_i = 0.315) was observed under irrigated conditions. In rainfed conditions, peduncle length showed significant positive correlation with grain filling period (r_r = 0.519), mobilized water soluble carbohydrates (r_r = 0.179), grains number per spike (r_r = 0.202), 1000 grain weight (r_r = 0.353) and grain yield (r_r = 0.267). Bogale *et al* (2011) reported a strong positive correlation among peduncle length, 1000 grain weight and grain yield and suggested that the peduncle length was an indirect selection criterion in wheat under drought conditions. It might suggest that maximum peduncle length had more carbohydrates reserve during pre-anthesis stage and it remobilizes during grain filling period under harsh environments or drought stress conditions. Prior to anthesis carbohydrates accumulated in peduncle and second internodes which help in contribution to grain filling.

Under irrigated conditions, relative water content showed significant positive correlation with chlorophyll content (r_i = 0.181) and grains number per spike (r_i = 0.150). In case of rainfed environment, RWC showed significant positive correlation with chlorophyll content (r_r = 0.288) and grains number per spike (r_r = 0.190). Shamsi (2010) reported highly significant correlation of RWC with grain number and chlorophyll content.

Under irrigated conditions, stomatal density showed non-significant correlation with all the traits except grain filling period. However, in case of rainfed conditions, stomatal density had significant positive correlation with chlorophyll content and number of grains spike^{-1} (r_r = 0.180 and 0.204, respectively) and had negative correlation with canopy temperature (r_r = -0196). Similar results were also

Table 4. Correlation among various physio-biochemical and yield components traits in RILs under irrigated and rainfed conditions

Irrigated											
Trait	GFP	CTA	CCI	PL	RWC	STD	MWSC	GN	TGW	GY	HI
GFP	1										
CTA	0.002	1									
CCI	0.060	-0.037	1								
PL	0.228**	0.053	0.063	1							
RWC	0.131	-0.024	0.181*	0.082	1						
STD	0.155*	-0.140	0.006	0.022	0.102	1					
MWSC	0.212**	0.005	-0.033	0.136	0.025	-0.082	1				
GN	-0.004	-0.154*	0.282**	0.195**	0.150*	0.095	0.117	1			
TGW	0.238**	0.004	0.045	0.315**	0.071	0.076	0.381**	0.286**	1		
GY	0.193*	-0.092	-0.029	0.088	0.059	0.071	0.203**	0.273**	0.498**	1	
HI	0.120	-0.066	0.109	0.053	0.147	0.120	0.102	0.284**	0.293**	0.451**	1
Rainfed											
Trait	GFP	CTA	CCI	PL	RWC	STD	MWSC	GN	TGW	GY	HI
GFP	1										
CTA	-0.058	1									
CCI	0.149*	-0.094	1								
PL	0.296**	-0.052	0.074	1							
RWC	-0.026	-0.089	0.228**	0.036	1						
STD	0.088	-0.196**	0.180*	0.048	0.110	1					
MWSC	0.135	0.040	0.065	0.179*	0.013	-0.024	1				
GN	-0.042	-0.232**	0.204**	0.202**	0.190*	0.231**	0.121	1			
TGW	0.294**	-0.186*	0.122	0.353**	0.116	0.025	0.331**	0.258**	1		
GY	0.219**	-0.132	0.012	0.267**	0.028	-0.045	0.186*	0.205**	0.457**	1	
HI	0.112	-0.080	0.023	0.022	-0.100	-0.132	0.024	0.216**	0.270**	0.608**	1

** and * indicates significant at 1% and 5% probability level, respectively
See Table 1 for foot note

reported by Ahmadi and Siosemardeh (2005).

Under irrigated conditions, water soluble carbohydrates showed significant positive correlation with grain filling period, 1000 grain weight and grain yield (r_i = 0.212, 0.381, 0.203, 0.176, respectively). However, under rainfed conditions, water soluble carbohydrates among entries had significant positive correlation with peduncle length, 1000 grain weight and grain yield (r_r = 0.179, 0.331, 0.186, respectively).

Thousand grain weight had significant positive correlation with grain filling period (r_i = 0.238), peduncle length (r_i= 0.315), mobilized water soluble carbohydrates (r_i = 0.381), grain number (r_i = 0.286), grain yield (r_i = 0.498) and harvest index (r_i = 0.293) under irrigated conditions. In rainfed conditions, thousand grain weight was found significantly correlated with grain filling period peduncle length, water soluble carbohydrates, number of grains per spike, grain yield and harvest index, and had negative correlation with canopy temperature. Munir *et al.* (2006) observed that grain filling period, grains per spike and 1000-grain weight were positively correlated with grain yield under rainfed environment.

Grain yield had a significant positive correlation with grain filling period (r_i = 0.193), mobilized water soluble carbohydrates (r_i = 0.203), grain number (r_i = 0.273), 1000 grain weight (r_i = 0.498) and harvest index (r_i = 0.451) under irrigated conditions. Under rainfed environment, grain yield had positive significant correlations with grain filling period), peduncle length, mobilized water soluble carbohydrates, grain number, 1000 grain weight and harvest index. The correlation coefficient between grain number and grain yield was significantly positive indicating that increase in grains per spike will also have a better influence on grain yield (Aycicek and Yildirim, 2006). It is concluded that the traits related with 1000 grain weight and grain yield can be important for the evaluation and improvement of wheat cultivars under drought stress. The grain filling period, peduncle length, mobilized water soluble carbohydrates, grains per spike and 1000 grain weight showed strong positive correlation and canopy temperature showed negative correlation with grain yield under rainfed environment. These traits may be considered as effective selection criteria for drought tolerance in wheat cultivars.

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Organic Paddy Cultivation in Haryana: Constraints Analysis

Rajesh Bhatia, S. K. Mehta, A. K. Godara, V. P. Mehta and B. S. Ghanghas
Department of Extension Education
Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004, India
E-mail: rajesh.bhatia68@gmail.com

Abstract: Organic farming is recognized as the best known alternative to the modern/conventional agriculture. It also encourages ecosystem service which sustains agricultural productivity and resilience and advocates production intensification through ecosystem management. The organic paddy farmers face both multiple opportunities and complex challenges. Lack of agencies to purchase organic paddy, lack of timely and appropriate transfer of organic paddy growing practices, low premium prices for organic paddy and dependence/interference of middleman for disposal were the major constraints faced by the organic paddy farmers.

Key Words: Adoption, Constraints, Knowledge, Organic paddy cultivation

Green revolution technologies involving greater use of synthetic agrochemicals such as fertilizers and pesticides with adoption of nutrient-responsive, high-yielding varieties of crops have boosted the production output per hectare, but available evidences proved that those gains from the green revolution are being eroded and now facing a serious ecological threat (Yadav and Rai, 2001). Moreover, the success of industrial agriculture and the green revolution has masked significant externalities, affecting natural resources and human health as well as agriculture itself. Increasing consciousness about conservation of environment as well as of health hazards caused by agrochemicals has brought a major shift in consumer preference towards food quality. Declining soil fertility, organic matter loss, land degradation, declining/rising water table, increasing nitrate content in ground water and hazardous residual content in food and fodder chain appeared to be important factors. Gravity of the situation has forced the farmers and professional associations in the state to turn towards organic farming. A number of private companies, non government organization (NGO) and professional associations are working for the promotion of organic farming in the state. As a result a small number of farmers have converted and started organic farming successfully (Markanday, 2000).

The entire agricultural community is trying to find out an alternative sustainable farming system, which is ecologically sound, economically and socially acceptable. Organic agriculture is unifying concept, which considers ecological, environmental, philosophical, ethical and social impacts, balanced with cost effectiveness. Organic agriculture is in harmony with the farmers' traditional customs, practices and beliefs. Organic farming systems have attracted increasing attention over the last one decade because they are perceived to offer some solutions to the problems currently besetting the agricultural sector. However, to make organic agriculture remunerative, the problems/constraints in adoption of organic paddy cultivation need to be addressed.

MATERIAL AND METHODS

Three districts viz., Kaithal, Karnal and Kurukshetra were also purposively selected since these districts have maximum area as well as production of rice. Siwan, Karnal and Pehowa blocks were randomly selected from these districts, respectively. From each selected block two villages Siwan and Kangthali from Siwan, Kachchwa and Kunjpura from Karnal, Seonsar and Kamoda from the Pehowa blocks were selected randomly. Further, from each selected village, 25 organic paddy farmers were selected randomly and in this way a total number of 150 respondents were interviewed to ascertain the constraints faced by them in organic paddy cultivation. The data were collected a well-structured pretested interview schedule. The respondents were asked to state the constraints faced by them in organic paddy growing. Frequencies of the constraints were measured with the help of three point continuum as 'very serious', 'serious' and 'not so serious' responses and the scores were given as 3, 2 and 1, respectively. The frequency in each response category was multiplied with the score assigned to that category and then the scores were added up and divided by total number of respondents to arrive at mean weighted score of a constraint and accordingly rank order was assigned to each constraint, respectively.

RESULTS AND DISCUSSION

Economic constraints: Less premium prices for organic paddy ranked first with a weighted mean score of 2.45. Further elaboration indicated that 59.33 per cent farmers perceived it as a very serious constraint and 26.67 per cent as a serious constraint and rest 14.00 percent perceived it not so serious in the adoption of organic paddy cultivation. The main motivations described as opportunity to access was premium prices (Sadati *et al.,* 2010), prices have an important influence on the financial performance of organic agriculture (Pattanapant and Shivakoti, 2009; Setboonsarng *et al.,* 2008). The most important aspect influencing farmers' decision to become organic rice farmer was the higher price they were paid. However, the findings of Pimentel *et al.* (2005) are in contradiction, they confirmed that organic rice fetch price premium (10 to 20% higher). This has generated a high income for the participating farmers. Chouichom and Yamao (2010) mentioned that differences in market prices do not vary greatly between organic and conventional rice. Lack of subsidy or incentives by government to motivate organic paddy farmers ranked second followed by no minimum support price for organic paddy ranked third with 2.30 and 2.25 as a weighted mean score. Badodiya *et al*. (2011) also confirmed that poor financial condition and non-availability of loans in time were most serious problems. Substantial financial support by the governments is absolutely necessary to promote organic farming. Saha and Bahal (2012) favoured that support services such as credit to diversifying farmers through appropriate changes in policies and delivery mechanisms should be ensured for sustainable development. Sorensen *et al.* (2005) justified that adoption of organic rice practice is involved with production condition. These findings are in contrary to Sadati *et al.* (2010), interesting finding of their study was that none of the farmers had received any loan for organic farming. Further lack of local bulk demand for organic paddy and lack/poor cooperative societies at local level were also perceived as major constraints with weighted mean score of 2.15 and 2.14 and ranked 4th and 5th. The findings get support from Wheeler (2007) who observed that technical information can be obtained from cooperatives, unions and other organisations in addition to extension agents. The last ranked constraint among six economic constraints was that farmers have no access for direct exports of organic paddy with a weighted mean score of 1.95. The detailed analysis of this constraint revealed that less than one third (28.00%) farmers marked it

Table 1. Farmers' perception about economic and marketing constraints (n =150)

Constraints	Constraint frequency			Total weighted score	Mean weighted score	Rank
	Very serious (%)	Serious (%)	Not so serious (%)			
		Economic constraints				
Low premium prices for organic paddy.	89 (59.33)	40 (26.67)	21 (14.00)	368	2.45	I
Lack of subsidy or incentives by government to motivate organic paddy farmers	78 (52.00)	39 (26.00)	33 (22.00)	345	2.30	II
No minimum support price for organic paddy	60 (40.00)	68 (45.33)	22 (14.67)	338	2.25	III
Lack of bulk local demand for organic paddy	61 (40.67)	50 (33.33)	39 (26.00)	322	2.15	IV
Poor cooperative societies at local level	58 (38.67)	55 (36.67)	37 (24.67)	321	2.14	V
Farmers have no access for direct exports of organic paddy	42 (28.00)	58 (38.67)	50 (33.33)	292	1.95	VI
		Marketing constraints				
Lack of agencies to purchase organic paddy	113 (75.33)	37 (24.67)	0	413	2.75	I
Dependence/interference of middleman for disposal	88 (58.67)	38 (25.33)	24 (16.00)	364	2.43	II
Lack of marketing news	77 (51.33)	48 (32.00)	25 (16.67)	352	2.35	III
Poor communication channels	69 (46.00)	43 (28.67)	38 (25.33)	331	2.21	IV
Purchase agencies at long distance	65 (43.33)	48 (32.00)	37 (24.67)	328	2.19	V
Lack of storage facilities	55 (36.67)	48 (32.00)	47 (31.33)	308	2.05	VI
More transportation charges	30 (20.00)	41 (27.33)	79 (52.67)	251	1.67	VII

as a very serious, 38.67 per cent as a serious and rest one-third of organic paddy growers as not so serious. Organic paddy cultivation is most suitable for basmati paddy which is most fesible for export. Organic food concept is flourishing among high economic classes of the world.

Since scanty information is available for organic food market in India and the consumers' attitude towards these products. Mostly the organic foods in our country are produced targeting the export markets of developed world. Along with the increase in production, marketing of the organic products, awareness level of the consumer ultimately influences the price premium for the organic produce. Study of the behaviour of the consumers towards the organic product is one of the important aspects for the future of the organic practices in agriculture. Consumers may not know whether a product is produced using organic or conventional methods, not even after repeated purchase and consumption, unless they are told so. If an individual cannot clearly differentiate between two alternative products, a price premium on the organic product can confuse and/or affects the individual purchase decision, in favour of the cheaper product. However, the domestic market of the organic product in India is at the budding stage, but recently demand for organic foods in domestic market of India is also showing upward trend. Thus organic producers bring their crop to the conventional market and cannot sell to the organic exporting companies, who often have a rather low demand and high quality-requirements (Bacon, 2005; Valkila, 2009).

Marketing constraints: The major marketing constraints encountered by the respondents were lack of agencies to purchase organic paddy, dependence/interference of middleman for disposal and lack of marketing news with a weighted mean score of 2.75, 2.43 and 2.35 and ranked first, second and third, respectively. The exploration of first constraint revealed that three-fourth (75.33%) organic paddy farmers perceived it as a very serious. The 4^{th} and 5^{th} constraints were poor communication channels and purchase agencies at long distance with a weighted mean score i.e. 2.21 and 2.19, respectively. Similarly inadequate marketing networks and no separate market for organic produces and weak marketing network/sale point (Baker, 2012) were the findings in resemblance to the present study. Market development for the organic products is a crucial factor to promote domestic sales. There is a huge demand for organic products by the supermarkets and lack of marketing skill and communication may deter the small farmers from approaching these outlets. Farmer associations and marketing contracts through them could enable them to secure better prices. Moreover, contract farming may also provide access to advisory services. Public-private partnerships could facilitate the transition of farmers without heavy reliance on the government. Farmers neither have the means to grow the organic rice, nor equipped with the proper market channels to process and sell the organic rice on the international market. Contract farming might facilitate price information from the international market to farmers, provide access to the new market through market links, and provide credits for new inputs as well as technical assistance essentially made the transition to organic rice possible (Paull, 2009), ultimately it is expected to reduce the risk for both parties as the farmers will get a reliable buyer and market for their product and the contract farming firm will be guaranteed the supply of the demanded crop. Singh and Varshney (2010) reported that due to the absence of regulated market at village level, farmers sell their produce to middle men and get lower price for their produce and Tewatia and Tanwar (2008) reported lack of suitable marketing and distribution network. Lack of storage facilities and more transportation charges were the sixth and seventh ranked constraints with a weighted mean score of 2.05 and 1.67, respectively. Further narration of last constraint i.e. more transportation charge showed that only 20.00 per cent respondents perceived it as a very serious while more than half of the organic paddy farmers (52.67%) took it as not so serious. Improper storage resulting to deterioration of quality (Tewatia and Tanwar, 2008) and separate transportation of organic products to avoid mixing with conventional products (Kennvidy, 2008) are another area of concern.

Technology transfer related constraints: The farmers' perception about constraints regarding technology transfer depicted that lack of timely and appropriate transfer of organic paddy cultivation practices by extension organizations, department of agriculture and private agencies was ranked first with weighted mean score of 2.50. Further it narrated that 59.33 per cent of farmers had perceived it as a very serious constraint followed by nearly one-third (31.33%) of them perceived it as a serious constraint whereas, only one-tenth (9.33%) perceived as not serious. The findings are in conformity with weak extension activities at village level (Singh and Varshney, 2010), lack of government support (Prasad *et al*., 2013), lack of proper training at grass root level (Soni *et al*., 2012). Kumar and Prasad (2008) also opined similarly that extension personnel can play an important role in making farmers aware about organic farming. The respondents reported that the personnel of the state department of agriculture were not taking adequate efforts to create awareness regarding benefits given by the government to boost organic paddy cultivation. The second ranked constraints was lack of co-ordination between various service, supply and marketing

Table 2. Farmers' perception about technology transfer and miscellaneous constraints (n=150)

Constraints	Constraint frequency			Total weighted score	Mean weighted score	Rank
	Very serious (%)	Serious (%)	Not so serious (%)			
			Technology transfer related constraints			
Lack of timely and appropriate transfer of organic paddy cultivation practices	89 (59.33)	47 (31.33)	14 (9.33)	375	2.50	I
Lack of co-ordination between various service, supply and marketing agencies/organic promoting organizations.	73 (48.67)	51 (34.00)	26 (17.33)	347	2.31	II
Lack of dedicated and competent extension personnel	69 (46.00)	56 (37.33)	25 (16.67)	344	2.29	III
Lack of published information	59 (39.33)	47 (31.33)	44 (29.33)	315	2.10	IV
			Miscellaneous constraints			
Lack of proper guidance and training on organic paddy practices	69 (46.00)	54 (36.00)	27 (18.00)	342	2.28	I
Irregular visit of agriculture officers	57 (38.00)	54 (36.00)	39 (26.00)	318	2.12	II
Lack of risk ability	47 (31.33)	51 (34.00)	52 (34.67)	295	1.97	III
Lack of testing facilities (soil and water)	42 (28.00)	55 (36.67)	53 (35.33)	289	1.93	IV

agencies/organic promoting organizations with a weighted mean score of 2.31. Further analysis indicated that nearly half population of respondents (48.67%) had perceived it as a very serious. Baker (2012) pointed the lack of coordination among different organic production agencies/firms, one of the major constraints. NGOs always may not have the necessary business skills to succeed in marketing, under such situations, collaborations between NGOs and governments may be effective. The government can be criticised for lack of co-ordination and co-operation with the well organised NGOs (Kennvidy, 2008). Lack of dedicated and competent extension personnel for organic paddy promotion was ranked third with weighted mean score 2.29, further analysis of which indicated that 46.00 percent of farmers had perceived it as a very serious in the adoption of organic paddy cultivation. Baker (2012) expressed the need of competent extension personnel. Pattanapant and Shivakoti (2009) observed that many extension officers still believed in the conventional agriculture, and that such officers continued to promote the application of chemicals. Lack of published information regarding various practices of organic paddy cultivation was ranked fourth with a mean score of 2.10 and about two-fifth of the farmers (39.33%) perceived it as a very serious whereas, nearly one-third perceived it as a serious (31.33%). The findings of the study are in conformity with non-availability of relevant and appropriate literature (Slathia *et al*., 2013; Soni *et al*., 2012). Makwan and Trivedi (2011) reported that agricultural scientists play catalyst role for the transmission of innovative farm information and create interest and stimulate the farmers for modern agriculture.

Miscellaneous constraints: The major constraints found were lack of proper guidance and training on organic paddy practices and irregular visit of agriculture officers ranking first and second with weighted mean score of 2.28 and 2.12, respectively. Further analysis indicated that 46.00 per cent and 38.00 per cent of farmers perceived first constraint and second constraint as a very serious constraint. Thirty six per cent farmers perceived both constraints as serious, rest 18.00 per cent and 26.00 per cent of farmers perceived first and second constraint as a not so serious. Kumar and Prasad (2008) also opined similarly that extension personnel can play an important role in making farmers aware about organic farming. The respondents reported that the personnel of the state department of agriculture were not taking adequate efforts to create awareness regarding benefits given by the government to boost organic paddy growing. Soni *et al.* (2012) concluded lack of proper training. Singh and Varshney (2010) also mentioned lack of information supply and services offered by the state and central governments was the institutional constraint. Lack of risk ability and lack of testing facilities (soil and water) ranked third and fourth with mean score of 1.97 and 1.93. Further analysis of fourth constraints showed that 28.00, 36.67 and 35.33% of organic paddy growers perceived last constraint lack of testing facilities (soil and water) as a very serious, serious and not so serious.

CONCLUSION

On the basis of above discussion regarding constraints in organic paddy cultivation, it may be concluded that inadequate attention and efforts by various organizations for the promotion of organic paddy growing were the main constraints. Sincere efforts should be made by the extension personnel to motivate the farmers to adopt organic paddy cultivation practices to minimize ill effects of chemicals. Any movement for the promotion of organic farming in Haryana will have to counter opposition from the sections who benefit from policies in the conventional farming system. Agriculture department should publish and distribute relevant and practical information among the farmers. Government should announce separate support price to the organic paddy to enhance their profits, and shifting to organic paddy, as consumers are willing to pay a premium price for organic products. Demand for organic food among high gentry and health conscious consumers' in India is increasing. The establishment of organic input marketing channels is necessary to encourage nascent organic farming in India.

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Crop Residue Management – A Sustainable Way to Control Weeds in Rice

Chandrima Shyam and Simerjeet Kaur

Department of Agronomy, Punjab Agricultural University, Ludhiana- 141 004, India
E-mail: chandrima.shines@gmail.com

***Abstract*:** Literature has been critically reviewed for crop residue management through residue incorporation, mulching and burning for controlling weeds in rice. The incorporation of allelopathic residues such as that of rice, wheat, sorghum and sunflower significantly control weeds. Mulching with residues also suppress weeds through physical hindrance, allelopathy and inhibition of light penetration. Burning reduce weeds because of high temperature produced on the soil surface but also caused environmental pollution and hampered nutrient recycling.

Key Words: Rice, Residue-incorporation, Residue-mulching, Residue-burning

Retention of crop residues is an important aspect of conservation agriculture. Conservation agriculture is a resource saving agricultural practice which goals higher yields while optimizing natural resources (Abrol and Sangar, 2006). The three interrelated pillars of conservation agriculture are direct planting, permanent soil cover and crop rotation (FAO, 2015). Conservation agriculture is superior over traditional agricultural practices as it leads to higher soil fertility, higher water infiltration in soil, reduced wind and water erosion, lower cultivation cost and reduced environmental hazard. Various conservation agriculture practices comprise crop residue management through soil incorporation, mulching etc., zero tillage, reduced tillage, crop rotation especially with fertility enhancing crops such as legumes etc. This paper reviewed the weed management aspect in rice through proper crop residue management.

Crop residue status in India: According to MNRE (2009), annual crop residue generation in India is about 500 Mt. Out of this huge amount, cereals comprise the largest share i.e., 372 Mt, followed by fibres (66 Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt). Thus, the cereals (rice, wheat, maize, minor millets etc.) contribute 70 per cent out of which rice comprises 34 per cent and wheat 22 per cent. The fibre crops (cotton, jute, mesta, etc.) comprise 13 per cent of total residues and the largest share is of cotton residues (11%). Pathak (2004) reported annual crop residue production to be 523 Mt in India out of which 127 Mt is surplus. Fate of these crop residues differ according to the prevailing situations; however in India mostly these are burnt. About 93 Mt of crop residues are burnt annually in India (Pathak *et al.,* 2010).On-farm burning of crop residues are practiced by farmers for a large number of reasons such as reduced number of livestocks, labour shortage and lack of awareness. Increased mechanization is another factor behind increased burning of crop residues. Though combine harvesters can ease up the process of harvesting, yet around 80 per cent of the crop residues are left in field, which are finally burnt by the farmers (IARI, 2012). A very little percentage of these residues are being used nowadays for incorporation in soil and mulch purpose.

Status of yield loss in rice due to weeds: Rice is the most important cereal crop in India, which was grown over an acreage of 43.95 mha with a production of 106.54 mt during 2013-14 (Anonymous 2014) .Weeds are considered to be the major biotic stress in rice cultivation. Though the rice cultivation techniques vary depending on the methods of rice seedling establishment, weeds are problematic in all methods. Comparing the seeding methods, rice yield loss due to weeds was found to be least in transplanted rice (Singh *et al.,* 2011) and highest in aerobic direct seeded rice on a furrow-irrigated raised-bed systems (Singh *et al.,* 2008) along with in dry-seeded rice sown without tillage (Singh *et al.,* 2011). Azmi and Baki (1995) estimated the yield loss caused by grasses (mainly *E. crus-galli*), broadleaved weeds and sedges was 41, 28 and 10 per cent, respectively in rice. Babar and Velayutham (2012) reported that in SRI too weeds causes 69.15 per cent yield. Haden *et al.* (2007) attributed weed infestation to be the major problem in SRI. Wayayok *et al.* (2014) enlisted the factors associated behind such loss as alternate wetting and drying of the field (Krupnik *et al.,* 2012), wider planting geometry of single seedling (25x25cm or 50x50 cm) and aerobic or moist environment (Singh *et al.,* 2012). Pillai *et al.* (1976) reported that weeds can cause loss of 93 kg N, 25 kg P and 90 kg K ha^{-1}. Apart from loss of macro-nutrients, micro-nutrients such as Fe (2.5 kg ha^{-1}), Zn (61g ha^{-1}), Cu (15 g ha^{-1}) and Mn (168g ha^{-1}) are also lost due to weed infestation (Pandey and Thakur, 1988).

Residue management based weed control strategies: Nowadays the mostly followed weed control strategy in rice includes use of chemical herbicides which involve risk of serious environmental hazards (Chung *et al.,* 2001). Not only environmental pollution (Abdin *et al*., 2000), sometimes over use of these herbicides can cause increased human exposure to harmful toxic materials (Zimdhal, 2004). Other than this threat to environmental safety, continuous use and also over use of herbicides lead to problems such as weed flora shift, herbicide resistance, evolution of super weeds, soil toxicity, etc. Biological weed control methods for cereals like rice are not yet available to farmers. Mechanical and physical weed management techniques are safe to environment but with the growing problem of labour scarcity, there is a need to opt for alternatives such as crop residue management for controlling weeds in rice. Putnam and Duke. (1974) first stated about controlling weeds using allelopathic crop residues. Crop residue management influences weed count due to their influence on weed seed germination by altering top soil temperature, moisture, releasing allelochemicals (Chung *et al.,* 2003) and by controlling weed seed distribution in soil profile (Froud-William, 1988). Apart from the weed control aspect other benefits include decreased cost of cultivation, increased soil fertility and improved soil tilth resulting higher crop yields. The different methods of crop residue management with respect to weed management include residue incorporation, residue mulching and residue burning.

Residue incorporation: Crop residue incorporation involves mixing or blending crop residue with 0-15 cm top soil layer. Incorporation of allelopathic plant materials in rice field can significantly reduce weed problem (Xuan *et al.,* 2005). These plant materials once incorporated undergo decomposition and produce a series of phytotoxins which cause harm to weeds (Nelson, 1996). Gallandt *et al*. (1999) stated that incorporation of residues affect weed dynamics by affecting weed germination and establishment and this can significantly reduce the density of the weed community in soil. Pheng *et al*. (2010) reported that there may be cases of auto-toxicity due to incorporation of allelopathic crop residues, such as rice but these can be avoided by delaying incorporation for about two weeks. Crop residue incorporation has been successfully used to manage weeds in rice (Khaliq *et al*., 2011a; Mahato *et al*., 2014), wheat (Brar and Walia, 2010; Khaliq *et al*., 2013), maize (Zaji and Majid, 2011), soybean (Dadkhah, 2015), etc. Cover crop residue incorporation before solarization can also lead to significant weed suppression. Besides weed control other benefits of residue incorporation include carbon sequestration (Lal and Stewart, 2010), addition of biomass, nutrient recycling, improved saturated hydraulic conductivity, increased soil infiltration, decreased bulk density thus improving soil structure and soil biological properties.

Residue mulching: Residue mulching is residue retention over soil on the surface which can be done before or after the crop is sown. Covering or mulching the soil surface using crop residues can reduce weed problems (Buhler *et al.,* 1996) by preventing weed seed germination or by suppressing the growth of emerging weed seedlings (Chauhan *et al.,* 2006; Chauhan and Abhogo, 2013b). This weed growth inhibition by mulches is attributed to the release of allelo-chemicals (Chung *et al*., 2001; 2003), changes in soil temperature (Hu *et al*., 1995) and physical barrier due to mechanical hindrance (Teasdale and Mohler, 1993; Rahman *et al.,* 2005). Mulches get heated up very easily due to their low heat conductance and kill the weeds due to the elevated soil temperature. Germinated weeds find it difficult to penetrate the barrier posed by mulches. Ossom *et al*. (2001) reported that mulches prevent penetration of light and exclude definite wavelength of light that is needed for weed seed germination. Mulches also inhibit photosynthesis by prevent light penetration. With increase in amount of residue cover weed emergence and growth decreases (Ranaivason *et al.,* 2015). Utilizing differential tillage techniques to remove residue over crop rows, different residue effects to crops and weeds can be obtained giving advantage to the crop. Effects of residue mulching on weeds has been studied in crops such as rice (Devasinghe *et al.,* 2011; Wayayok *et al.,* 2014), wheat (Chaudhary and Iqbal, 2011), maize (Cheema *et al*., 2004; Ali *et al*., 2011; Sarajuoghi *et al*., 2012), etc. Residue mulching also helps in conserving soil moisture, moderating soil temperature, improving beneficial soil microbe status and adding biomass after decomposition.

Residue burning: Burning is sometimes considered as an economical method to control weeds. Burning of residues is often useful for killing unwanted vegetation, destroying dry aboveground top of weeds, kill green-weeds and also for destroying underground weed seed bank and buried vegetative propagating structures such as rhizomes. Viable weed seeds present on the surface soil are killed by residue burning (Singh *et al.,* 2005), due to the production of high temperature for a prolonged period over the soil surface over a particular stratum of soil. However, this burning may also sometimes lead to emergence of weeds such as wild oats (Chitty and Walsh, 2003). Richard *et al.* (2001) and Roder *et al*. (1995) concluded that burning of crop residues and fallow vegetation can be effectively used as a weed management tool. But, residue burning can lead to decreased herbicide efficacy due to increase in ash content in soil which makes its adsorption potential higher (Singh *et al.,* 2005). However, rice burning leads to serious problems viz., emissions of harmful green-house gases such as methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), nitrous oxide (N_2O), reducing beneficial microbe population and destroying soil physical properties (IARI, 2012). For example, burning of 1kg straw produces upto 1.46 kg CO_2 (Singh *et al*., 2013). Burning also causes nutrient loss from residues and harms human health (Chauhan *et al.,* 2012). Few crop residue management studies in rice for controlling weeds are given below:

Table 1. Effect of different crop residues on weeds in rice

Residue management techniques	Types of residue	Dose of residue	Weed control	References
Incorporation	Rice	4-5 t ha^{-1}	Reduced weed germination by 27%, density by 32% and dry weight by 41%	Wathugala and Ranagalage (2015); Singh and Guru (2011)
	Wheat	8 t ha^{-1}	Suppressed weed density by 45%	Khaliq *et al.* (2011b)
	Sorghum	8-12 t ha^{-1}	Suppressed weed density by 54% and dry matter by 51% and Reduced *Echinochloa colona* germination by 14%	Khaliq *et al.* (2011a, b)
	Sorghum with other residues combined (brassica/ sunflower/ brassica+sunflower)	12 t ha^{-1}	Reduced *Echinochloa colona* germination by 7-12%	Khaliq *et al.* (2011a)
	Brassica	12 t ha^{-1}	Reduced *Echinochloa colona* germination by 17%	Khaliq *et al.* (2011a)
	Brassica with other residues combined (Sunflower/ Sorghum)	12 t ha^{-1}	Reduced *Echinochloa colona* germination by 12-17%	Khaliq *et al.* (2011a)
	Sunflower	8-12 t ha^{-1}	Suppressed weed density by 51%, dry matter by 45% and *Echinochloa colona* germination by 18%	Khaliq *et al.* 2011a,b)
	Sunflower with brassica	12 t ha^{-1}	Reduced *Echinochloa colona* germination by 17%	Khaliq *et al.* (2011a)
	Lantana camera	3 t ha^{-1}	Reduced weed count by 23%	Mahato *et al.* (2014)
	Goose weed	3 t ha^{-1}	Reduced weed count by 34%	Mahato *et al.,* (2014)
	Ariach	3 t ha^{-1}	Reduced weed count by 24%	Mahato *et al.,* 2014
	Brassica kaber	3 t ha^{-1}	Reduced weed count by 23%	Mahato *et al.* (2014)
Mulching	Rice	4-6 t ha^{-1}	Weed density reduced by 25 -98.3% and weed dry matter by 33-98.4%; Time taken to reach 50% maximum emergence increased in *Amaranthus spinosus* and *Leptochloa chinensis*	Wayayok *et al.* (2014); Devasinghe *et al.* (2011); Chauhan and Abhugo (2013a, b)
	Wheat	4-7.5 t ha^{-1}	Weed density decreased by 48-85% and weed dry matter by 52-92%	Singh *et al.* (2007); Mohtisham *et al.* (2013); Khaliq *et al.* (2015); Gaire *et al.* (2013); Towa *et al.* (2013)
	Sorghum	6 t ha^{-1}	Weed density decreased and weed biomass by 45-58%	Mubeen *et al.* (2014)
	Sugarcane	5 t ha^{-1}	Weed density decreased by 33%	Mohtisham *et al.* (2013)
	Maize alone	5 t ha^{-1}	Weed density decreased by 51%	Mohtisham *et al.* (2013)
	Maize with Dolichos	4.79 t ha^{-1}	Weed growth decreased by 70%	Ranaivoson *et al.* (2015)
	Stylosanthes	3.2 t ha^{-1}	Weed growth decreased by 70%	Ranaivoson *et al.* (2015)
	Eupatorium	5 t ha^{-1}	Weed density reduced by 18-90% and weed dry matter by 52-95%	Gaire *et al.* (2013)
Burning	Wheat	-	Weed density and weed dry matter decreased by 26%	Khaliq *et al.* (2015)

CONCLUSION

Crop residue management can be a sustainable technique of controlling weeds in rice. Both incorporation and mulching provide good control of weeds in rice. Burning of residues may cause temporary reduction in weed but it causes harm both to the environment and soil. Raising awareness among farmers regarding weed management aspect of crop residues in rice is very important.

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Use of EST-SSR and RGA Markers in Molecular Analysis of Segregating Populations of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] Derived from Intervarital Crossing

Bhagwat Singh, G. S. Dahiya and N. R. Yadav

Department of Genetics and Plant Breeding
Chaudhary Charan Singh Haryana Agricultural University, Hisar -125 004, India
E-mail: bhagwat237@gmail.com

Abstract: Forty segregating F_2 derived F_3 plants along with their parents (HG75×Pusa Nav Bahar) were selected for molecular marker analysis using 30 EST-SSR and 5 RGA markers. All the RGA and 19 EST-SSR markers were polymorphic in molecular analysis, showing different allele sizes in parents and population. Diversity analysis using all polymorphic markers suggested that all the genotypes formed two different groups at a similarity coefficient 0.48. The similarity coefficient of major cluster ranged from 0.48 to 0.97. Cluster as well as PCA analysis clearly indicated that the F3 population were scattered between both parents.

***Key Words*:** Cluster bean, EST-SSR, Molecular analysis, RGA marker

Clusterbean is believed to be originated in Africa but it is grown throughout the Southern Asia since ancient times as a vegetable and fodder crop. It is widely cultivated in countries like India, Pakistan, USA, Morocco, Italy, Germany, Greece, and Spain and is thus considered as a new crop for western agricultural practices. Clusterbean is an upright, bushy, drought hardy, deep rooted crop and assumed to be highly adapted to poor and erratic rains, less care and low input areas (Pabal and Yengokopam, 2013). Being a member of legume family, it has a property to fix atmospheric nitrogen, which improves the soil health and yield of succeeding crops. Due to its drought hardy nature, it can be easily cultivated in arid and semi arid regions.

India is the largest supplier of clusterbean seed in the world contributing 80 per cent of the total production followed by Pakistan and United States (Sharma *et al.,* 2013). Total area under clusterbean production in India is about 2.56 million ha with a production of 0.72 million tones of guar seed. Molecular characterization of plant population can facilitate effective and precise identification of QTLs and tagged genes for BLB resistance. In clusterbean, SSR markers are not developed, however EST database is available. Resistance gene analogs (RGA) and EST-SSR can be ideal markers for targeting BLB resistance. In this study analysis of segregating population and differentiate into different cluster on basis of diversity.

Molecular breeding provide new avenues in improving crop plants, however, no progress has been made for guar improvement due to lack of good genomic recourses. The use of molecular markers can be very useful for the development of improved varieties with quality traits in clusterbean in shorter period and with fewer efforts. Molecular analysis in 40 F_3 progenies along with their parents (HG75×PNB) using EST-SSR and RGA markers was done in present investigation.

MATERIAL AND METHODS

The experiment was conducted at Chaudhary Charan Singh Haryana Agricultural University, Hisar. The analysis was performed on 40 F2 derived F3 line of clusterbean along with their parents (HG75×PNB). The protocol of cetyl trimethyl ammonium bromide (CTAB) DNA extraction method of Saghai-Maroof *et al*. (1984) was used with some modifications. Quality and quantity of DNA was checked by comparing DNA samples with known amount of DNA. The DNA concentration thus estimated and rechecked qualitatively by running on 0.8 per cent Agarose gel. Part of DNA samples were diluted with appropriate quantity of TE buffer to yield a working concentration of 50ng/ml and stored at 40C until PCR amplification. The DNA samples were analyzed using primers as given in Table 1 and 2. The reaction was optimized at 50 ng of DNA template, 200 µM of dNTPs mix, 2.5 mM, MgCl2, 0.6 µM of primers and 2 units of Taq DNA Polymerase. The optimized reaction conditions for PCR given in Table 3.

The amplified products were resolved on 8% PAGE. After proper run gel image were recorded in Gel DOC unit under UV light. Bands were scored as present (1) or absent (0). Missing and doubtful cases were scored as (0). Molecular weights of the bands were estimated by using 1kb DNA ladder (MBI, Fermentas, UK) as standards. The data was used for similarity based analysis using the programme

Table 1. EST-SSR primers used in the study

Marker	Forward primer (5'→3')	Reverse primer (5'→3')	Tm (ºC)
CTN03	GTTGGGGAGTTATGATGAGA	TTCCAGTCTTTTTGTCGAGT	49.6
CTN04	GGAGATAGTTGCAAACAAGG	TGCTTGAACAACACTCTTTG	49.3
CTN05	GCCTGCAACAGAAGATAGAC	GACTGAGAAGCTTGGAAATG	50.3
CTN07	TAAACTCATGAAAGGCTCGT	CTTGAATGTGCTTTAGGACC	49.4
CTN09	GTTCTCACTCTTTCCGTGAG	AGTTTCTTCCTGTTTCCCTC	50.5
CTN10	GAGGGAAACAGGAAGAAACT	GTTCAAAGTCCAACTCAAGC	50.0
CTN11	CACAAGCAAGGAAAGCTAAT	AACATTCAGCATCCCACTAC	49.7
CTN12	GCTTCACAGTATCTTCAGGG	TCCATTGGAGGACAGATAAG	50.0
CTN13	TTCCCTACACTAAGGTCGAA	CCATCCGAACTATGAGAAGA	48.9
CTN14	AATGAGCTGCAATTACCAGT	CAATTCGTTAGTGGTTGGAT	49.3
CTN15	TTCTGAGGAAAGCTGAAGAG	CAGGGTATCCCAAGACATTA	49.5
CTN16	GTGAGAGTCAGAAGCCTGTC	GCTACTTGTAATGGTGGTCC	52.0
CTN17	ATACAAGGAAGGGCCTAAAC	CTGAGAAAGAACTTGGTTGG	49.6
CTN18	ATATTCTC CGTGACATCCAG	TTAGGCTACACGTCAAGGTT	50.5
CTN30	TAGGCAGAAGAAGAGAGCTG	GAGCTGTCTCGGCAATATAC	51.3
CTN31	AGGATATGGAATGGGAGTTT	GACTCTGGAATGAAAAGCAG	49.0
CTN32	CTTTGAAACTAACCCTCACG	ACACTGCATTCTATCATCCC	49.6
CTN39	TTAGCTCCCACGAAGAGTAG	CCCATCTATCACCAATCCTA	50.0
CTN40	TAACACCACACTTGTTCCAA	ACTCGTTGTATGCATCCTTT	49.9
GDR1	CTGCTCG CTGCAATTCTTG	GAATTCCTCGATGCTGCCTA	49.4
GDR2	GACGATGGAACCCTTCTGAT	CGTAGTAGCTGGTAGCATGCAG	52.2
GDR3	TTTCCCCTCATCCTTCTTCA	TATCATCGTCCCCATCGTTT	46.7
GDR4	GCCCAAAACTTACCGAGTTG	CAGAACCCCCTCTCACTGAC	51.8
GDR5	TTGCTCTCATTGCCATTGTC	AAATCCCAAGCGTCAATCT	47.7
GDR6	GGCACCGCCATTGTTATTATT	CCAAAATGGACATGTGTTTGG	48.1
GDR7	GACCTTGCCCGAGAATACAT	CTTCCCAGCTTCACCAAGAG	50.8
GDR8	GGAAAAGCGGTGAG AGTG AG	TGCCTTATCTTGGCAAATGTC	50.1
GDR9	CACGAGGCCTGAATCAATCT	TGAGGAACAGGGAGCCTATG	50.8
GDR10	CCCTAAATCAAACGCAACAGA	GG ACGTGG GTG GTGT AACTC	51.1
GDR11	GGTTTACACGCAGGTGGTTT	TTCCACTCGCATTACCCAGT	49.7

Table 2. RGA primers used in the study

Marker	Sequence	Tm (ºC)
RGK07/HD03	GVGGVYTNGGCAARACDAC/AGNCTAARGGGAGGGCC	48
RGK08/HD03	GVGGVTCNGGSAARACDAC/AGNCTAARGGGAGGGCC	48
RGK07/HD04	GVGGVYTNGGCAARACDAC/AGCGCCARCGGGAGGCC	52
RGK08/HD04	GVGGVTCNGGSAARACDAC/AGCGCCARCGGGAGGCC	52
RGK06/HD04	GHGGGATGGGGAARACDAC/AGCGCCARCGGGAGGCC	54

V= A/C/G Y= C/T N=A/C/G/T R=A/G M=A/C W= A/T S= C/G K=G/T H= A/C/T D=A/G/T

Table 3. PCR conditions for EST-SSR analysis in cluster bean

Initial denaturation	94°C for 3 min.
Denaturation	94°C for 1 min.
Annealing	46-52 °C* for 1:50 min.
Extension	72°C for 2 min.
Final Extension	72°C for 10 min.

*Annealing temperature varied with different primers used in PCR

NTSYS-Pc (Version 2.02) developed by Rohlf (1990). Dice's similarity coefficients (F') was calculated using the programme SIMQUAL. Similarity coefficients were used to construct UPGMA (unweighted pair group method with average) to generate Dendrogram.

RESULTS AND DISCUSSION

A total of 19 EST-SSRs (Table 4) and five RGAs primers out of 29 EST-SSRs and 5 RGAs primers showed polymorphism which was used to screen F_3 progenies of clusterbean cross (HG75×PNB) along with their parents with a view to detect polymorphism for gum content and disease resistance (Table 4).

A total of 19 EST-SSR and five5 RGA primers were used for DNA amplification in 40 F_3 progenies and 2 parents to detect polymorphism (Table 5). Amplification was observed in all the genotypes with 100 per cent polymorphism. Allele scoring was done for the obtained EST-SSR and RGA primers in the form of 0/1 matrix which was used to calculate the similarity genetic distance using 'SIMQUAL' sub-programme of NTSYS-PC (version 2.02) software (Numerical Taxonomy and Multivariate Analysis System Programme, Rohlf, 1990). Dendrogram, representing the association among different progenies, was constructed by using distance matrix by the Unweighted Pair-Group Method with Arithmetic Average (UPGMA) (Fig. 1). The dendrogram indicated that 42 clusterbean genotypes

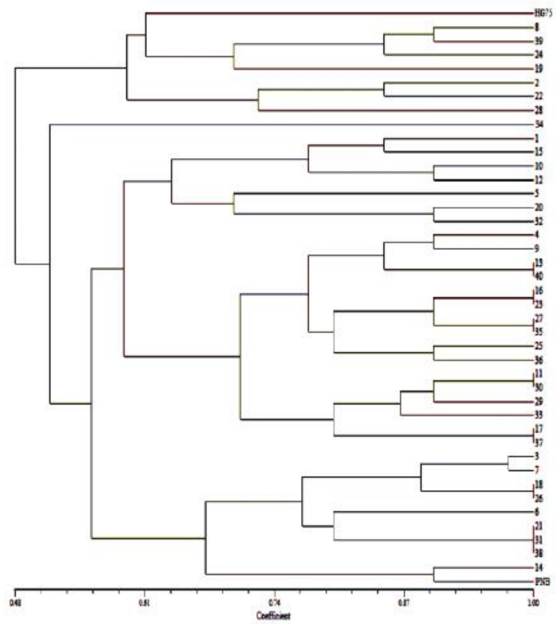

Fig.1. Dendrogram of genetic relationships among 40 progenies and two parents based on 19 EST-SSR and 5 RGA primers

Table 4. Polymorphic EST-SSRs primer, their predicted function and allele size

Primer name	Predicted functions	Allele size (bp)	
		PNB	HG75
GDR1	CDSP32 Protein (Chloroplast Drought-induced Stress Protein of 32kda) (*Solanum tuberosum*)	250	275
GDR2	Chitinase (*Medicago truncatula*)	250	275
GDR3	Fiber Protein Fb2 (*Gossypium barbadense*)	550	~575
GDR4	Grr1 (*Glycine max*)	275	300
GDR6	Pathogenesis-related Protein Bet V I Family (*Glycine max*)	275	300
GDR7	Salt Tolerance Protein 3 (*Beta vulgaris*)	550	575
GDR8	Salt-tolerance Protein (*Glycine max*)	300	275
GDR9	Selenium Binding Protein (*Lotus corniculatus* Var. *japonicus*)	350	375
GDR10	Singnal Transduction SRC2 (*Glycine max*)	250	260
GDR11	Pahsts14 (*Solanum tuberosum*)	250	260
CTN05	Beta-1,4-mannan Synthase (*Cyamopsis tetragonoloba*)	400	380
CTN09	Nodule-enhanced Sucrose Synthase (*Pisum pativum*)	280	300
CTN14	Putative Gdp-mannose Pyrophosphorylase (*Arabidopsis thaliana*)	850	700
CTN16	Sucrose Synthase [*Lotus corniculatus* Var. *japonicus*)	520	500
CTN17	Udp-glucose 4-epimerase (Galactowaldenase) (Udp-galactose 4-epimerase)	400	380
CTN21	Mannosidase	860	890
CTN31	Carbohydrate Transporter/ Sugar Porter (*Arabidopsis thaliana*)	550	500
CTN32	Nucleotide-sugar Transporter/ Sugar Porter (*Arabidopsis thaliana*)	400	450
CTN40	Transferase, Transferring Glycosyl Groups / Transferase, Transferring Hexosyl Groups (*Arabidopsis thaliana*)	250	240

Table 5. Primers and their polymorphism and PIC value

Primer	Mmonomorphic band (Number)	Polymorphic band (Number)	Percent polymorphism	PIC
GDR1	0	2	100	0.49
GDR2	0	2	100	0.50
GDR3	0	2	100	0.49
GDR4	0	2	100	0.50
GDR5	1	0	-	-
GDR6	0	2	100	0.48
GDR7	0	3	100	0.52
GDR8	0	2	100	0.46
GDR9	0	2	100	0.49
GDR10	0	2	100	0.50
GDR11	0	2	100	0.47
CTN3	-	-	-	-
CTN4	-	-	-	-
CTN05	0	2	100	0.50
CTN7	-	-	-	-
CTN09	0	2	100	0.49
CTN10	-	-	-	-
CTN11	1	0	-	-
CTN12	1	0	-	-
CTN13	-	-	-	-
CTN14	0	2	100	0.49
CTN15	1	0	-	-
CTN16	0	2	100	0.49
CTN17	0	2	100	0.49
CTN18	-	-	-	-
CTN21	0	2	100	0.49
CTN31	0	2	100	0.50
CTN32	0	2	100	0.50
CTN39	-	-	-	-
CTN40	0	2	100	0.50
RGK07/HD03	0	2	100	0.50
RGK08/HD03	0	3	100	0.84
RGK07/HD04	0	2	100	0.42
RGK08/HD04	0	7	100	0.50
RGK06/HD04	0	2	100	0.49

(40 progenies and two parents) formed two major clusters at a similarity coefficient of 0.48. Cluster I included HG75 and 8,39,24,19,2,22 and 28 number of progenies. The second cluster was occupied by PNB and other 33 progenies. The second cluster was further divided into sub clusters at 0.51 similarity level. These sub groups are further divided into small clusters as the similarity coefficient level increases. Progenies 13 and 40, 16 and 23, 27 and 35, 11and 30, 17 and 37, 18 and 26, 21 and 31 showed maximum relatedness with each other

The estimated PIC can be used to quantify the genetic polymorphism of each locus in a segregating population. PIC value ranged from 0.42 to 0.84 with a mean value of 0.50. The lowest value (0.42) was for the loci RGK07/HD04 and the highest PIC value (0.84) was for the loci RGK08/HD03. The PIC values indicated discriminatory power of the loci analyzed.

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Estimation of Genetic Components Affecting Inheritance of Yield Contributing Traits in Linseed (*Linum usitatissimum* L.)

Vivek Kumar Singh, Mohit Chaudhary, Vijay Sharma[1], Bunty Sharma[2], Sunil Kumar Paswan[2] and Moolchandra Verma

CCS Haryana Agriculture University, Hisar-125 004, India
[1]MaharanaPratap University of Agriculture and Technology, Udaipur-313 001, India
[2] CSA University of Agriculture & Technology, Kanpur-208 002, India
E-mail: vks.slay@gmail.com

Abstract: This study was conducted in order to estimate the gene effects, which determine the inheritance of yield and its contributing traits and to search the genetic structure of each group in an 8 x 8 diallel (excluding reciprocals) cross group established by crossing diverse genotypes of linseed. Analysis of variance reveals that additive (except for seeds per capsule and harvest index) and dominance genetic variances were significant for all characters. The value of D is less than H_1 and H_2 for all the traits except plant height. The value of h^2 component was highly significant for all characters except plant height, number of seed per capsule, 1000 seed weight and harvest index. The significant of positive value of h^2 indicated presence of dominance. The value of mean degree of dominance $(H_1/D)^{0.5}$ in F_1 generation was more than unity for all the characters.The proportion of positive and negative alleles in the parent were distributed asymmetrically. The dominant genes for all the characters were frequently distributed in F_1s. The estimate of (h^2/H_2) in F_1 indicated that one major gene group is controlling the inheritance of all the characters except days to 50% flowering, biological yield per plant and seed yield per plant.

Key Words: Genetic inheritance, Heritability, Linseed

Oilseed crops occupy prestigious place in Indian agriculture due to their vital role in the sustainable economy of the country. Linseed (*Linum usitatissimum* L.) stands next to rapeseed mustard in respect of area as well as in production in the country and is annual self-pollinated diploid (2x=2n=30) oilseed crop belonging to *Linaceae* family. In India, linseed occupied 3.59 lakh hectare area with 1.46 lakh tonnes production and productivity of 408 kg ha^{-1} in 2011-12 (Anonymous, 2012). The low productivity of Linseed in India is also attributed to its cultivation in marginal and sub-marginal, rainfed soils, lack of seed of improved varieties, meagre or no application of fertilizers, etc.. Qualitative characters controlled by one or a few major genes are more readily manipulated in a breeding programme as compared to quantitative traits controlled by many genes. Nevertheless, the breeder is concerned mainly with quantitative characteristics which could be of use in both formulating and performing the breeding programme. The inheritance of the characteristics chosen has a major influence on the strategy employed for cultivar development. With limited scope to bring additional area under Linseed cultivation bulk of future increases in linseed production have to come primarily from a combination of high yielding plant types and standard crop management practices. Therefore, there is a need of concerted effort to develop high yielding varieties of this crop for increasing its productivity and production. Considering all above facts, the present investigation will be taken with following objectives, estimation of six components of variance which helps in estimation of various genetic ratios like average degree of dominance, ratio of dominance and recessive genes in the parents, proportion of genes with positive and negative effects in the parents and number of gene group which control the characters. The estimation of genetic components helps in the selection of suitable breeding procedure for the genetic improvement of various quantitative traits in Linseed.

MATERIAL AND METHOD

The experimental material for present investigation comprised of 28 F'1s (developed by crossing eight parental lines viz., NDL 2004-05, R-552, TL-11, TL-27, EC-1392, A.95.B, GS-234 and Shekhar) in half diallel fashion design during *rabi* 2011-12. The test genotype Shekharwas used as check. A total of 36 treatments (28 F1's + 8 parents) were evaluated in randomized block design with three replication at N.D. University of Agriculture and Technology, Faizabad, India. The entries were sown in a single row of 3 meter length with inter and intra row spacing of 30 cm and 15 cm, respectively. All recommended agronomic practices were adopted in order to raise normal and healthy crop.

The observations were recorded from five randomly selected competitive plants from each row on eleven distinct morphological characters i.e., Days to 50% flowering, Plant height (cm), No. of secondary branches plant^{-1}, No. of seeds capsule^{-1}, Biological yield plant^{-1} (g), Harvest index (%), Days to maturity, No. of primary branches plant^{-1}, No. of capsules per plant^{-1}, 1000 seed weight (g) and Seed yield per plant (g). The simple additive-dominance model, proposed by Jinks (1954) and Hayman (1954) for diallelcross analysis and h*eritability (h^2) in broad sense for all characters was computed using the formula adopted by* Hanson *et al.* (1956). Genetic components of variation (D, H_1, H_2, F, h^2 and E) for eleven characters in F_1s generation were estimated (Hayman, 1954) and genetic advance as per cent of mean for each character was computed (Johnson *et al.,* 1955).

RESULTS AND DISCUSSION

Analysis of variance: The analysis of variance revealed highly significant genotypic variations for all the characters among eight genotypes. Mean squares for parental lines and the crosses were significant at P<0.01 for all the characters, whereas, the mean squares due to parents vs. crosses were significant for majority of characters (Table 1).The estimates of b and t^2 values for eleven characters indicated that the value of t^2 was found to be non-significant for all the characters studied (Table 2). The non-significant values of t^2 support the validity of the hypothesis.

Estimation of component of variance: Genetic components of variation namely D, H_1, H_2, F, h^2 and E with their standard error (SE+) for eleven characters in F_1s generation are presented in Table 3. Additive component (D) was highly significant and positive for all the characters studied except for number of seeds per capsule and harvest index, indicated that additive gene actions condition the above characters. Patel *et al.* (1997) and, Kurt and Evans (1998) have also reported additive genetic variance for number of seeds per capsules and Patel *et al*. (1997) for oil content.The estimates of dominance component H_1 and H_2 showed highly significant values for all the characters. This indicated that dominant gene actions condition the above characters. However, for traits such as the days to 50 per cent blooming, days taken to maturity, plant height, number of primary and secondary branches per plant, 1000-seed weight, biological yield per plant and seed yield per plant, significant value of D and H revealed the importance of additive and dominant genetic effects. The value of dominant components was higher than additive components for all the characters studied except plant height, indicating that genes showing dominant genetic effects for such traits were more important than additive genetic effects. The importance of dominant variation was also indicated by significant H components (H_1 and H_2). The values of H_1 were higher than the value of H_2 for all the characters in the F_1 population,

Table 1. Analysis of variance for parents and F_1s for eleven characters in eight parent'sdiallel cross in Linseed

Source of variation	d.f.	MS of characters										
		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Secondary branches/ plant	Capsules plant^{-1}	Seeds capsule^{-1}	1000 Seed weight (g)	Biological yield plant^{-1}(g)	Seed yield plant^{-1} (g)	Harvest index (%)
Replications	2	9.19	1.08	9.35	0.00	2.14	89.21	0.32	0.02	1.15	0.43	4.64
Treatments	35	64.50**	31.89**	78.89**	1.14**	86.70**	1791.78**	0.67**	2.20**	27.91**	3.82**	75.32**
Parents	7	68.28**	35.79**	262.48**	0.78**	110.92**	2114.81**	0.72**	3.07**	20.87**	1.97**	70.83**
F_1s	27	54.35**	28.99**	30.82**	1.13**	67.10**	1468.65**	0.68**	2.00**	21.57**	3.41**	78.20**
Parent Vs. F_1s	1	312.15**	82.88**	91.72**	3.88**	446.23**	8255.35**	0.16	1.65**	248.20**	27.81**	29.12*
Error	70	5.48	6.41	3.04	0.16	6.48	54.73	0.24	0.03	1.01	0.15	7.21

Table 2. Uniformity test for Wr - Vr using regression coefficient and t^2

Characters	B	SEb ±	b-0/SEb	1-b/SEB	t^2
Days to 50 % flowering	0.691	0.195	-3.551**	1.589	0.577
Days to maturity	0.405	0.146	-2.777**	4.072**	5.873
Plant height (cm)	0.954	0.160	-5.973**	0.290	0.038
No. of primary branches plant^{-1}	-0.011	0.279	0.041	3.626**	0.913
No. of secondary branches plant^{-1}	0.520	0.207	-2.506*	2.317*	1.297
No. of capsules plant^{-1}	0.673	0.347	-1.937	0.942	0.065
No. of seeds capsule^{-1}	-0.011	0.376	0.029	2.689**	0.041
1000- seed weight (g)	0.674	0.217	-3.109**	1.506	0.372
Biological yield plant^{-1} (g)	-0.043	0.203	0.212	5.126**	3.393
Seed yield plant^{-1} (g)	0.115	0.212	-0.542	4.173**	2.855
Harvest index (%)	-0.111	0.203	0.547	5.462**	3.301

*,** Significant at 5% and 1% level; respectively

which reflected that the dominant genes were unequally distributed. Highly significant and positive value of F component recorded for characters plant height, number of secondary branches per plant and number of capsules per plant, indicated that the dominant genes were more frequently distributed than the recessive genes in the parents. Days to 50 per cent flowering, days to maturity, number of primary branches per plant, number of seeds per capsule, 1000 seed weight, biological yield, seed yield per plant and harvest index were non-significant .The significance of values of h^2 indicated the important effect of heterozygous loci for the days to 50% flowering, days to maturity, number of primary branches secondary branches t, number of capsules plant^{-1}, biological yield plant^{-1} and seed yield plant^{-1}. The estimates of the component E were non-significant for all the characters in the present study except days to maturity and number of seeds per plant. The presence of non-significant effects of component, E showed that environment did not affect the expression of the genes for various traits. Even though the environmental component was significant it was much lower than additive and dominance variance.

Estimation of genetic ratio: The components of variance were exploited for the estimation of various genetic ratios namely mean degree of dominance $(H_1/D)^{0.5}$, proportion of genes with positive and negative effects in the parents $(H_2/4H_1)$, ratio of dominant and recessive genes in the parents (KD/KR) and the number of gene groups which control the characters (h^2/H_2) are presented in Table 3.Estimates for mean degree of dominance $(H_1/D)^{0.5}$ for all the characters were more than one signifying over dominance in F_1 hybrid which was denoted by the regression slope. This indicated, that all the characters might be governed by over-dominance. These results are supported by earlier report of Yadav (1997). The proportion of positive and negative alleles in the parent $(H_2/4H_1)$ was less than unity for all the characters, which indicated that the positive and negative alleles were distributed asymmetrically. The proportion of the dominant and recessive genes in the F_1s (KD/KR) was recorded more than unity for all the characters, indicated that the dominant genes were frequently distributed as compared to their recessive genes. The number of gene group which control the character in $F_1(h^2/H_2)$ was observed less than unity for all the characters except days to 50% flowering, biological yield plant^{-1} and seed yield plant^{-1}, which indicated that one major gene group is controlling the inheritance of these traits. The values obtained more than unity showed that more than one major gene groups were responsible for their inheritance. The coefficient of correlation (r) between parental order of dominance and parental measurement was positive for all the traits except, number of primary branches plant^{-1}, number of seeds plant^{-1}, biological yield plant^{-1} and harvest index.

Estimation of heritability and genetic advance: High heritability coupled with moderate genetic advance in per cent of mean was recorded for harvest index, seed yield plant^{-1}and number of capsules plant^{-1}offered scope for improvement through selection (Table 4). Moderate or high heritability along with low genetic advance in per cent of mean was observed for remaining characters indicated selection is not much affected for these traits. Other workers who support our study are by Mahto *et al.* (1998), Bhateria *et al.* (2006) and Belete *et al.* (2013).

Various components analysis showed highly significant differences for dominance components in the F_1 generation for all the characters. The magnitudes of H_1 were higher than H_2 for all the traits in F_1 generation. Lower value of additive components, indicates that dominant genetic effects

Table 3. Estimates of genetic components of variance in respect to eleven characters in diallel cross in Linseed

Characters	D	H_1	H_2	h^2	F	E	$H_1/D^{0.5}$	$H_2/4H_1$	KD/KR	r	h^2/H_2
Days to 50 % flowering	20.90**	45.16**	33.60**	50.40**	6.77	1.86	1.47	0.86	1.25	0.82*	1.50
Days to maturity	9.84**	24.70**	17.37**	12.68**	5.74	2.09*	1.58	0.17	1.45	0.75*	0.73
Plant height (cm)	86.42**	84.02**	51.30**	14.58	103.21**	1.07	9.9	0.15	4.07	0.93**	0.28
No. of primary branches plant^{-1}	0.207*	1.59**	1.23**	0.61**	0.41	0.05	2.78	0.19	2.11	-0.02	0.50
No. of secondary branches plant^{-1}	34.85**	124.76**	104.79**	72.28**	51.52*	2.12	1.89	0.21	2.28	0.72*	0.70
No. of capsules plant^{-1}	686.37**	2493.30**	1968.03**	1346.27**	987.94**	18.56	1.91	0.20	2.21	0.62	0.68
No. of seeds capsule^{-1}	0.16	0.90**	0.68**	-0.01	0.32	0.08*	2.34	0.19	2.48	-0.01	-0.01
1000- seed weight (g)	1.01**	1.31**	1.12**	0.27	0.21	0.01	1.14	0.21	1.20	0.77*	0.24
Biological yield plant^{-1} (g)	6.62*	34.53**	31.61**	40.57**	6.84	0.34	2.28	0.23	1.59	-0.09	1.28
Seed yield plant^{-1} (g)	0.60*	4.60**	4.39**	4.54**	0.35	0.05	2.76	0.24	1.23	0.22	1.03
Harvest index (%)	21.23	105.25**	94.45**	3.74	25.67	2.38	2.23	0.22	1.75	-0.22	0.04

*, ** Significant at 5% and 1% level; respectively

Table 4. Estimates of heritability and genetic advance for eleven characters in Linseed

Characters	Heritability in broad sense (%)	Genetic advance in per cent of mean
Days to 50 % flowering	91.50	13.56
Days to maturity	79.90	4.31
Plant height (cm)	96.10	29.96
No. of primary branches plant^{-1}	85.90	24.60
No. of secondary branches plant^{-1}	92.50	58.47
No. of capsules plant^{1}	96.90	101.74
No. of seeds capsule^{-1}	64.40	7.86
1000- seed weight (g)	98.50	35.83
Biological yield plant^{1} (g)	96.30	32.36
Seed yield plant^{-1} (g)	96.00	96.86
Harvest index (%)	90.40	104.95

for such traits were more important than additive genetic effects. High estimates of heritability showed that the characters were governed by additive genes. Thus, the selection in later generations may be more effective. The estimate of (h^2/H_2) in F_1 indicated that one major gene group is controlling the inheritance of most of the characters. The coefficient of correlation (r) between parental order of dominance and parental measurement was found to be positive for most the traits. It may be said that overall information obtained in the present study, if practiced with care can go a long way in developing promising hybrids of linseed.

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Effect of Tillage and Weed Control Methods on Productivity and Profitability of Maize

R. R. Upasani, Sheela Barla, A. N. Puran, R. Thakur and M. K. Singh
Birsa Agricultural University, Ranchi - 834 006, India
E-mail: upasani.ravikant@gmail.com

Abstract: Field experiment was conducted to find out the effect of conservation tillage and weed control methods on productivity and economics of maize production. Zero tillage along with crop residue in rainy and winter seasons ZT+R-ZT+R recorded higher grain and straw yield during 2014 compared to conventional tillage (CT) both in rainy and in winter seasons CT-CT method of tillage. CT-CT method of tillage during 2013 and ZT+R-ZT+R during 2014 recorded significantly higher gross return compared to rest of the treatments. The higher net return and B:C ratio was recorded under zero tillage along with crop residue in rainy and winter seasons (ZT+R - ZT+R) compared to CT-CT and zero tillage (ZT) in winter seasons (CT-ZT) method of tillage. Integrated weed management performed in maize crop recorded higher gross return and net return during 2013 and 2014 compared to application of recommended herbicide and weedy checks. However, application of recommended herbicides in maize recorded significantly higher B:C ratio during 2013, while during 2014 it was similar to integrated weed management. It can be concluded that for higher productivity and profitability maize can be grown under zero tillage along with soil cover with crop residue of previous wheat crop.

Key Words: Tillage, Weed control, Maize, Conventional tillage, Zero tillage

Maize is one of the main foods for millions of people due to compatibility with different climatic conditions. It is most sensitive to weeds competition especially during early stage of crop growth. It grows slowly during first 3 to 4 weeks. The damage in maize caused by weeds, is estimated between 10 to 15% of total production in developed countries in temperate zones. Farmers sometimes spend more than half struggle to control weeds (Rashed *et al*., 2001). Results of some studies showed that weeds are able to use nutrition of soil more than crops (Yadavi *et al*., 2008; Rashid *et al*., 2008). Many research results showed that ploughing increases weed population. However, other studies indicated that weeds population is higher in non tillage and reduced tillage methods. It is reported that a deep ploughing reduced weeds due to transfer of weed seeds through deep soil, and shallow ploughing and reduced tillage increased the density of weed seeds due to transport through the soil surface. Tillage methods have significant effect on grain yield, biological yield, grains per cob and leaf area index (Abdollahi *et al*., 2011). Combination of different methods of weed control appears necessary due to importance of weed management in maize crop. The aim of this study was to determine the effects of weed control methods under different tillage sequences adopted during rainy and winter seasons on weed density and maize yield.

MATERIAL AND METHODS

Experiment was conducted at Birsa Agricultural University during rainy seasons of 2013 and 2014 to find out the effect of tillage and weed control methods on productivity and economics of maize production. The treatments comprised of five different tillage methods in main plots i.e., conventional tillage both in rainy and in winter seasons (CT-CT), conventional tillage in rainy and zero tillage in winter seasons (CT-ZT), zero tillage both in rainy and winter seasons (ZT-ZT), zero tillage in rainy and zero tillage along with crop residue in winter season (ZT-ZT+R) and zero tillage along with crop residue in rainy and winter seasons (ZT+R-ZT+R) and weed control methods in sub plots namely recommended herbicide i.e., atrazine 1.0 kg ha^{-1} (RH), integrated weed management containing intercropping with black gram + pre emergence application of pendimethalin 1.0 kg ha^{-1} + manual weeding at 30 days after sowing (IWM), and weedy check. The experimental soil was poor in nitrogen (167 kg ha^{-1}) and phosphorus (19 kg ha^{-1}), medium in potash (187 kg ha^{-1}). The pH was 6.2. The plot size was 8.4 X 6 meter. The conventional method of tillage was performed by ploughing field twice each followed by planking to break the clods. In zero tillage method the field was cleaned with prevailing weeds by spraying paraquat @ 1.0 kg ha^{-1} and the sowing was performed three days after application of paraquat by opening the furrows. The seeds and fertilizers were placed in the furrows. Seed rate for maize and wheat was 20 and 125 kg ha^{-1} respectively. Row to row and plant to plant spacing for maize was maintained at 70 X 20 cm and for wheat it was 20 cm row to row. The seeds sown under zero tillage were treated with chlorpyryphos @ 10 ml in 40 ml water in order to protect seeds from insect pests like termites

Table 1. Effect of tillage and weed control methods on weed density (no. m^{-2}) at different crop stages of Maize during 2013 and 2014

Treatments	2013								2014							
	30 DAS				60DAS				30 DAS				60DAS			
Tillage methods	G	BL	S	T	G	BL	S	T	G	BL	S	T	G	BL	S	T
CT-CT	7.21 (61)	8.71 (86)	3.74 (15)	12.69 (172)	8.34 (84)	9.75 (106)	4.61 (24)	14.02 (214)	6.48 (42)	6.19 (50)	7.14 (55)	11.69 (147)	7.21 (53)	7.90 (72)	7.54 (65)	13.22 (190)
CT-ZT	7.85 (69)	8.85 (83)	3.86 (16)	12.98 (180)	10.33 (124)	10.03 (106)	4.74 (24)	15.24 (254)	5.37 (31)	6.02 (57)	8.16 (76)	11.69 (163)	6.52 (43)	7.28 (61)	7.78 (67)	12.56 (171)
ZT-ZT	12.75 (169)	8.60 (81)	5.56 (32)	15.74 (267)	9.53 (124)	9.79 (106)	6.88 (51)	15.64 (281)	5.60 (32)	7.74 (67)	7.20 (58)	12.16 (157)	6.40 (44)	7.59 (62)	7.01 (54)	12.16 (159)
ZT-ZT+R	10.32 (114)	8.42 (81)	5.56 (36)	13.97 (219)	10.51 (128)	9.5 (104)	6.85 (56)	15.82 (289)	5.35 (30)	7.69 (64)	7.64 (67)	12.21 (161)	6.53 (43)	6.73 (55)	6.24 (47)	11.49 (145)
ZT+R-ZT+R	11.01 (134)	9.88 (108)	6.23 (42)	14.50 (235)	11.67 (162)	11.20 (137)	7.68 (65)	18.04 (365)	5.15 (28)	7.32 (65)	6.53 (51)	11.25 (144)	7.29 (55)	7.25 (58)	5.85 (39)	11.99 (153)
CD at (p=0.05)	4.18	NS	2.15	NS	3.16	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.81	1.58
Weed Control																
R – H	9.08 (95)	7.69 (61)	4.34 (20)	11.56 (138)	7.03 (52)	8.73 (79)	5.33 (30)	12.57 (161)	4.74 (23)	5.06 (29)	5.98 (38)	9.37 (91)	6.05 (37)	5.83 (35)	5.07 (27)	9.9 0(99)
IWM	7.58 (60)	7.04 (51)	3.67 (14)	10.98 (122)	6.83 (48)	7.97 (65)	4.52 (22)	11.55 (135)	5.25 (29)	4.77 (27)	5.40 (30)	9.14 (85)	6.28 (41)	5.17 (27)	5.19 (28)	9.76 (97)
WC	12.82 (173)	11.95 (151)	6.95 (51)	19.39 (383)	16.36 (273)	13.51 (192)	8.60 (80)	23.13 (546)	6.78 (46)	11.15 (126)	10.63 (115)	16.88 (288)	8.05 (65)	11.05 (122)	10.39 (109)	17.18 (296)
CD (p=0.05)	8.37	6.67	3.01	7.34	4.58	6.42	3.80	5.57	NS	4.21	2.30	2.65	1.82	4.16	1.82	2.89
Interaction																
CD (p=0.05)	NS	NS	1.48	3.62	2.26	NS	2.53	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	18.88	21.87	17.87	9.22	14.71	21.80	18.24	10.90	16.53	25.84	22.14	13.81	18.56	12.45	13.85	9.33

G- Grassy, BL- Broad leaf, S- Sedges, T- Total weeds
The data in parenthesis are the original values

and cut worm. A fertilizer dose of 120 kg nitrogen, 60 kg phosphorus and 40 kg potash was given to both the crops. Half of nitrogen was given at the time of sowing and remaining half in two splits i.e. at knee height, and tasseling stages in maize while after first irrigation at 25 days after sowing and another at 45 days after sowing in wheat. Weed samples for weed density and their dry weight were selected randomly from one meter square. The samples were uprooted, cleaned and sun dried after grouping them under grassy, broad leaf and sedges weeds. The threshed straw of previous wheat crop was applied as residue in maize plots as per treatment.

RESULTS AND DISCUSSION

The field was infested with major weeds like *Alternenthera sessils, Commelina nudifolia, Paspalam distichum, Ageratum conyzoides, Celosia argensia, Stellaria media,* as broad leaf weeds, *Digitaria sanguinalis*, *paspalam distichum*, *Echinocloa crusgalli*, *Cynodon dectylon* as grassy and *Cyperus rotundus* as sedges weeds.

Tillage methods: Conventional method of tillage in rainy and winter seasons recorded reduced density of grassy and sedges weeds in maize crop at 30 and 60 DAS during 2013 while during 2014, ZT+R-ZT+R being similar to ZT-ZT and ZT-ZT+R recorded reduced density of sedges compared to CT-CT and CT-ZT to the extent of 40 and 41.79 per cent, respectively. The total weed density in ZT - ZT+R at 60 DAS was similar to CT - ZT, ZT - ZT, and ZT+R - ZT+R and was significantly lower compared to CT - CT during 2014. The weed dry matter also (Table 2) significantly reduced in ZT+R - ZT+R compared to mean of rest of the tillage combinations. The result confirms the findings of Arif *et al*. (2007) and Cardina *et al*. (2002).

Weed control methods: Among weed control methods integrated weed management (IWM) performed in maize recorded significantly reduced density of grassy, broad leaf and sedges weeds as well as total by of 65.31, 66.22, 72.54 and 68.14 per cent, respectively, compared to weedy checks at 30 DAS during 2013 . At 60 DAS, IWM reduced grassy and broad leaf and total weeds by 82.41, 67.71 and 75.27 per cent, respectively, compared to weedy checks during 2013. During 2014 IWM, recorded reduced density of broad leaf, sedges as well as total weeds by 78.57, 73.91 and 70.48 per cent compared to weedy checks at 30 DAS while at 60 DAS the reduction of grassy, broad leaf, sedges as well as total weeds were 36.92, 77.87, 74.31 and 67.22 per cent. The weed dry matter accumulation recoded under IWM was significantly lower compared to weedy checks to the extent of 68.57, 75.46 during 2013 and 41.82 and 43.26 per cent during 2014 at 30 and 60 DAS, respectively.

Yield and Economics

Tillage methods*:* Conventional or zero tillage methods performed prior to sowing of maize crop did not influence grain nor straw yield of maize during 2013. The comparable yield under different tillage methods was also reported by Ram *et al.* (2010). However, during 2014, ZT+R-ZT+R being similar to CT-ZT , CT-ZT, ZT-ZT+R recorded 86.82 and 97 per cent higher grain (3133 kg ha^{-1}) and straw (6676 kg ha^{-1}) yield

Table 2. Effect of tillage and weed control methods on weed dry matter at different crop stages of Maize during 2013 and 2014

Treatments	2013		2014	
	30 DAS	60 DAS	30 DAS	60 DAS
CT-CT	6.73(48.70)	9.01(88.47)	7.99(66.61)	8.89(80)
CT-ZT	6.85(49.83)	9.76(104.21)	7.78(62.43)	9.14(85)
ZT-ZT	8.27(72.99)	10.04(115.90)	7.06(51.64)	8.40(73)
ZT-ZT+R	7.41(62.14)	10.17(119.81)	7.54(56.96)	8.33(71)
ZT+R-ZT+R	7.62(64.47)	11.54(148.46)	7.70(58.97)	8.19(67)
CD (p=0.05)	NS	NS	NS	1.04
Weed Control				
R – H	6.10(38.14)	8.07(66.07)	6.68(44.71)	7.87(62)
IWM	5.80(33.65)	7.41(55.18)	7.00(49.01)	7.70(59)
WC	10.23(107.09)	14.83(224.86)	9.16(84.25)	10.20(104)
CD (p=0.05)	4.95	4.88	1.57	2.21
Interaction				
CD (p=0.05)	2.44	NS	1.20	NS
CV%	8.77	10.75	7.93	7.86

The data in parenthesis are the original values

Table 3. Effect of conservation tillage and weed control methods on yield attributes and yield of maize (2013 and 2014)

Treatments	Grains/cob		100 seed weight (g)		Grain yield (kg ha^{-1} (p=0.05))		Stover yield (kg ha^{-1} (p=0.05)	
Tillage	2013	2014	2013	2014	2013	2014	2013	2014
CT-CT	294	396	28.92	19.68	2415	1677	5530	3389
CT-ZT	299	444	31.50	19.41	2043	1872	4946	3997
ZT-ZT	282	458	26.91	21.46	1842	2694	4517	5588
ZT-ZT+R	322	414	27.48	22.02	2245	2839	4153	5892
ZT+R-ZT+R	286	381	26.61	20.45	2104	3133	4762	6676
CD (p=0.05)	NS	71.64	2.36	2.58	NS	1417.34	NS	2633
Weed control								
RH	343	433	28.83	20.66	2364	2672	4798	5549
IWM	300	443	28.22	22.30	2609	3098	5686	6517
WC	247	380	27.80	18.86	1417	1559	3860	3260
CD (p=0.05)	86.85	69.33	NS	4.72	505	1175.93	2377	4291
Interaction								
CD (p=0.05)	104.0	NS	3.66	3.60	NS	NS	1816	3277
CV%	17.29	11.37	6.41	6.22	18.32	25.75	22.41	13.98

Table 4. Effect of conservation tillage and weed control methods on economics of maize (2013 and 2014)

Treatments	Gross return (Rs ha^{-1})		Net return (Rs ha^{-1})		B:C ratio	
Tillage	2013	2014	2013	2014	2013	2014
CT-CT	47285	31933	28293	12943	1.49	0.61
CT-ZT	40537	36073	21549	17083	1.15	0.83
ZT-ZT	3664	51583	21980	36893	1.49	2.51
ZT-ZT+R	41981	54367	27286	39677	1.87	2.81
ZT+R-ZT+R	41084	60342	26392	45652	1.83	3.10
Sem±	3665	7598	3665	7598	0.20	0.47
CD (p=0.05)	NS	24774	NS	24774	NS	1.52
Weed control						
RH	45055	51173	30497	36615	2.13	2.73
IWM	50507	59497	29586	38583	1.43	1.90
WC	28976	29908	15218	16150	1.13	1.34
Sem ±	2511	4470	2510	4470	0.11	0.26
CD (p=0.05)	9855	17547	9854	17546	0.42	1.02
Interaction						
Sem±	2511	4470	2511	4470	0.11	0.26
CD (p=0.05)	7526	13400	7526	13400	0.32	0.78
CV%	17	21.22	20.43	12.36	4.09	4.43

Price of per grain – Rs. 15/-kg^{-1} and straw – Rs. 2/-kg^{-1}

compared to CT-CT method of tillage. CT-CT method of tillage during 2013 and ZT+R-ZT+R similar to ZT-ZT and ZT-ZT+R during 2014 recorded significantly higher gross return (Rs. 47285 and 60342 respectively) owing to higher grain and straw yield compared to rest of the treatments. The higher net return (Rs. 45652) and B:C ratio (3.19) was recorded under ZT+R-ZT+R which was similar to ZT-ZT and ZT-ZT+R compared to CT-CT and CT-ZT method of tillage.

Weed control methods: Integrated weed management performed in maize crop recorded higher gross and net return during 2013 and 2014 compared to weedy checks and was similar to application of recommended herbicides. However, application of recommended herbicides in maize recorded significantly higher B:C ratio (2.13) during 2013 while during 2014 (2.73) it was similar to integrated weed management.

Thus for higher productivity and profitability maize can be realised under zero tillage along with soil cover with crop residue of previous wheat crop.

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Genetic Divergence Analysis in Genotypes of Soybean [*Glycine max* (L.) Merril]

Stuti Mishra, Avinash Jha and A. N. Shrivastava

Department of Plant Breeding & Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalya, Jabalpur-482 004, India
E-mail:stuti.curious@gmail.com

Abstract: An investigation was conducted with fifty soybean genotypes to identify the diverse genotype for the use in hybridization through genetic diversity analysis by Mahalanobis's D^2 statistics (1936). The results revealed significant differences among genotypes for all studied traits. Fifty genotypes were grouped into eleven clusters. Cluster I and cluster II were polygenotypic found to be the largest cluster eachcomprising of 13 genotypes. Cluster X showed maximum intra cluster D^2 value (D^2 = 64.02) followed with cluster V (D^2 = 53.07), cluster IV (D^2 = 43.20). The traits number of pods per plant (30.86%) contributed most towards genetic divergence followed by biological yield (30.04%). Cluster IV and cluster VI revealed highest contribution towards genetic diversity. Entries from cluster I, II, IV, V and X can be used of crossing programme for development of new in place of advance breeding genotypes in place of lines. The potential genotypes based on the D^2 statistics was found to be JS 20-69, JS 95-60, JS 20-29, JS 20-34, JS 20-50, JS 20-65, JS 20-71, JS 20-97, JS 20-86, JS 20-53, JS 20-98, JS 20-96, RVS 2007-4, JS 20-89, JS 20-29, JS 20-88, JS 20-41, JSM 230, which a be used for further studies.

***Key Words*:** D^2, Genetic diversity, New breeding genotypes, Soybean

Soybean [*Glycine max* (L.) Merill] is the chief oilseed crop in India contributes 43 % oilseeds and 29 % edible oil production in the country. Madhya Pradesh contribution has always been largest and substantial in respect of area and production of country's total. It is characterized by low yield, partly because of low yield varieties, lodging and pod shattering, in addition to other constrain.The development of new variety is directed by the genetic diversity among the population and scope of variability for the desired traits. Soybean being a self pollinated oilseed crop faces the constraint of narrow genetic base. Every crop improvement programme, genetic diversity analysis is the primary and major step. In recent years soybean productivity has been declining due to impact of abiotic and biotic stresses alongwith environmental fluctuations. Large yield gap requires superior pre-breeding efforts to broaden the genetic base suitable for screening better genotypes. There is a possibility of increasing soybean yield potential upto 27% through developing four seeded plant ideotype (Shrivastava *et al.,* 2011). Genetic diversity among genotypes requires a proper strategy. Selection of genotypes with wider adaptability and enhanced genetic diversity is key factor for development of varieties. Genetic divergence analysis is of crucial significance to the plant breeder as it helps in forming an efficient breeding programme. Genetically diverse parents produce better and desirable segregates. Thus Mahalanobis's D^2 statistics is a powerful tool to measure genetic divergence within a set of genotypes. It allows accurate comparison among all the population in given group and degree of diversity among them.They are often extended to the classification of a population into groups of distinct orders based on similarities in one or more traits, and thus guide in the choice of parents for hybridization. Das *et al.* (2001) reported that grouping pattern of the diverse genotypes suggested no parallelism between genetic divergence and geographical distribution of the genotypes. The genotypes which have greater morphological similarity were grouped in clusters. (Ghatge and Kadu, 1993). Some potentially important traits have been identified and could be exploited for specific trait improvement and assemblage of core collection from a bulk genetic stock. Present study aims to analyze the genetic diversity of fifty recently evolved soybean genotypes for identifying promising parental genotypes.

MATERIAL AND METHODS

The investigation was carried out consisting of fifty new breeding genotypes of soybean which includes mutant lines, released varieties, and advance breeding lines. The experiment was conducted during *Kharif* 2013 in RBD with three replications at seed breeding farm, Jawaharlal Nehru Krishi Vishwa Vidyalya, Jabalpur; M.P. Observations were recorded for phenological traits and ten morphological traits. Recommended package of cultivation practices were followed in the trial. Five random plants were selected to record data on phenological traits i.e. vegetative and

Table 1. Percentage contribution towards genetic divergence by all the traits

Traits	Times ranked	Percentage contribution
Number of branches plant^{-1}	0	0
Number of nodes plant^{-1}	1	0.08
Number of pod clusters plant^{-1}	9	0.73
Reproductive phase in place of stage (days)	30	1.35
Plant height at (cm) plant^{-1}	45	2.67
Vegetative phase in place of stage (days)	57	3.79
100 seed weight (g)	47	4.60
Seed yield plant^{-1}	18	4.65
Number of seeds plant^{-1}	92	7.51
Harvest index (%)	180	14.50
Biological yield plant^{-1} (g)	368	30.00
Number of pods plant^{-1}	378	30.18

reproductive phases in place of stages and morphological traits (Table 1) The replicated data of phenological and quantitative traits were subjected to genetic divergence analysis using Mahalanobis's D^2 (1936) statistic as suggested by Rao (1952). All the soybean genotypes were grouped into respective clusters on the basis of values following Toucher's method. The estimation of 'Ë' (Wilk's criterion) was done using the following relationship.

'Ë' = (E)/ (E+V) Where,

(E) = Determination of error sum of squares and sum of products matrix.

(E+V) = Determination of error + Varieties sum of squares a sum of products matrix

RESULTS AND DISCUSSION

Genetic diversity generalized distance (D^2): For the determination of genetic divergence among 50 parentages of soybean Wilk's Ë criterion value (28073.292) was found highly significant. The V statistics value (2794.063) was also highly significant at 588 degree of freedom. It showed that genotypes differed significantly, when all the traits in place of characters were considered simultaneously.The analysis of variance showed highly significant differences within the population for most of the traits studied.The D^2 values corresponding to possible comparison among 50 new breeding genotypes were computed separately in the analysis.

Contribution of individual traits in place of characters towards genetic divergence: The traits in place of character viz. number of pods per plant (30.18 %) contributed most towards genetic divergence followed by remaining traits in descending order *viz.* biological yield (30%), harvest index (14.50%), number of seeds per plant (7.51%), seed yield per plant (4.65%), 100 seed weight (g) (4.60 %), vegetative phase in place of stage (3.79 %), plant height (2.67 %), reproductive phase in place of stage (1.35%) and while 2 traits in place of characters viz., number of nodes per plant (0.08 %) and number of nodes per plant contributed less than 1 per cent towards divergence (Table 1).

Grouping of genotypes into different clusters: On the basis of D^2 values, the fifty recently evolved genotypes were grouped into 11 clusters following Tocher's method (Table 2.). Cluster I and cluster II were polygenotypic (largest cluster each with 13 genotypes) followed by cluster V (9 genotypes), cluster IV (4 genotypes), cluster VII and X with (3 genotypes each), while remaining 5 clusters were monogenotypic.

Intra and inter cluster divergence D^2 values: The average intra and inter-cluster D^2 values estimated as per the

Table 2. Distribution of 50 genotypes into different clusters

Cluster	No. of genotypes	Genotypes
Cluster I	13	JS 20-50, JS 20-65, JS 20-71, JS 20-97, JS 20-86, JS 20-53, JS 20-99, JS 20-96, RVS 2007-4, JS 20-94, JS 20-79, JS 20-88, JS 20-41
Cluster II	13	NRC 37, Bragg, JSM 146, JSM 283, JSM 126, JS 335, JS 20-95, JSM 230, JS 20-80, JSM 207, JSM 242, JS 20-64, JSM 20-85
Cluster III	1	JS 20-70
Cluster IV	4	JS 20-29, JS 20-98, JSM 127, JS 20-89
Cluster V	9	JS 20-73, JS 20-82, JS 20-59, JS 20-69, JS 97-52, JS 20-91, JS 20-93, JSM 302, JSM 20-90
Cluster VI	1	JS 20-92
Cluster VII	3	JSM 7, JSM 271, JSM 20
Cluster VIII	1	JSM 175
Cluster IX	1	JS 20-75
Cluster X	3	JS 95-60, JS 20-34, JS 93-05
Cluster XI	1	JS 20-74

Table 3. Inter and Intra-cluster distances for 50 genotypes

Cluster	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X	Cluster XI
Cluster I	32.53	122.99	47.04	67.97	88.22	257.43	252.98	52.90	60.08	255.78	151.67
Cluster II		39.52	63.73	262.16	124.12	173.79	72.94	130.26	115.52	128.06	184.63
Cluster III			0.00	119.98	103.42	216.71	154.98	22.88	39.03	188.31	60.11
Cluster IV				43.20	180.92	433.83	437.53	86.99	100.14	451.03	207.19
Cluster V					53.07	114.92	260.25	130.54	111.27	153.49	230.16
Cluster VI						0.00	285.43	267.49	241.56	95.70	317.71
Cluster VII							34.78	256.28	245.04	180.60	280.47
Cluster VIII								0.00	32.78	249.35	45.57
Cluster IX									0.00	223.46	107.72
Cluster X										64.02	280.40
Cluster XI											0.00

Table 4. Mean values for eleven clusters based on twelve quantitative traits of 50 soybean genotypes

Cluster means : Tocher method

Cluster	Vegetative phase (days)	Reproductive phase (days)	Plant height (cm)	Number of pod cluster plant^{-1}	Number of branches plant	Number of pods plant^{-1}	Number of nodes plant^{-1}	Number of seeds plant^{-1}	Biological yield plant^{-1} (g)	100 seed weight (g)	Harvest Index (%)	Seed yield (g)
Cluster I	35.69	54.51	46.84	20.53	2.93	49.38	11.61	92.28	20.12	7.37	34.98	5.18
Cluster II	35.10	55.13	40.12	13.55	2.19	28.77	11.19	53.77	11.72	7.65	36.56	5.01
Cluster III	35.33	55.33	46.03	18.10	2.73	37.00	12.47	69.15	15.08	8.11	35.08	5.29
Cluster IV	36.08	54.93	48.26	19.85	2.52	60.58	11.48	113.22	24.69	8.12	35.67	8.66
Cluster V	35.56	54.88	42.21	15.66	2.47	50.70	11.11	92.88	22.25	7.23	34.57	6.88
Cluster VI	35.00	58.67	36.07	12.07	2.01	35.67	11.00	66.66	14.54	7.10	35.07	5.92
Cluster VII	33.78	55.78	30.80	14.52	1.98	18.33	10.71	34.26	8.40	6.25	24.54	3.04
Cluster VIII	33.33	52.33	48.47	20.33	3.00	45.00	12.67	84.10	20.62	7.18	31.19	7.40
Cluster IX	38.67	60.00	49.83	14.23	2.47	46.00	12.60	85.97	21.08	7.10	31.20	7.56
Cluster X	26.78	54.56	41.51	16.66	2.12	30.78	10.28	57.52	14.11	7.52	30.12	5.06
Cluster XI	32.67	55.33	43.50	23.17	2.93	36.00	10.60	67.28	16.50	7.04	31.01	5.32

procedure given by Singh and Choudhary (1979) are presented in Table 3 and the cluster mean values are summarized in Table 4. Cluster X showed maximum intra cluster D^2 value (D^2 = 64.02) followed with cluster V (D^2 = 53.07), cluster IV (D^2 = 43.20), cluster II (D^2 = 39.52), cluster VII (D^2 = 34.78) and cluster I (D^2 = 32.53).

The highest inter cluster divergence was observed between genotypes of cluster IV and X (D^2 = 451.03), followed by cluster IV and VII (D^2 = 437.53) IV and VI (D^2 = 433.83). The genotypes belonging to the clusters separated by high statistical distance could be used in hybridization programme for obtaining a broad spectrum of variation among the segregates. It is true that more the divergence between genotypes, grand would be the heterosis when hybrid programme is planned to develop promising varieties (Bekele *et al.,* 2012), Cluster I (D^2 =32.53) was the largest poly-genotypic cluster with 13 genotypes and was nearest tocluster III (D^2 = 47.04), followed in descending order by cluster VIII (D^2 = 52.90), IX (D^2 = 60.08), IV (D^2 = 67.97), V (D^2 = 88.22), II (D^2 = 122.99), XI (D^2 = 151.67), VII (D^2 = 252.98) and cluster X (255.78), while cluster VI (D^2 = 257.43) was farthest or more distantly related to cluster I. Cluster II (39.52) was also poly-genotypic cluster with genotypes number same as above, but nearest to cluster III (D^2 = 63.73) followed by remaining clusters in ascending order viz., cluster VII (D^2 = 72.94),cluster IX (D^2 = 115.52), cluster V (D^2 = 124.12), cluster X (D^2 = 128.06), cluster VIII (D^2 = 130.26), cluster VI (D^2 = 173.79) and cluster VI (D^2 = 184.63), however it was placed at a maximum distance to cluster IV(D^2 = 262.16).Cluster IV (43.20) was poly-genotypic with four genotypes, but nearest to cluster VIII (D^2 = 86.99). Cluster V (53.07) was poly-genotypic with nine genotypes, but nearest to cluster IX (D^2 = 111.27). Cluster VII with three genotypes (34.78) was poly-genotypic, but nearest to cluster X (D^2 = 180.60). Cluster X (64.02) was poly-genotypic with three genotypes. Cluster III, Cluster VI, Cluster VIII and Cluster IX weremono-genotypic.

Clusters mean showing importance of grouped genotypes: In terms of traits under study Cluster I recorded highest value for vegetative phase, plant height, number of pod cluster per plant, number of pods per plant, number of seeds per plant and biological yield per plant. Cluster II revealed high value for 100 seed weight and harvest index. Cluster III recorded highest value for number of plant height, number of pod cluster per plant, number of branches per plant, number of nodes per plant 100 seed weight and harvest index. Cluster IV recorded highest value for vegetative phase, plant height, number of branches per plant, number of pod cluster per plant, number of pods per plant, number of seeds per plant, 100 seed weight, harvest index, biological yield and seed yield per plant. Cluster V recorded highest value for vegetative phase, number of pods per plant, number of seeds per plant, biological yield harvest index and 100 seed weight. Cluster VI recorded high values vegetative phase, reproductive phase and harvest index. Cluster VII recorded highest value for plant height, number of pod cluster per plant, number of branches per plant, number of pods per plant number of nodes per plant, number of seeds per plant and seed yield per plant. Cluster IX recorded the vegetative phase as the most late and the other high values recorded traits were plant height, number of pods per plant, number of nodes per plant, number of seeds per plant, biological yield and seed yield per plant. Whereas Cluster X recorded the earliest i.e. lowest value of vegetative and reproductive phase and high value of 100 seed weight. Cluster XI recorded high values number of pod cluster per plant, number of branches per plant, number of seeds per plant, number of nodes per plant and biological yield.

From the above diversity analysis significant and high values for different traits reveals that genotypes for early duration genotypes from Cluster X, VII, VIII and XI can be selected whereas for long duration genotypes fallen in Cluster IX, IV, V, VI, I can be selected. For economic traits viz., number of pods per plant, number of seeds per plant, 100 seed weight, biological yield and harvest index genotypes from Cluster IX, I, IV, VIII, V and XI were most suitable. For seed yield per plant genotypes of Cluster IV, VIII and IX are appropriate. From the above study the genotypes which recorded fair performance and can be implemented in hybridization program me and evaluate against abiotic stresses were JS 95-60, JS 20-29, JS 20-69, JS 20-34, JS 20-50, JS 20-65, JS 20-71, JS 20-97, JS 20-86, JS 20-53, JS 20-98, JS 20-96, RVS 2007-4, JS 20-89, JS 20-88, JS 20-41 andJSM 230.

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Waste Management of *Brassica oleraceae* Leaves to Develop High Fiber Wheat Biscuits and Noodles

Towseef A. Wani, Monica Sood[1] and QuraazahAkeemu Amin

Sher-e-Kashmir University of Agricultural Sciences and Technology-Srinagar, 190 025, India
[1] Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu,180 009, India
E-mail: towseef46@gmail.com

Abstract: *Cauliflower (Brassica oleraceae var. botrytis) l*eaves which are generally thrown away as waste are also rich source of iron and â-carotene. Standardised ratios of cauliflower leaf powder and different wheat flours were used to develop high fiber biscuits and noodles. Malted wheat flour increased the nutrition of the biscuits and noodles as compared to whole and roasted. Malted wheat fortification (70%) showed highest moisture (1.66%), protein (9.51%), ash (1.59%) and fiber (13.62%). In noodles malted wheat showed the same effect. Highest total sugar (3.77%), â-carotene (9.23 mg/100gm) and iron content (11.01 mg/100gm) was depicted in 70% malted wheat. However, the highest organoleptic score and cost of production was seen in treatment with 90% malted wheat flour.

Key Words: Biscuits, Cauliflower, Economics, Malted wheat, Noodles, Waste management

Various studies carried out to develop high fibre baked and extruded products but the main emphasis has been given on incorporation of cereal and pulse husk. But the scientists observed that the fruits and vegetables contain higher level of cellulose than cereals. Besides having good amount of dietary fibre, vegetables and fruits are also considered to be chemical power houses that produce dozens of unique, complex and biologically active organic compounds which are known to affect significantly the quality and duration of life.

Among vegetables, cauliflower (*Brassica oleraceae*var. *botrytis*) is the most popular cole vegetable grown extensively in India which is not only rich in nutrients but has highest waste index. The edible portion of cauliflower is curd (head), whereas, its leaves which are generally thrown away as waste are also rich source of iron and â-carotene and thus can be utilized in various value added products (Kowsalya and Sangeetha, 1999). These are cheap and within reach of common man and contribute about 50 per cent of the total production of cauliflower. The leaves of cauliflower are available only for a short period but these can be dried or stored for use during lean season (Singh *et al*., 2005). Dehydrated leaves are also rich source of â-carotene and iron which can be used in sparce season. Hence, incorporation of fibre rich ingredients in extruded products will improve their nutraceutical properties and help to cater to the health needs of various cross-sections of the population.

In context of this, the present study was carried out to examine the effect of cauliflower leaf powder on proximate composition of noodles during storage.

MATERIAL AND METHODS

Cauliflower (*Brassica oleracea*) leaves were obtained in a single lot from local market. The leaves were separated from their stalks, washed under running tap water and were blanched for 10-15 seconds. After blanchingthe leaves were dried at room temperature for 1-2 hours by spreading on filter paper followed by drying in hot air oven at 40^{o}C for 4-6 hours. The dried leaves were ground to fine powder, passed through 20 mesh seive and packed in air tight containers for further use.

Wheat was procured from local market, was cleaned manually to remove any foreign materials, washed thoroughly under running water to remove dust and dried in sun. The cleaned and dried wheat were divided into 3 lots. One lot was milled into flour and was treated as whole wheat flour. Malted wheat flour was prepared by soaking wheat for 12 hours in water twice their volume. After that the water was drained off, the soaked grains were wrapped in a moist muslin cloth and kept for germination for a period of 48 hours at room temperature (25±2^{0}C). The germinated wheat having an average root length of 1.6 - 3.3 cm, respectively were oven dried at 70 ± 5 ^{0}C and milled (Goyle and Gujral, 1998). However for roasted wheat flour the lot was cleaned, roasted for 3 minutes, cooled and milled into flour.

Preparation of biscuits (Sweet 'n' Salty): The process for preparation of sweet 'n' salty biscuits using flour of wheat was standardized using creaming method (Singh *et al*., 2005). Fat was creamed with sugar and water. The other ingredients *viz*. carom (ajwain), salt and ammonia powder were added and creamed. Then folded the wheat flour and dried leaf powder in above mixture. Rolled and cut into shape with the help of cutter, and baked at 160 ^{0}C till done.

Noodle preparation: The preparation of noodles involved the mixing of wheat flour and dried cauliflower leaf powder by adding optimum water. All these ingredients were mixed properly to get desirable consistency dough. The prepared dough was smeared with a little of refined oil and then it was extruded by the hand extruder through suitable shape. The product was then dried for 6 hours at 50-55 °C. After drying they were cooled and packed in polyethylene bags and stored under ambient temperature (Bui and Small, 2007). There were 12 treatments whole wheat / malted wheat / roasted wheat with cauliflower in ratio of 100:0 : 90:10 : 80:20 : 70:30 (Table 1).

Table 1. Treatment details

T_1	Whole wheat flour : cauliflower leaves	100:00
T_2	Whole wheat flour : cauliflower leaves	90:10
T_3	Whole wheat flour : cauliflower leaves	80:20
T_4	Whole wheat flour : cauliflower leaves	70:30
T_5	Malted wheat flour : cauliflower leaves	100:00
T_6	Malted wheat flour : cauliflower leaves	90:10
T_7	Malted wheat flour : cauliflower leaves	80:20
T_8	Malted wheat flour : cauliflower leaves	70:30
T_9	Roasted wheat flour : cauliflower leaves	100:00
T_{10}	Roasted wheat flour : cauliflower leaves	90:10
T_{11}	Roasted wheat flour : cauliflower leaves	80:20
T_{12}	Roasted wheat flour : cauliflower leaves	70:30

Proximate analysis of the formulated products: Moisture, ash, crude protein, fat and crude fibre were determined according to AOAC (1995). Free fatty acid in terms of oleic acid was determined by method given by Singh *et al.* (2000). Both reducing and total sugars were determined using potassium ferricyanide method and results were expressed as per cent glucose. (AACC, 1990). â-carotene was determined as per method given in Srivastava and Kumar (2002). Iron was determined according to method given in Thimmaiah (1999). The samples were evaluated for overall acceptability by semi-trained panel of 7-8 judges by using 9 point hedonic scale assigning scores 9- like extremely to 1- dislike extremely. A score of 5.5 and above was considered acceptable (Amerine *et al.,* 1965).

RESULTS AND DISCUSSION

Nutrient composition of dried cauliflower leaf powder: The moisture and protein contents were 2.41 and 26.54 per cent, respectively. However, â- carotene, iron, copper, manganese and zinc contents were observed as 43.11, 60.38, 1.55, 5.86 and 5.10 mg/100g.

Nutritional evaluation of wheat flour: Nutritional analysis of wheat showed that the moisture, ash, crude fibre, protein,fat, reducing sugar and total sugar were 9.12, 0.66, 1.26, 7.80, 1.55, 1.15 and 2.25 percent, respectively. The iron content in wheat was 9.26 mg/100g.

Nutritional evaluation of high fiber biscuits: The effect of treatment combinations on the nutritional composition of high fiber biscuits showed significant differences treatments. The highest moisture (1.66%), protein (9.51%), ash (1.59%) and fiber (13.62%) were reported in malted wheat flour: cauliflower leaf powder::70: 30 and the lowest in treatment whole wheat flour: cauliflower leaf powder, 100:0. However treatment T_8 also reported highest total sugar (18.00%), â-carotene (3.13mg/100gm) and iron content of 5.59 mg/100gm). Highest fat content of 22.62% was recorded in treatment whole wheat flour: cauliflower leaves::100:00 (Table-2). The malted wheat flour improves the nutritional content of flour because malting increases the enzyme activity which helps in the breakdown of complex sugars and starch in the flour. However the protein when digested and metabolised in the body provides energy proteins which are important bio-molecules (Ayo *et al.,* 2014). Results are found to be in cognizance with Iwe (2000); Ayo and Nkama (2003).

Nutritional evaluation of high fiber noodles: The data revealed in Table 4 represented the significant effect of treatment combinations on nutritional composition of high fiber noodles. The highest moisture (10.17%), protein (13.45%), ash (1.09%) and fiber (3.56%) were reported in treatment T_8 (malted wheat flour: cauliflower leaf powder::70: 30) and the lowest protein (11.38%), ash (0.82%), fiber (3.30%), total sugar (1.60%), â- carotene (7.90 mg/100gm) and iron content of 10.05 mg/100gm in treatment T_1 (whole wheat flour: cauliflower leaf powder::100:0). However treatment T_8 also reported highest total sugar (3.77%), â-carotene (9.23 mg/100gm) and iron content of 11.01 mg/100gm). Highest fat content of 2.52% was recorded inroasted wheat flour: cauliflower leaves:: 70:30 (Table 3). Malted flours are relatively rich source of minerals, proteins and flavour substances which accelerate dough conditioning and contribute a distinctive flavour and aroma to the products (Hruskova *et al*., 2003).

Sensory quality of the high fiber biscuits and noodles: Table 4 depicted the significant effect of flour combinations on the sensory/organoleptic quality of high fiber biscuits and noodles. Malted wheat flour: cauliflower leaves::90: 10 showed best results with regard to the sensory quality of the products which were evaluated for taste, colour, texture and overall acceptability using 9 point hedonic scale. In biscuits, the best score for taste (8.18), texture (8.17), colour (8.14) and over all acceptability (8.18) in treatment. However, this treatment also proved tohave the same result on noodles

Table 2. Nutritional composition of high fiber biscuits

Treatments	Moisture %	Protein %	Fat %	Fiber %	Ash %	Sugars %	â-carotenemg/ 100g	Iron mg/100g
T_1	1.64	7.36	22.62	6.12	1.10	15.03	2.76	5.10
T_2	1.62	7.37	22.29	6.82	1.13	15.29	2.78	5.13
T_3	1.61	7.38	22.24	7.57	1.14	15.43	2.80	5.14
T_4	1.60	7.38	21.97	8.39	1.20	15.89	2.86	5.20
T_5	1.62	9.42	20.98	10.72	1.33	16.44	2.91	5.33
T_6	1.64	9.43	20.83	11.50	1.46	16.99	2.99	5.46
T_7	1.64	9.44	20.64	12.53	1.43	17.54	3.07	5.43
T_8	1.66	9.51	20.12	13.62	1.59	18.00	3.13	5.59
T_9	1.58	8.40	21.56	8.65	1.18	15.50	2.81	5.18
T_{10}	1.55	8.42	21.19	9.30	1.25	15.97	2.86	5.25
T_{11}	1.54	8.44	21.11	9.96	1.35	16.31	2.91	5.35
T_{12}	1.51	8.45	21.07	10.21	1.36	16.48	2.93	5.36
Mean	1.60	8.42	21.38	9.62	1.29	16.24	2.90	5.29
CD ($p \leq 0.05$)	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.03

Table 3. Nutritional composition of high fiber noodles

Treatments	Moisture %	Protein %	Fat %	Fiber %	Ash %	Sugars %	â-carotene mg/100g	Iron mg/100g
T_1	9.70	11.38	2.86	3.30	0.82	1.60	7.90	10.05
T_2	9.60	11.38	2.80	3.35	0.84	1.67	7.91	10.11
T_3	9.47	11.39	2.77	3.39	0.85	1.73	7.95	10.13
T_4	9.20	11.40	2.75	3.41	0.87	1.81	7.98	10.24
T_5	9.50	13.41	2.97	3.44	0.99	3.55	9.05	10.51
T_6	9.90	13.42	2.94	3.47	1.01	3.63	9.09	10.76
T_7	9.70	13.43	2.93	3.52	1.05	3.70	9.17	10.69
T_8	10.17	13.45	2.91	3.56	1.09	3.77	9.23	11.01
T_9	9.77	12.38	2.61	3.38	0.94	2.58	8.03	10.24
T_{10}	9.57	12.40	2.58	3.40	0.96	2.64	8.07	10.38
T_{11}	9.43	12.40	2.55	3.43	0.98	2.69	8.96	10.58
T_{12}	9.27	12.43	2.52	3.45	1.01	2.75	8.98	10.59
Mean	9.61	12.41	2.76	3.43	0.95	2.68	8.52	10.44
C.D. ($p \leq 0.05$)	0.08	0.01	0.02	0.02	0.01	0.01	0.06	0.07

which depicted highest taste (8.15), texture (7.97), colour (7.92) and over all acceptability (8.13) (Table 4). This could be attributed to the malting process of wheat that increases the sugar content and hence the taste, crispness and over-all acceptability of the formulated products. However the colour enhancement was due to the sugar caramelisation and malliard reaction between sugar and amino acid. (Iwe, 2000; Fallico, 2003).

Cost of Production

Biscuits: The cost of production of wheat-cauliflower leaf powder biscuits (90:10:: malted wheat flour: cauliflower leaf powder) is based upon cost of all ingredients used and some other factors viz. processing charges, polythene pouches etc. The cost was calculated on the basis of current market prices of the ingredients and nominal processing charges. The cost of production per kg of biscuits came out to be Rs 86.88 (Table 5).

Noodles: The wheat-cauliflower noodles is a new product, its cost of production is very low *i.e.* Rs. 26.54 per kg of noodles whereas, noodles available in market costs Rs 40 kg^{-1} (Table 6).

Therefore, it can be concluded that incorporation of 30% malted wheat flour not only improves the nutritive value but increases the sensory attributes of the products. Hence there is a need for these types of value added functional foods to be commercialized. This initiative can be undertaken by small and large scale industries to provide healthy food to all. However, these new products are

Table 4. Organoleptic evaluation of high fiber biscuits and noodles

Treatments	Biscuits				Noodles			
	Texture	Colour	Taste	Overall Acceptability	Texture	Colour	Taste	Overall Acceptability
T_1	7.21	7.40	7.93	7.93	7.37	7.83	7.34	7.95
T_2	7.09	7.57	7.39	7.39	6.74	7.54	7.14	7.51
T_3	5.99	6.02	6.03	6.03	6.29	6.69	6.93	6.09
T_4	5.50	6.57	5.55	5.55	5.86	6.11	6.56	5.75
T_5	7.13	7.58	7.41	7.41	7.87	7.59	7.59	7.98
T_6	8.17	8.14	8.18	8.18	7.97	7.92	8.15	8.13
T_7	6.67	6.84	6.92	6.92	6.14	7.47	5.90	7.76
T_8	6.40	6.14	6.56	6.56	6.59	7.33	5.41	7.03
T_9	7.03	7.57	7.52	7.52	7.43	7.40	7.39	7.37
T_{10}	7.22	7.43	7.93	7.93	7.47	7.72	7.49	7.98
T_{11}	6.40	7.14	7.09	7.09	7.26	6.54	7.07	6.90
T_{12}	6.24	7.00	6.76	6.76	5.41	5.97	6.67	5.66
Mean	6.75	7.12	7.11	7.11	6.87	7.18	6.97	7.18
C.D. ($p \leq 0.05$)	0.05	0.03	0.04	0.02	0.05	0.05	0.04	0.06

Table 5. Cost of production of the best treatment combination biscuits

Ingredients	Rate (Rs kg^{-1})	Biscuits (90 : 10:: malted wheat flour: cauliflower leaves)	
		Quantity	Amount (Rs.)
Wheat	15	900 g	13.50
Cauliflower leaves	5	100 g	0.50
Pre- processing ingredient @ 20%		-	2.80
Ghee	80	400 g	32.00
Salt	12	37.5 g	0.45
Sugar	30	300 g	9.00
Ammonia powder	48	50 g	2.40
Ajwain	40	37.5 g	1.50
Sub total cost of ingredients			62.15
Processing charges (including labour and fuel) @20%			12.43
Polythene pouches	10 paisa	30 pouches	3.00
Machinery depreciation @12%		-	9.30
Total cost			86.88

Table 6. Cost of production of the best treatment combination noodles

Ingredients	Rate (Rs. Kg^{-1})	Noodles (90 : 10:: malted wheat flour: cauliflower leaves)	
		Quantity	Amount (Rs.)
Wheat	15	900 g	13. 50
Cauliflower leaves	5	100 g	0. 50
Pre- processing cost@20%		-	2. 80
Salt	12	37.5 g	0.45
Sub total cost of ingredients			17.25
Processing charges (including labour) @20%			3.45
Polythene pouches	10 paisa	30 pouches	3.00
Machinery depreciation @12%			2.84
Total cost per kg of noodles			26.54

unfamiliar to consumers, so they need to be properly advertised to educate the consumers prior to introduction into the market where a popular and more familiar competitor product already existed.

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Rice Production through Direct Seeded Rice– A Mitigation Option in Changing Climatic Scenario of Jharkhand, India

V. K. Singh, C. Kumari[1], B. Singh[1], M. Kumar[1], R. Ranjan[1], Rakesh K. Singh and Vinod Kumar

Indian Institute of Sugarcane Research, Lucknow-226002, India
[1]Krishi Vigyan Kendra, Koderma-825109, India
Email: vkspckoderma@gmail.com

Abstract: Short duration drought tolerant Sahbhagi dhan recorded maximum grain yield (31.42 q ha^{-1}) in rainfed condition under direct seeded rice (DSR) mode followed by CR Dhan 40. Application of brown manuring caused maximum suppression of weed biomass and with 56.34 per cent weed control efficiency followed by post emergence application of Bispyribac sodium @ 30 g ha^{-1}. Farmers observed that this method of rice cultivation reduced the water requirement and drudgery with reduced labour involvements. They showed positive response to adopt this technology due to its feasibility and profitability in rainfed situation.

***Keywords*:** Brown manuring, Drought, DSR, Rainfed, *Sesbania*

Rice (*Oryza sativa* L.) is life for more than half of humanity in globe. In 2013, the world dedicated 163.1 million hectares for rice cultivation and the total production was about 744.4 million tonnes with an average world farm yield for rice was 4.56 tonnes per hectare (FAO, 2014). Rice is one of the most important food crops of India in term of both area, production and consumer preference. India is the second largest producer and consumer of rice in the world. In India (2013), it is being grown in 42.75 million hectares and produces about 105.24 million tonnes, with an average productivity of 2.46 t ha^{-1}, which very low as compare with average global productivity (Anonymous, 2014).

Climate change is the most important global challenge facing humanity with implications for natural ecosystems, agriculture and health. For a country like India, sustainable agricultural development is essential not only to meet the food demands, but also for poverty reduction through economic growth by creating employment opportunities in non-agricultural rural sectors. To avoid the worst predicted impacts of climate change, there is need to enhance resilience of Indian agriculture to climate change and climate vulnerability through strategic research, field trails and technology demonstration covers crops, livestock, fisheries and natural resource management for sustainable food security. Climate change is projected to have significant impacts on changing of precipitation patterns, erratic rainfall, long dry spell, reduced rainy days, frequent drought is being observed, has become the major constraints to rice production in rainfed areas, resulting in large yield losses and limiting the average yield productivity. More specifically in rainfed uplands, which get saturated for a small period after the rainfall, drought not only damages the vegetative growth but also reduces the grain yield if it occurs for extended periods during vegetative and reproductive stages. Transplanting of rice is more water demanding, laborious, time consuming and entails a lot of expenditure on raising nursery, uprooting, and transplanting. Scarcity of labour during peak period of transplanting, uncertain supply of irrigation water, depletion of groundwater and increasing production cost necessitate the search for an alternative to the conventional puddled transplanting of rice. Drought stress is severely damaging during reproductive stages of the rice crop, especially during flowering, although drought in other stages can also lead to significant yield reductions (Liu *et al.,* 2006: Serraj *et al.,* 2009). In recent years, there has been a shift from transplanted rice to direct seeded rice in several countries of Southeast Asia (Pandey and Velasco 2002). Thus, direct seeding rice is gaining popularity among farmers of Jharkhand, India. The objectives of this research is to identify feasible practice that might help to boost the rice productivity under farmers' environment and cropping system in rainfed situation. The results of these trails will be used to plan future research and to make recommendations for farmers.

MATERIAL AND METHODS

The present study was carried out by Krishi Vigyan Kendra, Koderma under ICAR-CRRI, Cuttack during 2012-13 to 2014-15 on farmers' field. Village survey was done with using various participatory rural appraisal (PRA) tools. On farm trails were formulated and implemented by farmers to get the solution of low yield of rice in DSR under upland condition. DSR practiced by seeding dry seeds in unsaturated soil by line sowing with seed cum fertilizer drill. The experiment was in randomise block design with four treatments (rice local variety-Sita; Sahbhagi dhan; Dhan 40 and Vandana) and six replications (number of farmers) with plot size of 500 sm. The second experiment was on weed managment with four treatments (Farmers Practice; Application of pendimethalin @1kg ha^{-1}; Application of bispyribac sodium @ 30 g ha^{-1} and Brown manuring), in 6 replications (number of farmers), plot size of 500 sm with variety Sahbhagidhan. Pendimethalin was sprayed just 2 days after sowing and bispyriback sodium at 16 days after sowing. In farmers' practice one hand weeding was done at 20 days after sowing and in "brown manuring" *Sesbania* seed @ 40kg ha^{-1} was sown in between two rows of rice in those plots where it had to be inter-cropped, spraying with 2,4-D was done after 25 days of sowing for killing *Sesbania*. Rice was grown as per recommended practices (REF) plant height, plant population and weed biomass were recorded at 50% flowering. Weed control efficiency (WCE) was calculated (Cheema and Singh, 1991) as-

{(DMC – DMT)/ DMC}x 100

DMC = Dry matter of weeds in control plot

DMT = Dry matter of weeds in a particular treatment.

RESULTS AND DISCUSSION

The result (Table 1) of present field trial revealed that number of panicle m^2, number of grains per panicle, grain yield and harvest index were recorded significantly superior in all the treatments over farmers' practice. Grain yield was increased the tune of 34.15, 16.43 and 11.4 per cent with Sahbhagi dhan, C R Dhan 40 and Vandana, respectively over Farmers' practice (23.42 q ha^{-1}). The major weed flora observed in the direct seeded rice field comprised of *Echinochloa crusgalli*, *Echinochloa clolona*, *Leptochloa chinensis*, *Commelina diffusa*, *Eragrostis japonica*, *Cyperus rotundus*, *Cyperus iria, Fimbristylis miliacea, Caesulia axillaris, etc.* The major weed flora observed in the rice field comprised of *Echinochloa crusgalli*, *Echinochloa clolona*, *Leptochloa chinensis*, *Commelina diffusa*, *Eragrostis japonica*, *Cyperus rotundus*, *Cyperus iria, Fimbristylis miliacea, Caesulia axillaris, etc.* Data revealed from results (Table 2) that number of panicle m^{-1} and number of grains $panicle^{-1}$ were recorded significantly superior with all the treatments over farmers' practice. Rice grain yield and harvest index were recorded highest with brown manuring followed by application of bispyribac sodium which was significantly superior over farmers' practice. The brown manuring was superior as compared to herbicidal treatments as it recorded lowest weed biomass at harvesting followed by post-emergence application of byspiribac sodium and pre-emergence application of pendimethalin during both the 2013-14 and 2014-15. Weed control efficiency (WCE) was maximum in brown manuring followed by application of byspiribac sodium and pendimethalin. Brown manuring incorporation influenced grain and straw yields of rice may be due to reduce the weed biomass and some additional nitrogen added in the field through green biomass than application of herbicides and farmers' practice. Sharma *et al*, (2008) also reported higher grain yield in the *Sesbania* co-culture in direct seeded rice. Singh and Singh (2007) also reported that *Sesbania* co-culture reduced broadleaf and grass weed density and total weed biomass compared with a sole rice crop. Benefit-cost analysis calculation showed that

Table 1. Number of panicle, number of grains, grain yield, harvest index and B:C ratio as influenced by different cultivars

Treatments	No. of Panicle m^{-2}	No. of grains $panicle^{-1}$	Grain yield (q ha^{-1})	Harvest Index %
Farmers' Practice- Cv. Sita	130	84	23.42	36.4
Cv. Sahbhagi dhan	173	119	31.42	42.7
Cv. C R Dhan 40	162	114	27.27	40.6
Cv. Vandana	146	98	26.09	39.4
CD (0.05)	7.2	6.9	0.8	1.4

Table 2. Impact of weed management practices on weed biomass and growth and yield attributes of rice by method of weed control

Treatments	Weed biomass (g/s m)	Weed control efficiency %	Number of Panicle m^{-2}	No. of grains $panicle^{-1}$	Grain yield (q ha^{-1})	Harvest Index (%)	B:C ratio
Farmers' Practice	185	-	127	81	26.15	37.21	1.64
Pendimethalin @1kg ai /ha	122.45	33.85	146	96	27.26	38.2.1	1.71
Bispyribac sodium @ 30 g *ai* /ha	84.25	54.49	158	102	31.87	41.6	2.03
Brown manuring	80.82	56.34	171	108	35.46	43.8.2	2.21
CD (p=0.05)	3.3	-	6.42	3.84	1.99	2.98	-

brown manuring was the most economic followed by application of byspiribac sodium.

Farmers observed that rice cultivation in DSR mode reduced water demand and drudgery with reduced labour involvements as compared transplanting mode. The technology is more feasible and profitable for rainfed situation. For efficient resource utilisation, the DSR needs to be upscale in a large scale. The upscaling procedure requires more awareness on the practice by organizing field visit, publications with scientific results, block level recommendations through the agricultural department etc.

CONCLUSION

Rapid growth of *Sesbania* (brown manuring) helps to suppress weed by covering of soil surface and create a live mulch to conserve the soil moisture and reduce weed competition for nutrients, moisture and sun light. Adopting DSR with short duration drought tolerant rice variety sahbhagidhan with brown manuring for effective weed management, is the only option for sustainable rice production in rainfed condition of Jharkhand in changing climatic scenario.

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Identifying Drudgery Prone Rice Cultivation Activities in Northern India

Pragya Ojha and Seema Kwatra

Department of Family Resource Management, College of Home Science
G.B. Pant University of Agriculture & Technology, Pantnagar -263 145, India
E-mail: ojha.pragya063@gmail.com

Abstract: Manual uprooting and transplanting of rice is tedious, tiresome and labor consuming, because agricultural workers has to stand in puddle field and bend for hours for putting seedling into the soil by hand. Keeping this in view, the present study was planned to compare the rate of human drudgery among farm workers, during various phases of manual uprooting and transplanting with the mechanized methods. The results revealed that more than 75 per cent agricultural workers were belonged to lower middle socio economic status. It was also observed that as compared with others, manual uprooting was the maximum drudgery prone rice cultivation activity based on drudgery index.

Key Words: Agricultural workers, Body postures, Drudgery index, Ergonomics, Rice cultivation

The soil of *tarai* region of Uttarakhand is very fertile and support to number of crops. According to information of Area Production and Productivity 2010-11, the agricultural productivity of district Udham Singh Nagar, Haridwar, Nainital (plain) and Dehradun (plain) is very high. Rice is cultivated in all the 13 districts of the state, but maximum area (33%) is in district Udham Singh Nagar which produces about 48% of the total rice produced annually in the state (Mani, 2014). Manual paddy transplanting is a labour intensive operation which requires 200-250 man-h ha^{-1} (Das, 2012). Agriculture workers of India suffer from grave disadvantages and are subjects to a great deal of hardship and drudgery, particularly in rural areas. During manual rice uprooting and transplanting agricultural workers are suffered with the high level of drudgery and the work performance of the agricultural workers is also significantly reduced. Besides this, working conditions of agricultural workers are extremely difficult due to severe environmental conditions, long working hours, strenuous work and the use of improper equipment (Kar *et al*., 2012). Recognizing the importance of reducing drudgery and to improve the efficiency of workers, the present study was planned to find out drudgery index of uprooting and transplanting activities with manual and mechanized methods, in terms of frequency of performance of various activities by agricultural workers, time spent in activities and degree of difficulty perceived.

MATERIAL AND METHODS

Selection of subject and field: The ergonomical evaluation of paddy transplanting was conducted with female agricultural workers in Tarai agro- climatic zone of Udham Singh Nagar district of Uttarakhand state, India in the month of June- July. Forty agricultural workers in the age group of 20- 45 years were selected because they usually attain their highest strength level between 20-45 years. For the comparison of drudgery in mechanized and conventional method, agriculture workers performed the paddy uprooting and transplanting activity with manual method in bending posture and power operated eight row paddy transplanter adopted from Department of Farm Machinery and Power Engineering, College of technology, GBPUA&T, Pantnagar. The detail of specifications of power operated 8 row paddy transplanter is given in Table 1. Field women performed the continuous transplanting operations for 50 minutes and taking 10 minutes break.

Personal and demographic profile: Survey method was adopted to collect the data. Socio economic status scale developed by Aggarwal *et al.* (2005) and interview schedule was used to elicit information from the agricultural workers who were actively involved in rice cultivation activities. Interview schedule mainly consisted of frequency of performance, time spent (minutes/ day) and difficulty felt by the respondents. The perceived difficulty felt in performance of uprooting and transplanting activities was assessed in a five-point scale that is, very easy (1), easy (2), neutral (3), difficult (4) and very difficult (5).

Assessment of human drudgery among agricultural worker: Drudgery index (DI) was calculated as under

Drudgery Index = $[(X+Y+Z)/3] \times 100$.

X = coefficient pertaining to difficult felt.

Y = Coefficient pertaining to time spent in particular home activity.

Z = Coefficient pertaining to frequency of performance

Table 1. Specification of power operated eight row paddy transplanter

Details	Specifications
Type	Single wheel driven using mat type rice nursery
Dimensions(L×W×H)	2410×2130×1300 (mm)
Engine (hp)	4.0, air cooled diesel
Number of rows	8
Row spacing (mm)	238
Hill-to-hill spacing (mm)	100 -200
Working speed (km h^{-1})	1.5-2.0
Speed of travel on road (km h^{-1})	8.24
Field capacity (ha h^{-1})	0.13 -0.20
Weight (kg)	320
Type	Single wheel driven using mat type rice nursery
Dimensions(L×W×H)	2410×2130×1300 (mm)
Engine (hp)	4.0, air cooled diesel
Number of rows	8

Table 2. Frequency of performance in uprooting and transplanting (per cent)

Activities	Daily	Alternate day	Weekly
Manual Uprooting	35 (87.5)	4 (10)	1 (2.5)
Manual transplanting	37 (92.5)	3 (7.5)	-
Mechanical uprooting	24 (60)	15 (37.5)	1 (2.5)
Mechanical Transplanting	26 (65)	9 (22.5)	2 (5)

RESULTS AND DISCUSSION

On the basis of arbitrary classification, the social status was categorized into six groups, i.e. upper high, high, upper middle, lower middle, poor and very poor or below poverty line. Majority of the agricultural workers belonged to lower middle class (80%), whereas, 7.5 per cent agricultural workers falls in Upper Middle category, followed by 2.5 per cent agricultural workers who were from high class category and 10 per cent agricultural workers of upper high class category.

Uprooting and transplanting activities: Data pertaining to performance was elicited in a four point scale viz., daily (4), alternate day (3), weekly (2) and fortnightly (1). It was observed that majority of the agricultural workers i.e. 87.5 per cent, performed the manual uprooting daily. Further, 92.5 per cent agricultural workers performed the manual transplanting daily. Total 65 per cent agricultural workers performed the mechanical transplanting with eight rows rice transplanter on daily basis. Besides this, only 7.5 per cent respondents also reported that they performed the mechanical transplanting fortnightly (Table 2).

Time spent in various activities: The various phases of manual uprooting activity, uprooting the seedling by both the hands until those become hand full require maximum time (162.79 min day^{-1}) followed by washing the bundle of rice seedling requiring 93.67 min day^{-1}. In manual transplanting activity, agricultural workers spend their maximum time i.e. 193.65 min day^{-1} in taking few seedlings by the right hand and planting them into soil and left hand (with seedlings) remained on the left thigh near the folded knee (Phase 3) whereas phase 2 of manual transplanting required 97.10 min/day. As compared to manual uprooting and transplanting, mechanical method uprooting and transplanting required less time. During mechanical uprooting activity, for picking up the rice mat from ground agricultural workers required only 22.36 min day^{-1} and for putting the mat on the transplanter 26.10 min day^{-1} was required. For the transplanting of seedling by eight row paddy transplanter only 20.68 min day^{-1} was required.

Constraints in performance of uprooting and transplanting: During , Bending to reach the seedling on the seed bed i.e. phase 1 of manual uprooting, 67.5 per cent agriculture workers perceived the task to be very difficult (Table 3). Whereas, during phase 2 of manual uprooting, total 52.5 per cent agriculture workers were found it to be of very difficult. More than ninety per cent agriculture workers reported the activity as very difficult in phase 3 of manual transplanting. Besides this, in mechanical uprooting and transplanting activities, more than 85 per cent agricultural workers reported that they found the activity very easy to perform.

Drudgery index of uprooting and transplanting: Drudgery index of uprooting and transplanting activities was determined by calculating the time co-efficient, frequency of performance coefficient and difficulty coefficient. Thereafter, four major drudgery prone phases of manual uprooting and transplanting activities performed by agricultural workers were selected on the basis of Drudgery Index (DI). It is evident from table 5 that the uprooting the seedling by both the hands until those becomes hand full, washing the bundle of rice seedling and bending to reach the seedling on the seed bed were the maximum drudgery prone phases of manual uprooting activity. The difficulty index of uprooting the seedling by both the hands until those become hand full was highest (DI=64.96) followed by washing the bundle of rice seedling and bending to reach the seedling on the seed bed.

In manual transplanting, the drudgery index of phase 3 was highest (DI=63.20). Another study of Kishtwaria *et al.* (2009) reported that transplanting is perceived to be the

Table 3. Time spent (minutes day^{-1}) and difficulty felt in performance of uprooting and transplanting

Activities	Minutesday^{-1}	Very easy	Easy	Neutral	Difficult	Very difficult
Manual uprooting						
Bending to reach the seedling on the seed bed	73.36	(2.5)	-	(5)	(25)	(67.5)
Uprooting the seedling by both the hands until those become hand full	162.79	3 (7.5)	1 (2.5)	3 (7.5)	12 (30)	21(52.5)
Washing the bundle of rice seedling	93.67	-	3 (7.5)	1 (2.5)	15 (37.5)	21(52.5)
Tying the bundle	90.85	-	1 (2.5)	6 (15)	24 (60)	(22.5)
Keeping the bundle on the ground	55.36	-	7 (17.5)	11 (27.5)	2 (5)	20 (50)
Manual transplanting						
Taking the bundle of seedling and untying it	60.48	5 (12.5)	-	3 (7.5)	3 (7.5)	29 (72.5)
Making the bundle into two halves and griping one half in one hand	97.10	2 (5)	6 (15)	1 (2.5)	10 (25)	21 (52.5)
Taking few seedlings by the right hand and planting them into soil. Left hand (with seedlings) remained on the left thigh near the folded knee	193.65	-	-	-	3 (7.5)	37 (92.5)
Mechanical uprooting						
Pick up the rice mat from ground	22.36	35 (87.5)	2 (5)	3 (7.5)	-	-
Put it on the transplanter	26.10	40 (100)	-	-	-	-
Mechanical transplanting						
Transplanting of seedling by transplanter	20.68	40 (100)	-	-	-	-

Table 4. Drudgery index of uprooting and transplanting

Activities	Frequency coefficient	Difficulty coefficient	Average time spent coefficient	Drudgery index
Manual uprooting				
Bending to reach the seedling on the seed bed	0.98	0.65	0.009	54.63
Uprooting the seedling by both the hands until those become hand full	0.98	0.96	0.009	64.96
Washing the bundle of rice seedling	0.91	0.74	0.017	55.56
Tying the bundle	0.87	0.51	0.025	46.83
Keeping the bundle on the ground	0.98	0.47	0.007	48.56
Manual transplanting				
Taking the bundle of seedling and untying it	0.57	0.87	0.008	48.26
Making the bundle into two halves and griping one half in one hand	0.64	0.75	0.017	46.90
Taking few seedlings by the right hand and planting them into soil. Left hand (with seedlings) remained on the left thigh near the folded knee	0.98	0.91	0.006	63.20
Mechanical uprooting				
Pick up the rice mat from ground	0.57	0.68	0.008	41.93
Put it on the transplanter	0.63	0.60	0.074	43.46
Mechanical transplanting				
Transplanting of seedling by transplanter	0.55	0.51	0.009	35.63

most difficult task in farm operations. Ojha and Kwatra (2014) also highlighted that due to high level of physiological workload during manual method of paddy transplanting, maximum farm women suffered from the work related disorders and which decreases their performance on the field.

It was concluded that for the significant reduction of the physiological workload and human drudgery, there is dire need to create awareness about the use of mechanized method of paddy transplantation, among the farmers of northern India, who are usually involved in conventional and manual method of transplanting.

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Genetic Variability, Heritability and Genetic Advance for Seed Yield and its Component Traits in Urdbean Germplasm [*Vigna mungo* (L.) Hepper]

Baudh Bharti and Rajesh Kumar

Department of Genetics and Plant Breeding
N.D. University of Agriculture and Technology, Kumarganj, Faizabad-224 229, India
E-mail: *baudhbhartigpb@gmail.com*

Abstract: The genetic materials consisted of 100 germplasm lines with four checks viz., Uttara, Pant U-31, Shekhar and NDU-1, which showed significantly differences for all traits except, primary branches per plant and 100- seed weight. Differences among the check varieties were highly significant for plant height. However, it was non-significant for remaining ten characters under study. Relatively higher estimates of phenotypic coefficient of variation were observed for seed yield per plant followed by biological yield, clusters per plant, plant height, harvest index and primary branches. The highest genotypic coefficient of variability was observed for seed yield per plant, biological yield and plant height which indicates the presence of exploitable genetic variability for these traits. Seed yield per plant, plant height and biological yield, showed high heritability and genetic advance. Thus these traits would be more fruitful for direct selection in existing populations.

Key Words: Blackgram, Heritability, Genetic variability, Genetic advance

Pulses are the principal source of dietary protein among vegetarians and are an integral part of daily diet because of their high protein content and good amino-acid balance in several forms world-wide.Legumes adapt well to various cropping systems owing to their ability to fix atmospheric nitrogen in symbiosis with soil bacteria of *Rhizobium spp.*Urdbean [*Vigna mungo* (L.) Hepper,] are important legume crop widely cultivated in Asia. *V. mungo var. silvestris* is the wild proginator of urdbean.

However, to carry out effective selection, the information on available genetic variation among urdbean genotypes, the nature of component traits on which selection would be effective and the influence of environ-mental factors on each trait need to be known. Information on the nature and magnitude of variability and heritability in a population is one of the prerequisites for successful breeding program in selecting genotypes with desirable characters. It is therefore, of great importance for breeders to know the heritability of the agronomical characters to improve the yield of the crop effectively. Present investigation was carried out to assess the genetic variability, different traits towards yield and selection of high yielding genotypes with better architecture.

The experiment was conducted at Narendra Deva University of Agriculture and Technology, Narendra Nagar Kumarganj, Faizabad (U.P.) during *Kharif,* season of 2011. The genetic materials consisted of 100 germplasm lines with four checks *viz.,*Uttara, Pant U-31, Shekhar and NDU-1 (Table 1) under normal soil and irrigated condition using augmented design. The entire experimental field was divided into 10 blocks of equal size and each block was having 14 plots. The checks were accommodated randomly in each block with test genotypes. Each plot represented by one row of four meter length, keeping row to row distance of 30 cm and plant to plant spacing of 10 cm. All the recommended cultural practices were applied to raise a good crop.

The data on seed yield and its components were recorded on five randomly plants taken in each genotypes from each plot for eleven characters (Table 1). However, days to 50% flowering and days to maturity were recorded on plot basis. Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability and genetic advance in per cent of mean were computed as per standard formulas.

In general, urdbean genotypes showed wide range of variability for most of the characters and all the traits exhibited broad spectrum of ranges between the maximum and minimum genotype mean values (Table 2). Days to 50% flowering ranged from 40.05 to 60.05 with a mean of 52.51, days to maturity ranging from 64.12 to 93.12 with a mean of 81.90.

Similarly, plant height and primary branches plant^{-1} from 37.91 cm to 151.88 cm and 1.50 to 5.24, respectively while, clusters plant^{-1} varied from 3.43 to 12.60 with a mean clusters plant^{-1} of 7.57. Pods cluster^{-1} 1.67 to 5.34 with a mean seeds pod^{-1} of the test genotypes varied from 2.32 to 6.67 with mean of 4.64. Seed yield plant^{-1} 1.58 to 9.25g with a mean of 4.29g and that of 100 seed weight 2.95 to 5.08 g with a mean weight of 3.76g.

Table 1. List of Urdbean germplasm used in present investigation during *Kharif* season, 2011

Code	Genotype	Code	Genotype	Code	Genotype
G1	KU-314	G36	SU-313	G71	KU-714
G2	SU-322	G37	C-29	G72	C-441
G3	KU-1812	G38	G-12118	G73	KU-96-3xKU-309
G4	SU-323	G39	NDU-99-2	G74	KU-5-549
G5	KU-8/12	G40	C-14	G75	KU-300xIPU-94-10
G6	KU-311	G41	C-45	G76	KU-342
G7	SU-311	G42	C-126	G77	KU-10125
G8	KU-98126	G43	C-227	G78	KU-315
G9	KU-4-10	G44	AKU-15	G79	C-254
G10	KU-4/12	G45	KU-12/12	G80	KU-362
G11	KU-333	G46	KU-363	G81	KU-10/14
G12	KU-321	G47	PLU-83-64	G82	UHUG-197
G13	KU-362	G48	T-9	G83	KU-366
G14	C-288	G49	KU-367	G84	KU-814
G15	KU-714	G50	KU-512	G85	KU-369
G16	KM-6-132	G51	C-42	G86	KU-11/16
G17	SU-354	G52	C-19	G87	PLU-1036
G18	KU-2/10	G53	PLU-98213	G88	KU-5-571
G19	KU-5-53	G54	IPU-94-1xIPU-4	G89	KU-2/13
G20	C-312	G55	KU-17136	G90	KU-361
G21	C-209	G56	CU-7829	G91	PLU-42
G22	SU-355	G57	KU-96-3xIPU-96-1	G92	C-67
G23	KUS-553	G58	JU-77-44	G93	KU-820
G24	KU-9820	G59	DU-1	G94	C-237
G25	C-69	G60	KU-2115	G95	C-182
G26	KU-364	G61	PLU-143	G96	PU-192
G27	UL-9	G62	C-72	G97	KU-37/g
G28	KU-300	G63	KU-360	G98	C-81
G29	LBG-368	G64	OH-86-20	G99	KU-99
G30	KU-368	G65	PLU-7044	G100	C-42
G31	KU-370	G66	DPU-88-31	G101	NDU-1 (Check 1)
G32	KU-342	G67	KU-300xKU-309	G102	Uttra (Check 2)
G33	C-66	G68	KU-5-31	G103	Pant U 31 (Check 3)
G34	KU-372g	G69	KU-323	G104	Shekhar (Check 4)
G35	IC-1412	G70	GH-82-21		

The maximum yield obtained was 9.25g followed by 9.15g. Thus, it is possible to improve seed yield by direct selection. Biological yield ranged from 5.91 to 43.55g with a general mean of 18.29g, whereas, harvest index varied from 7.80 to 39.83% with a general mean of 24.48%.

The range of variation was wide for the plant height (cm), biological yield (g), harvest index (%) and days to maturity.

Estimates of variance components: The considerable variability suggests an opportunity of selection for the improvement of urdbean landraces. The higher the PCV and or GCV, the more will be chance for exploitation of that not sufficient for determination of amount of heritable variability. In addition, estimation of heritability and genetic advance as percent of mean is also needed to assess the extent of genetic gain expected from effective selection. As heritability in broad sense includes both additive and epistatic gene effects, it will be reliable only when it is accompanied with high genetic advance.

In general, phenotypic coefficients of variability were higher than corresponding genotypic coefficients of variability for all the traits which demonstrated the effect of

Table 2. Estimates of variability, heritability and genetic advance as percentage of mean

Characters	Range		Grand mean	Coefficients of variability		Heritability (b s)	Genetic advance	Gen. adv. as % of
	Lowest	Highest	$(\bar{X}) \pm$ SE	GCV	PCV	(%)	(GA)	means (5%)
Days to 50%flowering	40.05	60.05	52.51 ±0.43	7.28	8.26	77.69	6.99	13.23
Days to maturity	64.12	93.12	81.90±0.68	8.38	8.74	91.86	13.59	16.56
Plant height(cm)	37.91	151.88	85.72 ±2.50	25.76	26.07	97.64	45.06	52.45
Primary branches/ plant	1.50	5.24	3.50±0.08	8.82	20.55	18.42	0.27	7.81
Clusters / plant	3.43	12.60	7.57±0.20	19.34	26.23	54.36	2.23	29.39
Pods / cluster	1.67	5.34	3.34±0.07	13.01	18.38	50.14	0.64	18.99
Seeds / pod	2.32	6.67	4.64±0.09	12.00	18.44	42.29	0.75	16.08
Seed yield/ plant (g)	1.58	9.25	4.29±0.17	34.71	35.74	94.31	2.99	69.45
100 seed weight (g)	2.95	5.08	3.76±0.04	5.27	10.66	24.46	0.20	5.37
Biological yield (g)	5.91	43.55	18.29±0.80	31.23	35.67	76.66	10.29	56.34
Harvest index (%)	7.80	39.83	24.48±0.69	16.76	21.99	58.07	6.47	26.31

environment upon the traits (Table 2). A relatively higher estimate of phenotypic coefficient of variation (PCV of more than 20%) were observed for seed yield plant^{-1} (35.7) followed by biological yield (35.67), clusters plant^{-1} (26.23), plant height (26.07), harvest index (21.99) and primary branches (20.55).

The highest genotypic coefficient of variability was observed for seed yield plant^{-1} (34.71), biological yield (31.23) and plant height (25.76), which indicates the presence of exploitable genetic variability for these traits. Moderate genotypic and phenotypic coefficient of variation (10 to 20%) were observed for pods cluster^{-1} (13.01 and 18.38) and seeds pod^{-1} (12 and 18.44), which revealed that there is considerable scope for improving these trait in desirable direction through a selection programme. Low estimates of genotypic and phenotypic coefficient of variation were observed for the days to flowering (7.28 and 8.26) and days to maturity (8.38 and 8.74).

Estimation of heritability in broad sense and genetic advance: The heritability in broad sense was calculated for all characters under study and is presented in (Table 2). High estimate of heritability were exhibited for five traits *viz.,* plant height, seed yield plant^{-1}, days to maturity, days to 50% flowering, and biological yield. While moderate estimates of heritability were recorded for harvest index followed by clusters per plant,pods per cluster and seeds per pod.

In other words genetic advance denotes the improvement in the genotypic value of the new populationover the original population. The expected genetic advance as per cent of mean revealed that the highest (> 20%) genetic advance aspercent of mean was recorded for seed yield plant^{-1} (69.45), biological yield (56.34), plant height (52.45), clusters plant^{-1} (29.39) and harvest inde x (26.31). While moderate (>10 %) estimates of genetic advance as percent of mean for pods cluster^{-1} (18.99), days to maturity (16.56), seeds pod^{-1} (16.08) and days to 50% flowering (13.23). However, it was recorded lowest for 100 seed weight (5.37) followed by primary branches per plant (7.81). These findings were also supported by the results of Singh *et al.* (2011) and Ramya *et al.* (2010). Roychowdhury *et al.* (2012). From the present investigation, it is evident that the wide range of variability for different traits coupled with high heritability and high genetic advance should be considered for direct selection. Here seed yield plant^{-1}, plant height and biological yield showed high heritability and genetic advance, thus would be more fruitful for direct selection in existing populations.

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Effect of Planting Time on Physiolological Parameters of German Chamomile (*Matricaria chamomilla* Linn.)

Deepika, U. K. Varshney, Minakshi Pal[1] and G. Chand[*2]

Department of Botany and Plant Physiology, CCS HAU, Hisar-125 001, India
[1]Centre for Plant Biotechnology, Hisar-125 001, India
[2]Division of Plant Physiology SKUAST-180 009, India
**E-mail: gurdev74@gmail.com*

Abstract: A field experiment was carry out under natural conditions of screen house to estimate influence of chloride and sulphate dominated salinity on seedling establishment, days to flower initiation, days to maturity, stem and branches dry weight, leaf dry weight plant^{-1}, root dry weight and flower heads dry weight in German chamomile (*Matricaria chamomilla* Linn) at varying EC level 0, 4, 8, 12 and 16 dSm^{-1}. The parameters were studied at three different planting times i.e. early sown, timely sown and late sown. The various physiological parameters adversely affected by the presence of salinity in the growing medium. Chloride and sulphate dominated salinities affect the various growth and yield parameters differently at different planting time. The parameters such as stem and branches dry weight plant^{-1}, leaf dry weight plant^{-1}, root dry weight plant^{-1} and flower heads dry weight suffered a decline with the increasing salinity levels at different planting time. Sulphate dominated salinity was found more depressive than chloride dominated salinity with regard to all physiological parameters at different interval of time. It is concluded that there is not only a substantial delay in flower initiation but also an early maturity of German chamomile under salinity stress. Timely sown crop showed a remarkable growth as compared to early sown and late sown. German chamomile appears to be highly salt tolerant medicinal herb as it's plants survived and reproduced at the highest salinity level (16 dSm^{-1}).

Key Words: Growth, German chamomile, Salinity

Matricaria chamomilla Linn. popularly known as German chamomile is native of Europe and adjoining Asian countries. In India the seeds were obtained from France as early as in late fifties for trial cultivation at regional research laboratory, Jammu (Handa *et al.,* 1957) Agricultural production adversely affected by soil salinity is one of the worldwide problems (Levitt, 1980). Salinity stress is one of the main limiting the agriculture production in the world (Kerepesi *et al.,* 2002). Two phases of plant in response to salinity are: a rapid osmotic phase and a slower, ionic phase. Prolonged exposure of crop plants to higher level of salinity results in inhibition of growth and yield reduction. Yield stability and tolerance are complex; difficult to establish in crops at any stage of plant development. In future, agricultural production will increasingly rely on our ability to grow plants on salt affected and marginal lands using saline water (Roezma and Flowers, 2008). Due to presence of active ingredients such as Sezkoitropsflaw nods, komarins and polystilen chamomile has been introduced as medicinal plants in the world and due to its increasing use in cosmetic, pharmaceuticals, hygiene, perfumery and food flavorings is of highly importance (Afzali *et al.,* 2006). The evaluation of various plants' nourishment of particularly medical plants in order to increase the production and high quality is the basic requirements in agriculture planning. The environment is preserved with appropriate soil fertility and plant nourishment (Dermadrosian, 2001). Amelioration and utilization of these saline soils have been the focus of research for the last few decades. Various technical measures i.e. physical, chemical and mechanical have been developed to reclaim the soil, but these technologies are less attractive to the farmers due to economic viability and ecological concerns. Under these situations the viable alternative is to identify or develop salt tolerant crop genotypes for cultivation in these saline soils. Again, developing salt tolerant crop genotype is not an easy task because tolerance being a polygenic trait. Plants try to resist stress by undergoing morphological, biochemical and physiological changes brought about by altered expression of several genes. The different studies have shown that the building of effective medical plants is affected by environmental factors and genotypes (Garratt *et al.,* 2002). Therefore, integration of knowledge on physiological, biochemical and genetic aspects of salt tolerance is essential to make any progress in this direction (Ashraf and Foolad, 2007). In India about 12 million hectare of land is affected by salinity and/or alkalinity. In the state of Haryana, 0.63 million hectare of land having this problem. Salt stress creates both ionic as well as osmotic stress on plants. Also, ionic toxicity generated from salt contaminated soil has negative effects on plant growth and development (Munns *et al.,* 2006). From various studies it has been found that it is valuable crop suited for a variety of soils, its potential requires to be examined in India as an export crop in view of its high price (Rs. 15,000 kg^{-1} of oil). It is necessary to promote this valuable crop as a commercial crop for export. Therefore, the present study was carried out to observe the effect of chloride and sulphate dominated salinity on growth parameters at various planting time to find the best sowing time.

MATERIAL AND METHODS

The experiment was carried out in the screen house at CCS Haryana Agricultural University Campus, Hisar. Seeds of German chamomile were collected from medicinal section of CCS Haryana Agricultural University. The plants were raised in polythene bags each containing 6 kg of dune sand by sowing seeds at three different times i.e. early (sowing time 15 September), timely (18 October) and late (5 November). The sand filled polythene bags were saturated with the solution of salinity treatment along with the nutrient before sowing. Two types of salinity i.e. chloride and sulphate dominated salinity with three replication was given at 5 different salinity level such as 0 (control), 4, 8, 12 and 16 dSm^{-1}. Seeds were so small in size; so that seedling establishment was recorded after 15 days of sowing. Days to flower initiation and days to maturity were recorded. The dry weight was recorded after placing the fresh samples of stem, leaf, root and flower heads in an oven at 65°C for 3-4 days.

RESULTS AND DISCUSSION

The seeds germinate and emerge as seedling in 4 to 5 days of sowing. Experimental results demonstrate a cent per cent seedling establishment after 15 days of emergence in control indicating zero per cent seedling mortality The decline in seedling establishment was from 100 to 94.4% for time sown, 100 to 93.2% for early sown and 100 to 95.6% for late sown seeds. The maximum percent establishment for late sown seed was under sulphate dominated salinity at 16 dSm^{-1} (Table 1). Soil salinity creates uncongenial conditions for plants where the seeds fail to germinate either due to low osmotic potential of the medium with respect to cell sap or may be due to the injury caused by various toxic ions. The results revealed that the adverse osmotic effects superseded the ionic toxicity as far as seedling establishment of German chamomile is concerned. Salinity affects imbibition, germination and root elongation of *Matricaria chamomilla and result into decrease of germination percentage (*Joneidi, 2013). The remarkable ability of German chamomile seedlings to successfully excise the saline habitats appears to be due to small seed size with low availability of reserve food which leads to faster establishment of seedlings.

Days to flower initiation and days to maturity: A substantial delay in flower initiation but also an early maturity of German chamomile under salinity stress has been observed at different planting time. Late sown seed normally flowers fast and get mature early, but in this case reverse occur. A delay in flowering was observed under late sown but get matured early as compared to early and timely sown seed. Sulphate dominated salinity was found more depressive at different times in case of flower initiation (Table 2) The two salinity types, however, were indifferent in influencing the plants maturity (Table 3). Reports on deferred flower initiation in the medicinal plant Chandrashura (Singh, 2004) and in an ornamental *Calceoria hybrida* (Fornes *et al.,* 2007) also reveals the same observations.

Table 1. Effect of planting time on per cent seedling establishment under chloride and sulphate dominated salinity

Level of salinity	Early sown		Timely sown		Late sown	
	CDS	SDS	CDS	SDS	CDS	SDS
Control	100	100	100	100	100	100
$4dsm^{-1}$	98.4	98.4	98.6	99.5	98.9	99.6
$8dsm^{-1}$	98.1	96.2	98.4	97.9	99.1	98.2
$12dsm^{-1}$	95.6	96.4	97.7	97.3	98.2	97.5
$16dsm^{-1}$	94.2	93.2	95.8	94.4	97.6	95.6

CDS: Chloride dominated salinity; SDS: Sulphate dominated salinity

Table 2. Effect of planting time on number of days to flower initiation under chloride and sulphate dominated salinity

Level of salinity	Early sown		Timely sown		Late sown	
	CDS	SDS	CDS	SDS	CDS	SDS
Control	81.4	81.4	76.8	76.8	67.6	67.6
$4dsm^{-1}$	82.2	84.6	80.6	84	69.4	70.3
$8dsm^{-1}$	82.6	86.7	81.4	85.4	71.6	72.3
$12dsm^{-1}$	84.1	88.3	82.2	86.4	73.5	75.5
$16dsm^{-1}$	84.6	89.6	83.4	87.2	70.6	71.4

CDS: Chloride dominated salinity; SDS: Sulphate dominated salinity

Table 3. Effect of planting time on number of days to maturity under chloride and sulphate dominated salinity

Level of salinity	Early sown		Timely sown		Late sown	
	CDS	SDS	CDS	SDS	CDS	SDS
Control	145.6	145.6	136.6	136.6	125.6	125.6
4dsm^{-1}	143.6	145.2	133	133.8	124.7	125.2
8dsm^{-1}	142.5	144.2	131.4	132.8	121.6	122.7
12dsm^{-1}	138.6	138.4	129.8	130	119.2	121.3
16dsm^{-1}	140.6	141.2	132.4	133.2	120.2	122.2

CDS: Chloride dominated salinity; SDS: Sulphate dominated salinity

Table 4. Effect of planting time on stem and branches dry weight (g plant^{-1}) under chloride and sulphate dominated salinity

Level of Salinity	Early Sown		Timely Sown		Late sown	
	CDS	SDS	CDS	SDS	CDS	SDS
Control	15.42	15.42	14.98	14.98	14.79	14.79
4dsm^{-1}	14.92	14.81	14.67	14.38	14.58	14.49
8dsm^{-1}	14.73	14.6	14.45	14.19	14.39	14.25
12dsm^{-1}	14.34	13.92	14.09	13.36	13.85	13.72
16dsm^{-1}	14.12	13.74	13.8	13	13.67	13.51

CDS: Chloride dominated salinity; SDS: Sulphate dominated salinity

Table 5. Effect of planting time on leaf dry weight (g plant^{-1}) under chloride and sulphate dominated salinity

Level of salinity	Early sown		Timely sown		Late sown	
	CDS	SDS	CDS	SDS	CDS	SDS
Control	3.96	3.96	3.36	3.36	3.3	3.3
4dsm^{-1}	3.86	3.62	3.34	3.16	3.1	3.06
8dsm^{-1}	3.35	3.24	3.05	2.96	2.92	2.81
12dsm^{-1}	3.15	2.95	2.99	2.85	2.62	2.52
16dsm^{-1}	3.04	2.84	2.82	2.75	2.43	2.23

CDS: Chloride dominated salinity; SDS: Sulphate dominated salinity

Stem, branches, leaf, and root and flower heads plant^{-1} dry weight: The parameters such as leaf dry weight plant^{-1} stem and branches dry weight plant^{-1}, root dry weight plant^{-1}, flower heads dry weight, all suffered a decline with the increasing salinity levels of the growing medium. Leaf dry weight was more affected in late sown seed and least in early sown at both salinity types. Level of salinity and type of salinity is harmful to growth and development. Sulphate dominated salinity was found more depressive at different interval of time (Table 4, 5 and 6). Although flower initiation starts late in late sown seeds, but more number of flower produced in short period of time which results in greater dry weight of flower heads in late sown seed as compared to timely sown. Early sown and late sown seed did not show marked difference in flower heads dry weight at highest salinity level (Table 7). Reduction of plant metabolism results into lack of energy may be one of the causes of reduced plant growth. Reduction in dry matter production under saline environment is may be both to the decreased availability of soil water and increased toxicity of sodium and chloride or sulphate ions. The effect of salinity on growth in Chamomile (*Matricaria chamomilla* L.) in controlled environment was also observed by Heidari and Sarani (2012) by giving salinity treatment 0, 50, 100 and 150 mM NaCl in nutrient solution. Results evinces the increasing salinity from 0 to 150 mM, decreased fresh weight of shoot (76.3%) and increased of root fresh weight (53.8%). Salinity affects on the growth of plants by reduction of shoot length and biomass. The reason for the decrease in plant growth may be explained by the in osmotic pressure due to increasing salt level, which lessens the available water to plant (Huang *et al.,* 2006). German chamomile is a highly salt tolerant plant species with different medicinal values. Plants survived and complete its life cycle even at highest salinity level (16 dSm^{-1}) at all planting time. The early sown seeds produce flower which results into high oil yield. This herb can therefore be grown earlier in the areas affected by salts.

Table 6. Effect of planting time on root dry weight (g plant^{-1}) under chloride and sulphate dominated salinity

Level of Salinity	Early Sown		Timely Sown		Late sown	
	CDS	SDS	CDS	SDS	CDS	SDS
Control	1.24	1.24	1.14	1.14	1.02	1.02
4dsm^{-1}	1.19	1.16	1.12	1.12	0.98	0.95
8dsm^{-1}	1.13	1.09	1.1	1.08	0.92	0.93
12dsm^{-1}	1.08	0.98	0.95	0.93	0.85	0.87
16dsm^{-1}	0.94	0.88	0.9	0.87	0.82	0.81

CDS: Chloride dominated salinity; SDS: Sulphate dominated salinity

Table 7. Effect of planting time on flower head dry weight (g/plant) under chloride and sulphate dominated salinity

Level of Salinity	Early Sown		Timely Sown		Late sown	
	CDS	SDS	CDS	SDS	CDS	SDS
Control	4.95	4.45	4.47	4.47	4.35	4.35
4dsm^{-1}	4.84	3.82	3.91	3.54	3.88	3.82
8dsm^{-1}	3.98	3.74	3.67	3.43	3.82	3.72
12dsm^{-1}	3.72	3.54	3.36	3.14	3.24	3.12
16dsm^{-1}	3.52	3.49	3.29	1.62	2.975	2.805

CDS: Chloride dominated salinity; SDS: Sulphate dominated salinity

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Microbial and Nutritional Quality of Buck Wheat Incorporated Low Gluten Bread

Quraazah Akeemu Amin, Towseef A. Wani, Hafiza Ahsan and Nuzhat Quadir
Sher-e-Kashmir University of Agricultural Sciences and Technology- Kashmir, Srinagar – 190 025, India
E-mail: widaad57@gmail.com

Abstract: A highly nutritious pseudocereal buck wheat was incorporated into wheat flour at standardized levels of 2 ,4 ,6 and 8 % against control (no buck wheat flour incorporated) in order to study the improvement in physico-chemical quality and shelf life of sweetened bread. Adding buckwheat influences nutritional, textural and safety properties. A significant decrease in moisture, alkaline water retention capacity, per cent loss in freshness and fungal count was recorded with increasing levels of buck wheat. However, the physical properties revealed that composite flour bread showed low baking losses, increase in hardness (N) and decrease in springiness and cohesiveness of crumb texture. The highest crude protein (8.81%), crude fat (1.71%), crude fibre (2.39%) and ash (0.62 %) was in 8% buckwheat fortified bread.

Key Words: Alkaline water retention capacity, bread, buck wheat, fungal count, low gluten, texture

Bread is the most important convenient food universally accepted by all population rich and poor, rural and urban (Malomo *et al.,* 2012). Prepared from a variety of cereals dominated by wheat, bread is a valuable source of nutrients like carbohydrates, proteins, lipids in our diet. Wheat is rich in gluten, a protein composite of gliadin and glutenin, responsible for the strength, elasticity of dough, the size and uniformity of the air cells and the presence of heterogeneous matrix within the dough (Engleson and Atwell, 2008). The strength of the gluten in bakery industry is critical to mimic. Bread kept at low temperatures stale quickly due to retrogradation (Mohamed *et al.,* 2009) and kept in warm, moist environments is prone to the growth of mould. Retaining its freshness is important to keep it appetizing. Gluten is extremely important for the texture of bread but with significant increase in our gluten intake due to ubiquity and over consumption of products made with highly refine flour is just beginning to ignore glutens impact on our health. Gluten is responsible for triggering an immune response commonly referred as cereal intolerance/celiac disease (Ozola *et al.,* 2011).

Buck wheat is rich in fiber, calcium, iron, vitamins and essential amino acids (lysine, threonine and tryptophan) as compared to wheat (Steadman *et al.,* 2001). The flour is low in sugars and its bran contains fagropyritols, a galactosyl that may be useful in the treatment of of non-insulin related diabetes mellitus (Manthey *et al.,* 2004). It is gluten free and is excellent source of easily digestible proteins and contains all eight essential amino acids, so it's close to being a “complete” protein (Franjka and Zeljko, 2003).

Therefore, it's a need to incorporate this pseudocereal to increase the nutritional quality of bread, enhance its storage life and cutting back gluten. Keeping this in view the above factors the present study was designed to incorporate buck wheat for formulation of low gluten bread.

MATERIAL AND METHODS

Wheat (Shalimar wheat-1) was procured from the division of genetics and plant breeding, SKUAST, Kashmir. Buck wheat was purchased from the Global Trading Ltd., Jagadhari, Haryana, India. The wheat flour used for product formulation was extra short flour (40% extraction rate), while as, buck wheat flour used was straight run flour (100% extraction rate). The milling was done in Buhler Pneumatic Mill.

Bread formulation: The process for preparation of sweetened bread using flour of wheat and buck wheat was standardized using straight dough process (Neelam*et al.* 2005). Formulation show that with 100 % weight flour basis of wheat flour basis water (60%), salt (2%), sugar (2%), yeast (1.5%) and shortening (2%) were used to produce sweetened bread. Bread was prepared from wheat and buck wheat flour in ratios F_0 (wheat: buck wheat; 100:0), F_1 (wheat: buck wheat; 98:2), F_2 (wheat: buck wheat; 96:4), F_3 (wheat: buck wheat; 94:6), F_4 (wheat: buck wheat; 92:8). The bread was prepared using straight dough process. In this method, all the formula ingredients are mixed into developed dough that is then allowed to ferment. During fermentation, the dough is usually punched one to three times. After fermentation it is divided into loaf sized pieces, round moulded into the loaf shape and placed into pan and is given an intermediate proof (floor time 30^{o}C and 85 % RH) of 20-30 minutes during which the loss of gas (in scaling and rounding) is compensated. It was then placed in oven and baked for 28 minutes at 245-250 °C after which the unpalatable dough was transformed into light, porous and readily digestible flavoured product. After baking the bread is cooled at room temperature, sliced and packed.

Crude protein (using the factor 6.25 for converting nitrogen into protein), moisture, fat, fiber were estimated using standard method of AOAC (1995). Bread and cake crumb texture was measured by Texture Analyser (TA / HD Plus) with HDP BSK Blade Set with Knife probe. The weighted probe which was vertically positioned over the surface of the test sample was allowed to fall into sample. The software provided in the texture analyser was used to collect the data and the results were presented in terms of hardness (N), springiness (mm) and cohesiveness. Staling of the bread was tested for their alkaline water retention capacity according to the procedure shown by AACC (2000). Percent water absorption is evaluated on a farinograph where the curve is centered on the 500 brabender unit while as peak viscosity is recorded by rapid viscoanalyser (AACC, 2000). Yeast and mould count was determined during a storage period of 9 days with an interval of 3days, by the method on serial dilution technique using potato dextrose agar media. The incubation period was 48 hours at 25±2°C. The colonies so formed were expressed in log cfu g^{-1} (Karuna and Kolte, 2005).

RESULTS AND DISCUSSION

Highest protein (11.97%), fat (1.95%), ash (1.80%), fiber (2.36 %), dough development (2.50 min) were recorded in straight run buck wheat flour. However extra short wheat flour depicted highest percentage of water absorption (57.63%), peak viscosity (3932.4 cp) and moisture (13.49%) (Table 1).

Significant differences in nutritional properties of bread were observed with composite flour combinations. Increase in buck wheat flour concentration decreased the moisture. However flour combination (wheat: buck wheat; 100:0) recorded highest moisture content (33.39 %). Such an effect might be related to the difference in quantitative distribution of protein fractions and physico-chemical properties of starch in buck wheat flour (Attia *et al.,* 2010). The findings are in conformity with Doxastakis *et al.* (2002) and Vittadini and Vodovotz (2003). The effect of buckwheat fortification resulted in increased nutrient content among which flour combination (wheat: buck wheat; 92:8) had highest protein, fat, ash, fiber (Table 2). This is due to high fat, ash, low cholesterol and high concentration of easy digestible proteins in buck wheat flour hencecalled a complete protein pseudocereal (Baljeet *et al.,* 2010).

Textural Evaluation of bread: The lowest hardness (11.48 N) of bread crumb was achieved when bread was produced from wheat flour. Bread procured from flour combination (wheat: buck wheat; 92:8) was characterized by highest bread crumb hardness of 20.56 N. Cohesiveness of bread crumb was the least related to flour and dough properties. The results indicated highest cohesiveness of 6.71 was in flour combination (wheat: buck wheat; 100:0) and lowest of 0.54 in flour combination (wheat: buck wheat; 92:8). Springiness of bread samples were reduced by addition of buckwheat in the formulation (Table 3). The springiness of bread samples containing wheat were different because of interaction between gelatinsed starch and gluten in dough which caused dough to be more elastic (Feili *et al.,* 2013). The springiness varied from 0.77 mm in flour combination (wheat: buck wheat; 92:8) to 0.90 mm in flour combination (wheat: buck wheat; 100:0). The flour combination (wheat: buck wheat; 100:0 and 92:8) recorded baking losses of 0.833 and 0.820.

Table 1. Physico-chemical composition of wheat and buck wheat flour

Flour	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	% Water absorption	Peak viscosity (cp)	Dough development time (min)
Wheat (40%ER)	13.49	9.45	1.60	1.02	0.68	57.63	3932.4	1.41
Buck Wheat (100% ER)	11.12	11.97	1.95	1.80	2.36	30.4	1080	2.5

ER- Extraction Rate; cp- centipoise (12 centipoise (cp) = 1 rapid visco units (RVU))

Table 2. Nutritional evaluation of bread

Parameter	Flour combinations (Wheat: Buckwheat)						
	F_0 (100:0)	F_1 (98:2)	F_2 (96:4)	F_3 (94:6)	F_4 (92:8)	Mean	CD ($p \leq 0.05$)
Moisture (%)	33.39	32.96	32.55	32.12	31.67	32.53	0.014
Protein (%)	8.64	8.68	8.72	8.76	8.80	8.72	0.023
Fat (%)	1.51	1.56	1.61	1.65	1.70	1.61	0.023
Ash (%)	0.51	0.53	0.55	0.59	0.62	0.56	0.014
Fiber (%)	2.11	2.18	2.24	2.30	2.37	2.24	0.010

Microbial quality of bread: In general, most mould prefer high water activity (aw >0.80), while a few xerophilic mould prefer to grow at water activity as low as 0.65 (Abellana *et al*., 2001). Data pertaining on fungal count of bread depicted that flour combination had a significant influence. It was reported that no fungal growth was observed in ambient conditions (28±2°C) at 0 days of storage irrespective of treatment combinations. Similarly no fungal growth was observed in bread prepared using flour combinations (wheat: buck wheat; (98:2; 96:4; 94:6; 92:8) at 3 days of storage and the flour combinations (wheat: buck wheat; 94:6; 92:8) at 6 days of storage. Maximum fungal count of 3.425 log cfu g^{-1} was in flour combination (wheat: buck wheat; 100:0), followed by 3.301 log cfu g^{-1} in flour combination (98:2) at 9 days of storage (Table 4).

Staling: Highest AWRC of 302.86 was in flour combination of wheat: buck wheat; 100:0 at 0 days of storage while as lowest of 158.70 in flour combination wheat: buck wheat; 92:8 at 9 days of storage. However, it was observed that the percentage loss of freshness decreased with increasing buck wheat flour. Bread made with flour combination (wheat: buck wheat; 100:0) at 9 days of storage showed 45.58 % loss of freshness compared to 45.06% in flour combination of wheat: buck wheat; 92:8 (Table 5). There was a dramatic decrease in the alkaline water retention capacity from 0 day to 9 days of storage because the amylose that leached from granules by the time bread has completely cooled after baking, the interstitial amylose will have retrograded (became insoluble) therefore, plays a major role in subsequent moisture loss and staling of bread (Ahmed *et al.,* 2013). During storage the amorphous starch turns to crystalline form. Similar results were observed by Mohamed *et al.* (2009) and Ahmed *et al.* (2010).

Based on these results and discussions, it can be concluded that the incorporation of buck wheat flour increased the nutritional content of all the products. However on the basis of safety studies the buck wheat incorporation showed the decreasing fungal count (log cfu g^{-1}). These products had a low gluten content which is useful for prevention for celiac disease. Hence there is a need for incorporation of buck wheat flour in value addition of cereal based products to provide health and safe food to all.

Table 3. Textural studies and baking losses of bread

Texture characteristics	F_0 (100:0)	F_1 (98:2)	F_2 (96:4)	F_3 (94:6)	F_4 (92:8)
Hardness (N)	11.48	12.22	17.24	20.05	20.56
Cohesiveness	6.71	0.70	0.64	0.63	0.54
Springiness (mm)	0.90	0.90	0.85	0.84	0.77
Baking losses	0.83	0.83	0.83	0.82	0.82

Table 4. Microbial quality of bread

Storage days	Flour combinations					Mean
	F_0 (100:0)	F_1 (98:2)	F_2 (96:4)	F_3 (94:6)	F_4 (92:8)	
0 (S_0)	0.000	0.000	0.000	0.000	0.000	0.000
3 (S_1)	2.523	0.000	0.000	0.000	0.000	0.505
6 (S_2)	3.000	2.828	2.523	0.000	0.000	1.670
9 (S_3)	3.425	3.301	3.000	2.828	2.523	3.015
Mean	2.237	1.532	1.381	0.707	0.631	1.298

CD($p \leq 0.05$)- Flour Combination = 0.001, Storage = 0.001

Table 5. Alkaline water retention capacity of bread

Storage days	Flour combinations (wheat: buckwheat)										Mean
	F_0 (100:0)	% loss in freshness	F_1 (98:2)	% loss in freshness	F_2 (96:4)	% loss in freshness	F_3 (94:6)	% loss in freshness	F_4 (92:8)	% loss in freshness	
0 (S_0)	302.86	-	298.25	-	295.23	-	292.97	-	289.12	-	295.68
3(S_1)	250.22	17.38	246.53	17.34	244.42	17.21	242.84	17.11	239.96	17.00	244.79
6 (S_2)	203.94	32.66	201.08	32.58	199.51	32.42	198.31	32.31	196.08	32.18	199.78
9 (S_3)	164.79	45.58	162.57	45.49	161.31	45.36	160.54	45.20	158.70	45.06	161.58
Mean	230.45		227.11		225.12		223.66		220.96		

CD($p \leq 0.05$)- Flour Combination = 0.013, Storage = 0.012

However, these new products are unfamiliar to consumers so a proper knowledge regarding low gluten cereal based products is to be introduced in the market and popularized *vis-à-vis.*

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Variation in Surface and Hardpan Levels of Wet Rice Fields

Kusuma Guturu, D. Manohar Jesudas[1] and A. Surendra Kumar[2]
Vignan's University, Vadlamudi, Guntur-522 213, India
[1]Deptartment. of Farm Machinery and Power, TNAU, Coimbatore-641 003, India
[2]Agricultural Machinery Research Center, TNAU, Coimbatore-641 003, India
E-mail: Kusumaguturu.10@gmail.com

Abstract: A study was undertaken by the Department of Farm Machinery, Tamil Nadu Agricultural University, to measure the variation in the surface and hardpan levels of the wet rice fields in Coimbatore area. Total five experimental plots were taken, surface and subsurface levels were measured by using dumpy level. The maximum differences in the surface and hardpan levels were observed as 0.39m, 0.39m 0.27m, 0.43m, 0.48m and 0.42m, 0.45m, 0.17m, 0.42m, 0.45m, respectively for 1,2,3,4 and5 field plots . This paper also brings out the need for controlled pudding.

***Key words*:** Dumpy level, Hardpan level, Puddling, Surface level

Water is a scarce resource, and hence saving of water for the future is very essential. The amount of water consumed in the field to produce 1 kg of rice is significantly greater than for other important cereal crops. In Asia, irrigated agriculture accounts for 90% of total diverted fresh water and more than 50% of this is used to irrigate rice (Kukal and Sindu, 2004). Since, amongst cereals rice is the lowest productive crop per unit of water consumed, optimum water management and cultural practices need to be followed to ensure minimum losses of water. In rice cultivation the most important and highly water demanding step is seed bed preparation, which includes puddling and leveling of the field. Puddling reduces the percolation losses by eliminating the large pores, thereby decreasing the hydraulic conductivity of the soils (Kukal and Aggarwal, 2002). Leveling after puddling creates a uniform bed, eliminates the requirement of water to fill the uneven seed bed. There are different types of implements separately for puddling and leveling practices, which includes, animal drawn puddler, tractor drawn cultivator, tractor drawn rotavator for puddling and, draft animals , two wheel tractors using harrows and leveling boards, four wheel tractors using rear mounted tractor blades or drag buckets, four wheel tractor with laser controlled buckets for leveling.

The problems in existing method of seedbed preparation are uncontrolled depth of puddling and unleveled surface and hardpan levels. These two contribute to the high amounts of water losses during the seed bed preparation. Though these problems are well known, study on quantification of these parameters was not up to the extent. Hence a study was undertaken to quantify the variation in surface and hardpan levels of the wet rice fields to quantify the variation in surface and hardpan levels of the conventionally puddled wet rice fields.

MATERIAL AND METHODS

Study was done to quantify the variation in surface and subsurface levels. The surface and hardpan levels were plotted by contours using dumpy level in the puddle rice fields of the wetlands and paddy breading station, at Tamil Nadu Agricultural University, Coimbatore. The plots were examined for the level variations in the surface and hardpan. The experiments were conducted one day after leveling (by the animal drawn leveling boards) i.e. one day before transplanting. The experiments were done in five experimental plots, with the areas of 100 m^2 (10 x 10), 120 m^2 (10 x 12), 140 m^2 (10 x 14), 320 m^2 (20 x 16) and 484 m^2 (22 x 22) for 1, 2, 3, 4 and 5 plots, respectively. The level changes in the surface and hardpan were measured by using dumpy level. The field was marked for 2 x 2 m plots, by using bamboo pegs. The data was recorded for each 2m interval by keeping the staff at surface (surface reading), and by sinking the staff into the puddle field manually (hardpan reading). Distinctively such hardpans have higher penetration resistance of 150 k Pa (Ramachandran and Jesudas, 2013). The reduced levels of the plots were taken and the wireframes were drawn by using surfer 07 software.

RESULTS AND DISCUSSION

The level changes in the surface and hardpans were plotted as wire frames. The wire frame shows the contour profile of the field. The wire frames for surface and subsurface of the wet rice field No's 1, 2, 3, 4 and 5 were shown in Fig. 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11.

The observed elevations are computed for mean and standard deviations are given in the Table 1. It is observed that there was a gradual change in the level of the field from one end to another end. This may be because, absence of reference point while leveling the field and it

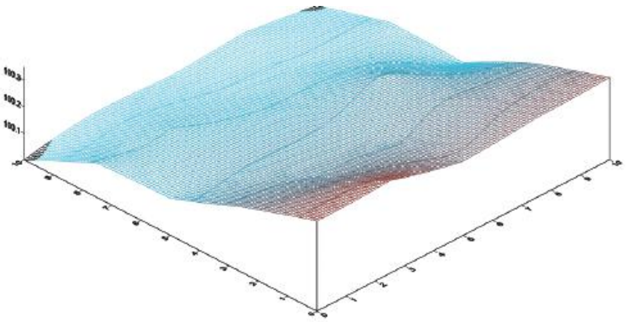

Fig.2. Wire frame diagram for surface of the field 1

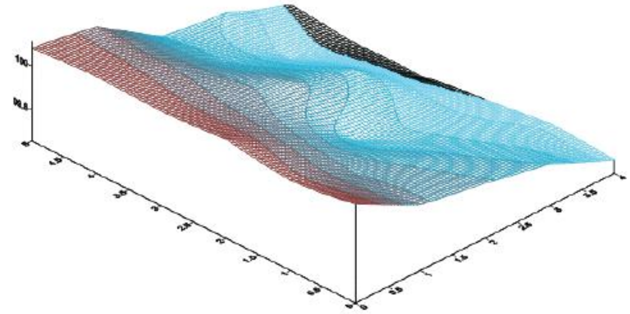

Fig. 3. Wire frame diagram for the subsurface of the field 1

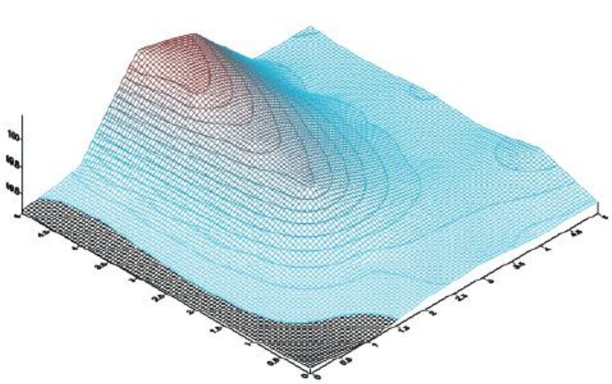

Fig. 4. Wire frame diagram for surface of the field 2

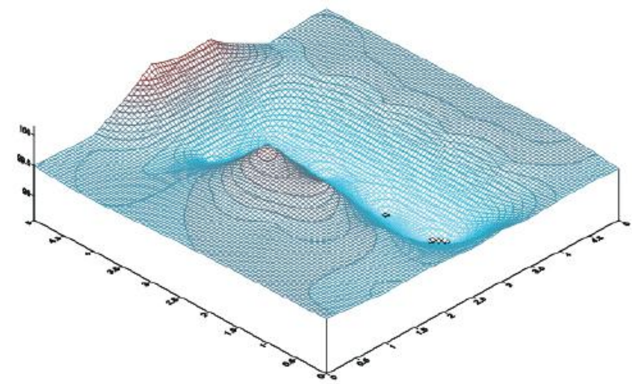

Fig. 5. Wire frame diagram for subsurface of the field 2

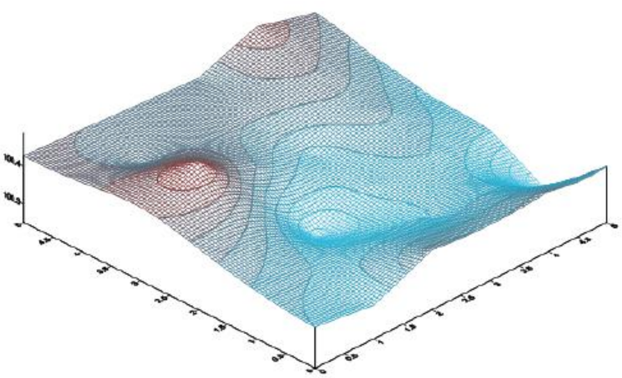

Fig. 6. Wire frame diagram for surface of the field 3

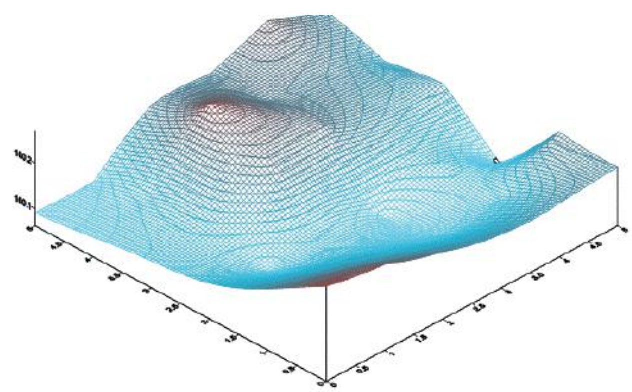

Fig. 7. Wire frame diagram for subsurface of the field 3

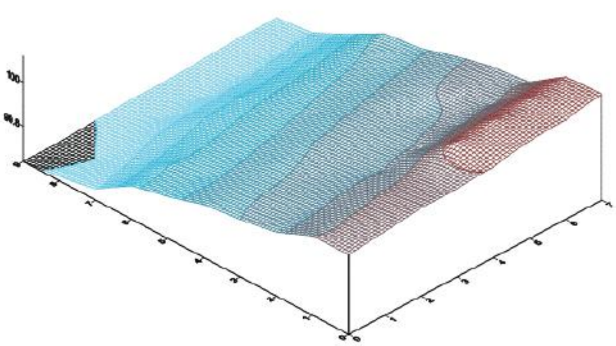

Fig. 8. Wire frame diagram for surface of the field 4

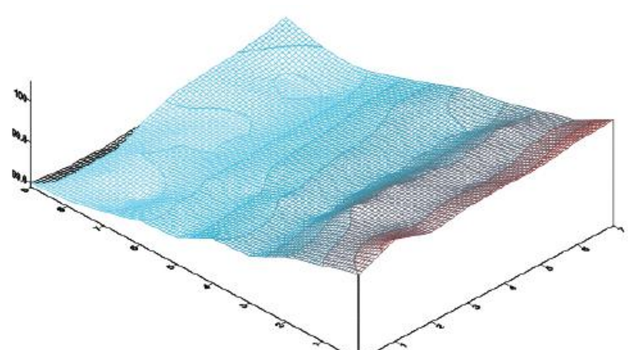

Fig. 9. Wire frame for subsurface of the field 4

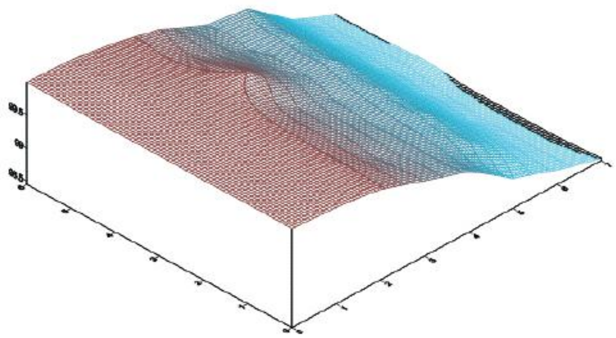

Fig. 10. Wire frame for surface of the field 5

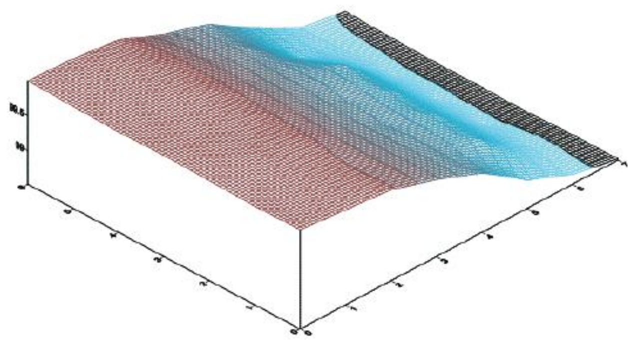

Fig. 11. Wire frame for subsurface of the field 5

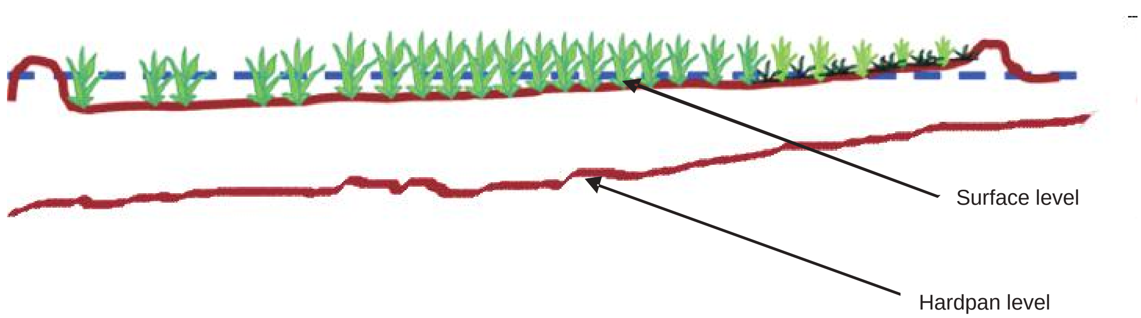

Fig. 12. Observed layout of the field

followed the implement movement in the field. The movement of the implement has a great effect on the contour profiles of the experimental plots. The maximum difference in the levels of the surface and hardpan plots were observed as 0.39 m, 0.39 m 0.27 m, 0.43 m, 0.48m and 0.42 m, 0.45 m, 0.17 m, 0.42 m, 0.45 m, respectively for 1,2,3,4 and 5 field plots. It was clear that the depth of puddling varies in the range of 8.2cm to 21 .9 cm at 95% confidence interval. The observed value of depth of puddling is varying much from the mean value, hence it was concluded that the depth of puddling has to be controlled for better crop performance and machinery operation. The observed layout of the rice field is shown in Fig. 12. Field measurements of variability with the surface and hardpan levels in rice fields that are continuously under rice cultivation were measured. It was observed that the surface levels for fields that are prepared by the conventional puddling techniques (puddling with power tiller or light weight tractor and leveling by animal drawn levelers) results in 0.27 m to 0.48 m variation of the surface when it is observed just prior to transplanting. The variation in the levels of the hardpan under these conditions 0.17 m to 0.45 m. the average depth of puddling varied from 10 cm to 35 cm. The rice crop will require the optimum puddling depth of 15 cm. Hence controlled puddling that maintains constant depth of puddling and also ensures table top level of the surface and hardpan layers will lead to considerable saving in the water requirement puddling, energy requirement and also in a long run lead to more stable and compact hard pans that reduces percolations and also provide better support for machinery like tansplanters and harvesters.

Table 1. Variation in surface and subsurface of the conventionally puddled rice fields (All dimensions are in m)

Field No.	Surface level (m)		Subsurface level (m)		Depth of puddling (m)	
	Mean (μ)	Standard deviation (ó)	Mean (μ)	Standard deviation (ó)	Mean (μ)	Standard deviation (ó)
1	1.507	0.105	1.647	0.141	0.140	0.053
2	1.064	0.055	1.274	0.057	0.210	0.069
3	1.562	0.185	1.644	0.195	0.082	0.041
4	2.650	0.268	2.848	0.244	0.198	0.129
5	1.787	0.031	1.963	0.043	0.176	0.048

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Standardization of Optimum Blends for Processing Value Added Ready-To-Serve Drink from *Aloe Vera*, Aonla and Papaya

Akanksha Jain, Rakesh Gehlot, S. Siddiqui and T. Harshita
Centre of Food Science and Technology, CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: akankshajain972@gmail.com

Abstract: In the present study, optimum blends for development of value added RTS drink from *Aloe vera*, aonla and papaya were standardized. Pulp/juice of fresh leaves of aloe and fruits of aonla and papaya was collected by cold extraction process and assessed for various physico-chemical constituents. The papaya pulp had highest yield (75.6%) followed by aonla juice (65.2%) and aloe juice (49.8%). Total soluble solids (TSS), acidity, pH and ascorbic acid content were recorded maximum in papaya pulp (7.1%), aonla juice (1.16 %), aloe juice (4.8) and aonla juice (497 mg/100 ml), respectively. The requisite quantities of pulp/juice, total soluble solids and acidity to be used in the preparation of RTS drink was optimized using response surface methodology (RSM) using papaya pulp. Then, formulations of different blends of aloe, aonla and papaya were standardized. On the basis of organoleptic evaluation, blends of aloe: aonla (25:75), aloe: papaya (25:75) and aloe : aonla: papaya (10:10:80) were optimized and recipe having 20% juice/pulp, 15% TSS and 0.28% acidity was most acceptable by RSM design for the preparation of RTS drink. Low calorie RTS drink developed by replacing 50% sugar with stevia and 35% sugar with sucralose were found most acceptable. Spices and ingredients namely salts, roasted cumin powder, small cardamom and black pepper (0.1% each), and chat masala (0.375%) were optimized for the preparation of spiced RTS drink.

Key Words: *Aloe vera*, Aonla, Low calorie, Papaya, Optimum blends, RSM

Fruits and vegetables are important constituents of our diet and provide considerable quantities of nutrients. Though, India is the world's second largest producer of fruits and vegetables, yet only 2-3 per cent of their total production is processed. Hence, more and more utilization of fruits and vegetables is necessary for processing into various processed products, like beverages so as to reduce post-harvest losses due to their perishable nature (Bhardwaj and Pandey, 2011). During the last few years, demand for nutritive fruit beverages has increased in India as well as in other countries. This might be attributed to change in dietary habits, taste preferences and lifestyle of present-day consumers. In addition, fruit and vegetable beverages have higher nutritional, medicinal and calorific values over synthetic beverages (Kaur and Kapoor, 2002).

In the present study, kwargandal (*Aloe vera),* aonla (*Phyllanthus emblica* L.) and papaya (*Carica papaya*) were selected for the development of blended therapeutic ready-to-serve (RTS) drink. *Aloe vera* with its numerous medicinal and therapeutic properties, have made it a novel valuable ingredient for utilization in food industry. Acemannan, a storage polysaccharide, rich in mannose units is the main bioactive component of *Aloe vera*. In food industry, it has been utilized as a source of functional food, especially for the preparation of health food drinks (Pugh *et al.,* 2001). *Aloe vera* gel is famous for facilitating digestion, aiding blood and lymphatic circulation, besides improving kidney, liver and gall bladder functions (Ehsun, 2004). The gel has a bitter taste and unpleasant in raw form, however, its palatability could be enhanced with addition of some other fruit juices such as aonla or papaya. Aonla or Indian gooseberry was chosen for blending with aloe because it is a rich source of natural vitamin C (200 to 900 mg/100 g of juice) (Barthakur and Arnold, 1991). It has antioxidant properties due to high vitamin C content. It also contains abundant pectin and minerals like iron, calcium and phosphorus. It is a very powerful anti-inflammatory herb. Thus, there exists lot of scope to explore the possibility of aonla for its utilization in beverage industries (Nayak *et al.,* 2011). Papaya was selected for being rich vitamin A and minerals. Today, papaya products need value enhancement with fortification of novel ingredients and promoting it as a high valued product fruit, owing to increase in demand of these products by the consumers.

Therefore, blending of *Aloe vera*, aonla and papaya pulp/juices with spices and low calorie ingredients is a convenient and economical alternative for its utilization in the development of value added nutritive and therapeutic beverages.

MATERIAL AND METHODS

Mature aonla fruits cv. Chakaiya was procured from local orchards adjoining Hisar and fresh *Aloe vera* leaves were procured Department of Genetics and Plant Breeding, CCSHAU, Hisar. Sucralose powder was purchased from Titan Biotech. Pvt., Bhiwadi (Rajasthan), while stevia powder from Green Valley Stevia Biotech. Pvt. Ltd., Nawashahr (Punjab), and citric acid from SRL, laboratories, Mumbai, India. Papaya pulp, aonla and aloe juice was collected by cold extraction method. Flow sheet for collection of papaya pulp, aonla and aloe juice has been shown in Fig. 1.

Optimization of RTS drink recipe using response surface methodology: RSM was applied only for the preparation of papaya RTS drink and the selected recipe with optimum pulp, total soluble solids and acidity was then followed for preparation of all the beverage blends including low calorie and spiced RTS drink variants.

Experimental design layout: RSM [design-expert version 9 (Stat-Ease Inc., Minneapolis, MN, USA)] was used for optimizing recipe of papaya RTS. Box-Behnken design (BBD) generated seventeen different recipes according to input fed into the experimental layout. Input was fed with three independent (process) variables such as pulp (%) coded as 'A' with levels ranged from 15 to 20%, TSS (%) coded as 'B' with levels ranged from 10 to 15% and acidity (%) coded as 'C' with levels ranged from 0.18 to 0.30 %. The minimum level of each independent variable was selected according to food safety and standards authority regulations [Food safety and standards authority, 2011] and then selection of range was done after carrying out preliminary trials. RSM optimized one most acceptable recipe from seventeen runs after analyzing the adequacy of the models based on five response parameters *viz*., pH, ascorbic acid, total phenols, total carotenoids and overall acceptability of the prepared recipes. For optimization process, the analysis of variance tables were generated and the adequacy of the model was determined using p-value, lack of fit test and coefficient of determination *i.e.*, R^2 after model evaluation by quadratic regression equations.

Preparation of RTS drink: The percentages of pulp, TSS and acidity were maintained in seventeen experimental recipes according to the runs given by BBD design (Table 2). For preparing RTS drink, total soluble solids and total acids were first analyzed in pulp/juice. Total soluble solids were estimated at ambient room temperature by Erma Hand Refractometer (0-32%). Total acids were extracted in water and were estimated by titration against 0.1N sodium hydroxide (Ranganna, 2009). On the basis of this analysis, requisite quantities of sugar and citric acid were dissolved in water by heating and then added to the weighed pulp for adjustment of TSS and acidity in RTS drink (w/w basis). The beverages were homogenized in colloidal mill, strained, mixing with sodium benzoate (@120 ppm), filled in pre-sterilized glass bottles (200 ml capacity) leaving 2.5 cm headspace and sealed with crown corks. The sealed bottles were processed in boiling water for 25 minutes. The bottles were then cooled in air, labelled and stored at room temperature for analysis of responses (Fig. 1).

Determination of physico-chemical parameters: The fresh pulp/juice and beverages were subjected to analysis for various parameters by different methods. Yield of the pulp/juice was calculated by taking weight of net screened pulp/juice in comparison to weight of fresh fruits and the values were expressed in per cent. Fresh pulp/juice and seventeen RTS recipes generated by RSM were assessed for pH using a digital pH meter. Ascorbic acid (Ranganna, 2009), total carotenoids of papaya RTS drink (Rodriguez-Amaya *et al*., 1999) and total phenols (Amorium *et al*., 1991) were analyzed by standard methods. Sensory evaluation of all the beverages was performed using 9 point hedonic scale (Ranganna, 2009). The products were evaluated for colour and appearance, taste, flavor, mouthfeel and overall acceptability. The overall acceptability of beverage blends was based on the mean scores obtained from all the sensory characters. The attributes with mean scores of 6 and above out of 9 were considered acceptable. The treatments were replicated thrice.

Designing formulations of blends: Different aloe, aonla and papaya based blends were prepared according to the proportions (Fig. 1). All the beverage blends were prepared according to the procedure as mentioned above by adjusting contents of pulp/juice, TSS and acidity according to the standardized recipe generated previously by RSM. For obtaining optimum formulation of blends, these were subjected to sensory evaluation as mentioned.

Development of Value Added RTS Drink Variants

Spiced RTS drink: The optimum quantities of common salt, black salt, rock salt, black pepper, cumin, chat masala and cardamom (small) was standardized for the preparation of spiced RTS drink from the most acceptable formulation of aloe : aonla : papaya juice blends using the standardized recipe generated previously by RSM. The optimum quantities of spices were mixed in 100 ml boiled water. The spice extract was strained after 10 minutes and it was finally added to the mixture of juice and sugar syrup.

Low calorie RTS drink: The optimum quantities of natural sweetener (stevia) and artificial sweetener (sucralose) was standardized to replace sugar with low calorie sweeteners for preparation of low calorie RTS drink from the most acceptable formulation of aloe : aonla : papaya juice blends using the standardized recipe. The formulation consisting of different quantities of spices and sweeteners are depicted in Fig. 1. On the basis of sensory evaluation, optimum quantities of spices and sweeteners were selected. The flow sheet right from the processing of pulp/juice till development of finished beverages has been shown in Fig. 1.

RESULTS AND DISCUSSION

Physico-chemical parameters of fresh pulp/juice: Yield of papaya pulp was highest (75.6%) followed by aonla juice (65.2%) and aloe juice (49.8%). Total soluble solids were 7.1, 6.1 and 0.8% in papaya pulp, aonla juice and aloe juice, respectively. Acidity percentage of aonla juice was highest (1.16) followed by papaya pulp and aloe gel juice, while pH was recorded 4.44, 2.66 and 4.86 for papaya, aonla and aloe juice, respectively. Ascorbic acid content (mg/100g or ml) was maximum in aonla juice (497) followed by papaya pulp and aloe gel juice. Similar results were reported by Kumar *et al.* (2013); Yadav *et al.* (2013).

Determination of response parameters of different recipes generated by RSM: Seventeen recipes were evaluated for different parameters (Table 2). Mean values of different parameters ranged for pH (3.40-3.78), ascorbic acid (2.79-6.74 mg/100 ml), total phenols (5.6-11.49 mg/100 ml), total carotenoids (245.7-508.5 µg/100 ml) and overall acceptability scores (6.4-8.2 out of 9). Regression model fitted to all the models show acceptable P-value for lack of fit was ($P>0.05$), which implies that the lack of fit was non-significant *i.e.*, all the models of response parameters were found to be fit and good. The fit of model was also assessed by coefficients of determination *i.e.,* R^2, which was higher than 0.96 and desirable for fitting all the models for further optimization.

Solutions generated by RSM through numerical optimization: For optimization process, desired criterion for each factor and response parameter was set from the numerical optimization menu in the software Acidity was targeted to 0.28%, and pH and total phenols values were kept in the range (Table 3). All the above given criteria were combined and program generated solutions with good set of conditions having maximum desirability. The recipe for papaya RTS drink was optimized with 20% pulp, 15% TSS and 0.28% acidity, and was selected for standardization with highest desirability of 0.962 (Table 4). This generated recipe was further used in the development of value added RTS drink variants. Deshpande *et al.* (2008) also optimized chocolate-flavored, peanut–soy beverage using response surface methodology (RSM). They formulated twenty-eight beverages by mixing three basic ingredients: peanut (*A*=30.6 g/100g–58.7 g/100g), soy (*B*=28.3 g/100g–43.5g/100 g), and chocolate syrup (*C*=13.0g/100 g–25.9 g/100 g). The optimum formulations were all the combinations of *A*: 34.1 g/100 g–45.5 g/100 g, *B*: 31.2 g/100 g–42.9 g/100 g and *C*: 22.4 g/100 g–24.1 g/100 g for Soy flour-based beverage formulations.

Standardization of aloe, aonla and papaya based RTS drink variants: Ten treatments (T_1-T_{10}) of RTS drink variants (Fig. 1) were prepared from different proportions of *aloe vera*, aonla and papaya pulp/juice blends. All the beverage blends were prepared with RSM optimized RTS recipe *i.e.*, 20% pulp/juice, 15% TSS and 0.28% acidity. On the basis of sensory evaluation, best treatments were selected and utilized further for the preparation of value added spiced and low calorie RTS drink variants (T_{11}-T_{18}).

Aloe: aonla RTS drink variants: On the basis of sensory evaluation (9 point hedonic scale), T_1 combination *i.e.*, aloe: aonla in 25:75 ratio was adjudged most acceptable with maximum overall acceptability scores of 7.8. The colour, appearance, taste, mouthfeel and overall acceptability of RTS drink variants declined with the increase in concentration of aloe gel juice and decrease in concentration of aonla juice (Fig 2). Kumar *et al*. (2013) also developed therapeutic ready-to-serve (RTS) beverage from blends of *aloe vera* juice, aonla juice and juice extracts from ginger. These were blended by using different proportions of *aloe*, aonla and ginger juice as 50:25:25 (A), 60:20:20 (B), 70:15:15 (C) and 80:10:10 (D). Sample C blended ratio of 70:15:15 recorded highest overall acceptability scores with the utilization of aonla juice up to 15%.

Aloe: papaya RTS drink variants: Besides improving nutritional value, papaya pulp provided a pleasant colour, aroma, taste and mouthfeel to the beverages when blended with aloe gel juice. On the basis of sensory evaluation, T_4

Table 1. Physico-chemical characteristics of papaya pulp, Aloe and aonla juice

Parameters	Mean ± S.D.		
	Aloe	Aonla	Papaya
Fruit or leaf weight (g)	584.5±79.24	30.11±0.23	1831±36.51
Pulp or juice weight (g)	291.8±46.06	19.62±0.53	1385.7±57.04
Yield of pulp or juice (%)	49.83±1.26	65.17±2.25	75.67±2.08
Total soluble solids (%)	0.8±0.1	6.1±0.12	8.2±0.20
Acidity (%)	0.075±0.01	1.16±0.14	0.14±0.02
pH	4.86±0.07	2.66±0.01	4.44±0.06
Ascorbic acid (mg/100 g)	1.30±0.23	497.01±2.21	40.77±2.65

Mature aonla fruits
↓
Washing
↓
Processing of aonla in multipurpose processing machine (Mfd. By autoflex)
↓
Seed and pomace
↓
Screw press
↓
Fresh aonla juice
↓
Sedimentation
↓ → Sludge
Clarified juice
↓
Mixing sodium benzoate (1g/ L)
↓
Filling in polypropylene jars
↓
Storing in deep freezer

Freshly harvested *Aloe Vera* leaves
↓
Dipping into 500 ppm KMS solution for 1hr
↓
Washing thoroughly with tap water
↓
Keeping for flash cooling at 5ºC for gel stabilization
↓
Cutting of leaves vertically into two halves and separation of gel using stainless steel knife
↓
Settling of gel for 12 hrs
↓
Washing of fillets
↓
Homogenization of fillets using MPP machine
↓
Passed through colloidal mill and filtration
↓
Mixing sodium benzoate (1g/L)
↓
Filling in polypropylene jars
↓
Storage in deep freezer

Ripe papaya fruits
↓
Washing
↓
Peeling
↓
Halving
↓
Removing seeds and inner whitish layer
↓
Cutting into pieces
↓
Blending in a mixer
↓
Homogeneous pulp
↓
Mixing of sodium benzoate (1g/kg pulp)
↓
Filling in polypropylene jars
↓
Storing in deep freezer

Blending of pulp/juice in different proportions

BLENDS	PULP/JUICE PROPORTIONS (TREATMENTS)			
A. *Aloe vera*: Aonla blend	25:75 (T_1)	50:50 (T_2)	75:25 (T_3)	
B. *Aloe vera*: Papaya blend	25:75 (T_4)	50:50 (T_5)	75:25 (T_6)	
C. *Aloe vera*: Aonla: Papaya blend	25:25:50 (T_7)	20:20:60 (T_8)	15:15:70 (T_9)	10:10:80 (T_{10})

↓

Best acceptable treatments from blend 'C' was selected for preparation of value added RTS

i. Spiced RTS — ii. Low calorie RTS

Treat-ments	Spices	Quantity (%)
T_{11}	a.Salts, cardamom, black pepper, cumin	0.1
	b.Chat masala	0.375
T_{12}	a.Salts, cardamom, black pepper, cumin	0.2
	b.Chat masala	0.4

Stevia replaced with sugar	
Treatments	Quantity (%)
T_{13}	25
T_{14}	50
T_{15}	75

Sucralose replaced with sugar	
Treatments	Quantity (%)
T_{16}	25
T_{17}	35
T_{18}	45

Selection of best treatment

Selection of best treatment

After blending pulp/juice as per different treatments
↓
Mixing syrup (water, sugar, citric acid or spice aqueous extract/sweeteners)
↓
Homogenization
↓
Straining and addition of preservative
↓
Filling into pre-sterilized glass bottles (200 ml capacity)
↓
Sealing with crown corks
↓
Processing (Boiling water for 25 minutes)
↓
Cooling, labelling and storage at room temperature

Fig. 1. Schematic figure showing flow sheet for processing of raw materials, suitable blend proportions and preparation of RTS drink variants

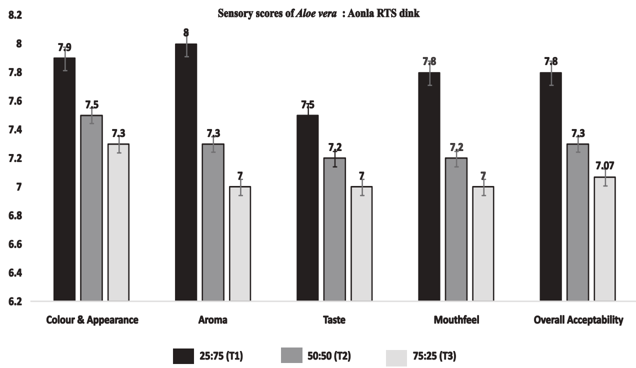

Fig. 2. Sensory scores of aloe: aonla RTS drink

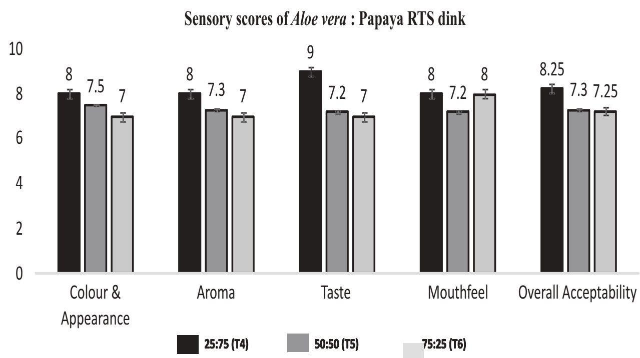

Fig. 3. Sensory scores of aloe: papaya RTS drink

(aloe: papaya juice/pulp in 25:75 ratio) was adjudged most acceptable with maximum overall acceptability scores of 8.25. All the sensory attributes improved with maximum proportion of papaya pulp (75%), while drastic reduction in taste scores was observed with the increase in proportion of aloe juice up to 75% due to imparted bitterness (Fig. 3).

Aloe: aonla: papaya RTS drink variants: The functional properties from aloe, aonla and papaya were combined into one novel beverage blend. Aloe: aonla: papaya in 10:10:80 ratio was adjudged most acceptable with maximum overall acceptability scores of 8.2. All the sensory attributes gradually decreased with the increase in concentration of aloe and aonla juice in the blend up to 25% (Fig. 4). Hence, only 10% of aonla and aloe vera juice was found acceptable for mixing with papaya. The mouthfeel of beverage blends improved with the increase in proportion of papaya pulp due to uniform distribution of granular particles of pulpy portion in the aqueous phase of the beverages imparting balanced taste. Boghani *et al*. (2012) also observed that aloe gel could be successfully incorporated in development of blended RTS drink with better sensorial quality profile up to the level of 10% only.

Value Added RTS Drink Variants

Spiced RTS drink variants: Aloe: aonla: papaya in 10:10:80 ratio was used for the preparation of two types of spiced

Table 2. Experimental recipes with response parameters of prepared papaya RTS beverages

Run No.	Pulp (%)	TSS (%)	Acidity (%)	pH	Ascorbic (mg/100 ml)	Total phenols (mg/100 ml)	Total carotenoids (µg/100 ml)	Overall acceptability (scores out of 9)
1.	15	10.0	0.30	3.45	5.83	8.69	370.5	7.2
2.	20	12.5	0.30	3.43	6.57	11.1	495.6	8.0
3.	10	15.0	0.24	3.58	3.49	5.79	248.3	7.0
4.	20	12.5	0.18	3.73	6.14	11.49	488.9	7.8
5.	15	12.5	0.24	3.54	5.22	8.25	367.8	7.6
6.	20	10.0	0.24	3.50	6.74	10.86	508.5	7.8
7.	15	10.0	0.18	3.78	4.86	8.54	375.2	7.2
8.	10	12.5	0.30	3.49	3.58	5.73	245.7	6.9
9.	20	15.0	0.30	3.40	6.62	10.78	489.5	8.2
10.	10	10.0	0.24	3.59	2.79	5.67	252.3	6.4
11.	15	15.0	0.30	3.46	5.61	8.42	372.5	7.9
12.	15	12.5	0.24	3.56	5.42	8.05	360.9	7.5
13.	15	12.5	0.24	3.53	4.96	8.41	365.2	7.3
14.	15	12.5	0.24	3.53	5.24	8.32	358.5	7.4
15.	15	15.0	0.18	3.76	5.66	8.6	369.1	7.2
16.	10	12.5	0.18	3.79	3.48	5.61	245.9	6.9
17.	15	12.5	0.24	3.56	5.32	8.3	369.2	7.4
		Lack of fit (p- value)		0.44	0.21	0.16	0.40	0.56
		R^2 value		0.99	0.987	0.99	0.99	0.96

*For good model lack of fit should be non-significant (p>0.05) and R^2 value should approach to unity

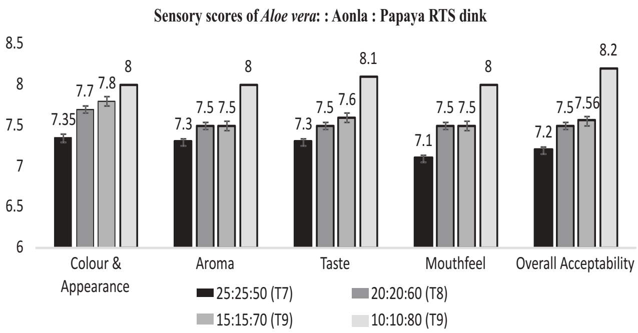

Fig. 4. Sensory scores of aloe: aonla: papaya RTS drink

Sensory scores of stevia substituted RTS drink

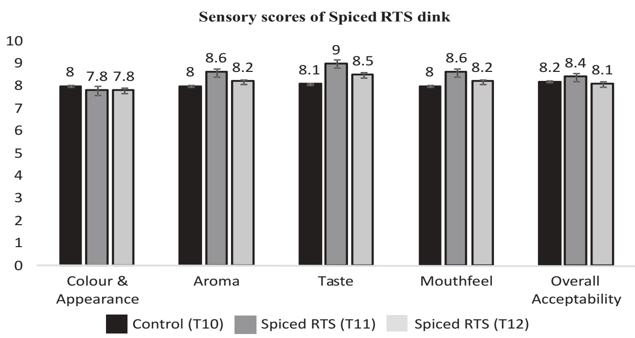

Fig. 5. Sensory scores of spiced RTS drink

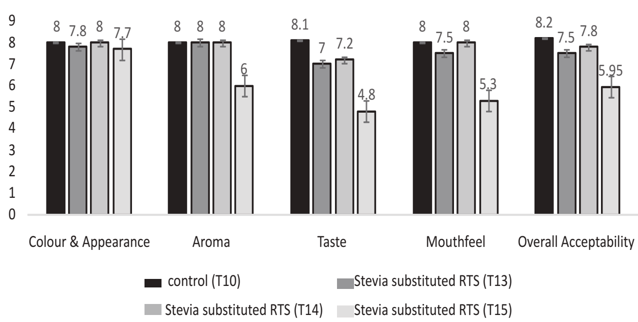

Fig. 6. Sensory scores of stevia substituted RTS drink

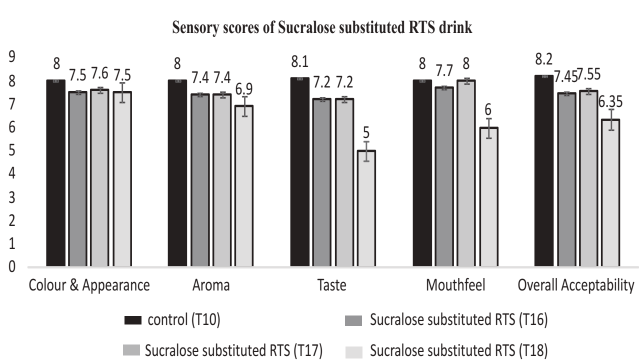

Fig. 7. Sensory scores of sucralose substituted RTS drink

blends (T_{11} and T_{12}) to increase the therapeutic value and storage life of beverage blends due to potent antimicrobial and antioxidant effects of the spices (Suhaj, 2006; Tajkarimi, 2010). T_{11} spiced RTS drink variant was most acceptable with overall acceptability scores of 8.40. The spices led to increased aroma and taste as compared to control but further increase in spice concentration led to decline in colour and taste profile due to high pungency mainly of black pepper in the beverage blends (Fig. 5). Change in colour was observed in spiced RTS drink blends as compared to control because spices masked the original colour of fruit juice, although, the colour noticed was also acceptable and gave uniqueness to the product. Deca *et al.* (2005) also developed mango-pineapple spiced beverages with aqueous spice extract consisted of curry leaf (0.5%), cumin (0.25%), cardamom (0.25%), black pepper (0.1%) and juice of ginger (0.5-2.0%) and mint (0.4%) along with 1 to 2 per cent salt (common and black salt), while Sundram *et al.* (2013) developed spiced sea-buckthorn mix fruit squash with the addition of aqueous spice extract consisting of cumin powder, pepper, black salt, cardamom powder @ 1.5% each, processed in 125 ml water, strained and mixed with sugar syrup for further processing.

Low calorie RTS blends: Substituting natural (stevia) and artificial (sucralose) sweeteners partially with sucrose may provide low calorie beverages with improved antioxidant properties and keeping quality, especially in case of stevia. Aloe: aonla: papaya in 10:10:80 ratio (T_{10}) was used for the preparation of three different stevia variants (T_{13}, T_{14} and T_{15}). Sensory evaluation (Fig. 6) indicate that recipe with 50% sugar replaced with stevia (T_{14}) was found most acceptable over other treatments (7.80 scores for overall acceptability). Sugar: acid ratio is also an important predictor of taste and aroma of a product. Taste and overall acceptability scores were significantly influenced due to changes in TSS: acidity ratio in stevia substituted RTS drink samples as compared to control. Results reveal that stevia can be replaced with half of the sugar without much impairing the quality of RTS drink, but when sugar was replaced with higher concentration of stevia up to 75%, it was responsible for diminishing the overall rating of product. Meena *et al.* (2011) also successfully replaced 50% sugar with stevia in developing low calorie mango RTS drink.

RTS drink variants prepared by replacing sugar with sucralose: Aloe: aonla: papaya in 10:10:80 ratio was also used for the preparation of three different sucralose variants (T_{16}, T_{17} and T_{18}). Sensory evaluation (Fig. 7) indicated that recipe prepared with 35% sugar replacement with sucralose (T_{17}) was found most acceptable over other treatments (7.55 scores for overall acceptability). In the present study, with the

Table 3. Criteria established for different factors in numerical optimization process

Factors	Goal/criteria	Lower limit	Upper limit
A:Pulp/juice content	Maximize	10	20
B:TSS	Maximize	10	15
C:Acidity	Target = 0.28	0.18	0.3
pH	In range	3.4	3.78
Ascorbic acid	Maximize	2.79	6.74
Total phenols	In range	5.61	11.49
Carotenoids	Maximize	245.76	508.51
Overall acceptability	Maximize	6.4	8

Table 4. Solutions generated by response surface methodology (RSM)

Pulp	TSS	Acidity	pH	Ascorbic acid	Total phenols	Carotenoids	O A scores*	Desirability
20	15	0.28	3.4	6.35	10.85	491.2	7.9	0.962
20	14.9	0.28	3.4	6.35	10.85	491.2	7.9	0.961
20	14.9	0.28	3.4	6.35	10.85	491.1	7.9	0.961
19.9	15	0.28	3.4	6.35	10.82	489.6	7.8	0.959
20	14.8	0.28	3.4	6.36	10.85	491	7.9	0.959
19.9	15	0.27	3.4	6.34	10.85	491.1	7.8	0.959
20	15	0.28	3.4	6.35	10.85	491.2	7.9	0.957
20	14.9	0.27	3.4	6.34	10.85	491.1	7.8	0.956
19.8	15	0.28	3.4	6.34	10.77	487.3	7.8	0.956
20	14.7	0.28	3.4	6.37	10.85	490.8	7.9	0.956

O.A.*= Overall acceptability sensory scores, Run No.1= Selected

increase in the substitution of sugar with sucralose, taste and mouthfeel scores declined because beverage with lower sugar content (T_{18}) was perceived with long lasting bitter aftertaste. This finding is in agreement with those of Dabbas *et al.* (2012). They reported that high sucrose content masked bitterness perception in sucralose substituted orange nectars.

Despite having high nutritional and medicinal qualities, the utilization of *aonla and* aloe have become limited in developing processed products owing to high acidity, astringency, bitterness and such other factors. Thus, it is the need of hour to introduce new types of value added beverages, which can be developed by blending fruit pulp/juice with medicinal plants, herbs, spice extracts or low calorie sweeteners that could help therapeutically in improving the general health of the consumers. Aloe, aonla and papaya RTS drink variants with low calorie sweeteners and spices have been successfully prepared by optimizing best recipe for preparation of RTS drink using Response Surface Methodology (RSM) in the present study. It can be concluded from the present investigation that aloe vera, aonla and papaya pulp/juices with spices and low calorie ingredients can be conveniently and economically utilized in the development of value added nutritive and therapeutic beverages. These beverages might also improve socio-economic status of the farmers and entrepreneurs in country by enhancing the internal and export trades.

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Unexploited Potential of Underutilized Fruits and Vegetables for Sustainability Building

Dashrath Bhati and Vibha Acharya[1]

College of Home Science, GB Pant University of Agriculture and Technology, Pantnagar-263 145, India
[1]College of Home Science, Maharana Pratap University of Agriculture and Technology, Udaipur-313 001, India
E-mail: bhati.dashrath.1@gmail.com

Abstract: Underutilized fruits and vegetables can be characterized by the fact that they are locally abundant but globally rare. Absence of scientific information and scant knowledge about them leads to limit its utilization. Such fruits and vegetables play a vital role in day to day life of indigenous community. These fruits and vegetables are rich in necessary nutritional components like vitamins, minerals and dietary fibres besides antioxidants and phytochemicals. The supplementation of underutilized fruits and vegetables in diet may help in prevent ageing related diseases, obesity and various disorders of the body. Underutilized vegetables and fruits could be used to prepare various value- added products. The growing demand in developed and developing countries, for diversity and novelty in foods is creating new market niches for underutilized fruits and vegetables.

***Key Words*:** Nutrition security, Tribal, Underutilized fruits and vegetables

In more general terms, sustainability is the endurance of systems and processes. The organizing principle for sustainability is sustainable development, which includes the four interconnected domains: ecology, economics, politics and culture. Underutilized fruits and vegetables are considered as minor foods because they are less important than conventional fruits and vegetables in terms of global production and market value. These foods are often known by various names such as neglected, tribal, indigenous, uncultivated or wild, etc. However, from the standpoint of the rural poor who depend on many of these species for their food, nutrition and economic security, they are hardly minor. Underutilized crops are grown more widely or intensively but consumers are using these crops less at global level. Their current use is limited relative to their economic potential (Gruère *et al.,* 2008; Chauhan *et al.,* 2010). Underutilized fruits and vegetables are those grown primarily in their centres of origin by traditional farmers, where they are still important for the subsistence of local communities. Underutilized fruits and vegetables, in both raw and processed form, have long been important constituent of rural population's diet. Many underutilized and neglected fruits and vegetables are nutritionally rich and adapted to low agricultural input. Most of these species could benefit from market development as a means of supporting their long-term use while generating sustainable income for the producers and market chain actors. Consumer's always welcome new products that are nutritious, attractive and delicately flavoured. A verity of products prepared from the underutilized and neglected fruits and vegetables would have great demand because of their nutritional value, attractive colour, exotic nature, excellent diverse flavour and therapeutic and medicinal value.

Role of underutilized fruits and vegetables: The underutilized fruits and vegetables are harvested or collected, from natural and semi-natural environments, for the purpose of human use. The contribution of these fruits and vegetables for livelihood support will depend largely on individual circumstances (FAO, 1999). Underutilized fruits and vegetables have been found to form an integral part of the daily diets and provide a significant contribution in nutritional requirements of many rural households (Fig. 1).

The method and purpose of use of these fruits and vegetables may vary from region to region. The importance of underutilized fruits and vegetables differs between countries, and even at the household level. These fruits and vegetables are important elements for regional identity. Food provides a means of expressing regional identity and at the same time it is often seen as an opportunity for local businesses to make money, with small-scale producers, traders and restaurants offering special local food items (Pieroni *et al.,* 2005). Moreover, an uncultivated food is an important component of the local society and culture. Therefore, the loss of uncultivated foods means loss of important components of culture and religion (Akhtar, 2001). The use of uncultivated plants for dietary and health purposes need to be seen in a social and economical context of the societies in general and communities in particular (Yakub and Ajmal, 2001). Shore (2000) indicated that uncultivated foods such as leafy greens, tubers and wild fruits constituted nearly 40 per cent of food requirement of the communities in Bangladesh. Amongst the very poor, landless

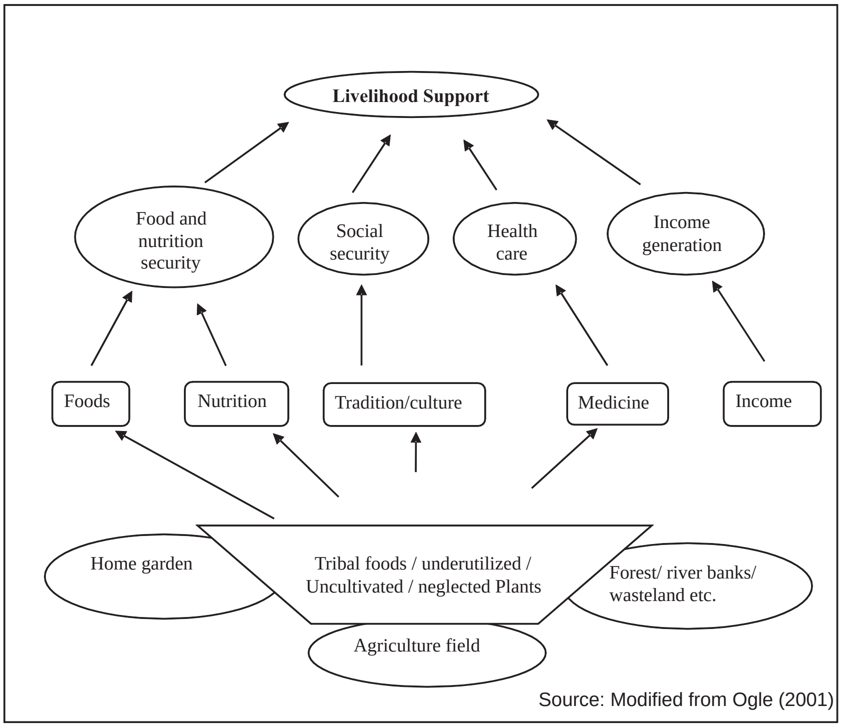

Fig. 1. Role of underutilized fruits and vegetables in livelihood support

members of these communities (comprising some fifteen per cent of the rural population, many of which are women-headed households) dependence on such sources of food and fodder is nearly 100 per cent (SANFEC, 2005). In India, most of the rural people, especially the poor, consume uncultivated crops at least 50-80 days per year. Earlier these were eaten more frequently (DDS, 2002). In addition to providing food directly, uncultivated plants provide an opportunity for cash generation. Traditionally, people have considered forest resources as a source of life and a symbol of creation (Manandhar, 2002). Farmer's traditional agricultural practices, like including wild relatives of crops usually maintained by indigenous communities and community forestry are linked to a rich cultural diversity. In particular, the hill people depend on a combination of forest products, livestock and agricultural products, and their livelihoods would not be sustainable without them (Manandhar, 2002). Although detailed data is lacking, reports show that a large number of uncultivated plant products are still used as a food supplement in rural areas (Shrestha, 2001). The availability of uncultivated plants is indispensable for food security and closely linked to the conservation and enhancement of biodiversity and genetic resources.

Nutritional significance: Indigenous fruits and vegetables play an important role in the nutrition of people and children in rural and tribal communities. These have the ability to grow under stressed and adverse conditions and also known for their nutritive values (Table 1). Tribal populations particularly children and women of these localities are fulfilling their nutritional requirements by consuming these fruits available freely in their vicinity (Malik *et al.,* 2010)**.** The nutritional value of traditional leafy vegetables found higher than several known common vegetables (Bhati and Jain, 2015; Orech *et al.,* 2007).

Natural medicine: Man has utilized plants as source of medicine for the treatment of several diseases since times immemorial. These plants have been the basis of traditional medicines in many countries and have continued to be vital importance. It has been estimated that about 80 percent of the world's population relies on the traditional system for primary health care. A large number of underutilized fruits and vegetable are known to possess high medicinal value and are recommended for therapeutic use (Table: 2). In traditional societies nutrition and health care are strongly interconnected and many plants have been consumed both as food and medicine (Pieroni, 2000).

Income generation: Many uncultivated plant resources have significant economic value. By preventing the need for cash expenditure, and income derived from the collection and sale of these resources is particularly important for the rural poor as a source of cash (Melnyk, 1994). Sale of gathered uncultivated products can contribute significant

Table 1. Major nutrients in edible portion of certain fruits (50g of edible portion of fruit)

Botanical name	Moisture (%)	Energy (Cal)	CHO (g)	Fibre (g)	Fat (g)	Protein (g)
Aegle marmalos Bael	61.5	68	15.9	1.5	0.15	0.9
Annona squamosal	70.5	52	11.8	1.6	0.2	0.8
Bambusa arundinacea	56.3	76	17.1	2	0.05	2
Diospyros melanoxylon	70.6	56	13.4	0.4	0.1	0.4
D. embryopteris	69.6	56	13.3	0.8	0.05	0.7
Emblica officinalis	81.8	29	6.8	1.7	0.05	0.3
Ficus bengalensis	74.1	36	5.9	4.3	1	0.9
Feronia limonia	64.2	67	9.1	2.5	1.85	3.6
F. indica	67.8	57	11.4	2.4	0.9	0.9
F. cunia	79.4	26	5.4	3.2	0.3	0.6
Manilikara hexandra	68.6	67	13.9	-	1.2	0.3
M. indica	73.6	56	11.4	-	0.8	0.7
Moringa oleifera	86.9	13	1.8	2.4	0.05	1.3
Manilikara elangii	54.7	80	18	2.2	0.5	0.9
Physallis peruviana	82.9	27	5.6	1.6	0.1	0.9
Phoenix dactylifera	59.2	72	16.9	1.9	0.2	0.6
Tamarindus indica	20.9	142	34	2.8	0.05	1.6

Source: Simlot (2001)

proportion of total household incomes, particularly for landless and people with marginal landholdings. In some cases, collection, use and marketing of wild resources can represent a better option than wage labour or farming (Watson and Hinchcliffe, 1996). Study conducted over five districts of the Orissa State in eastern India (a state with the second largest tribal population in the country, ca. 6.82 million) showed that tribal communities derive, on average, 15 percent of their gross family income from selling fruits, and that indigenous tribal families living within a 5–7 km radius of forests consume on average 82 kg yr^{-1} $household^{-1}$ of wild fruits, with about a quarter of households collecting regularly (Mahapatra and Panda, 2012). This has been observed for the majority of tribal populations in India, living within or near the forest (Bahuguna, 2000; Mohapatra and Sahoo, 2010). Underutilized fruits and vegetables are mostly consumed locally or traded in local/regional markets, with transportation distances highly limited by perishability of products and pest infestation (Akinnifesi *et al*., 2006). Bhati and Jain (2016) conducted a study at South western region of Rajasthan near to *Aravalli* ranges and observed that local population consumes a wide variety of fruits, green leafy vegetables, other vegetables and roots and tubers available in the forest. About 49- fruits, 35- green leafy vegetables, 34-other vegetables and 29-roots and tubers were identified in the region. Among them 17 fruits and vegetables were available round the year. The collection and sale of these fruits and vegetables can provide considerable support to local livelihoods, especially for those who lack the capital to engage in other livelihood activities (women and the most disadvantaged members of a community) (Delang, 2006). Forest products can also be sold in time of crisis to earn the income needed to ensure food security (Arnold, 2008).

Processed products: - Fruits and vegetables are perishable products, and cannot be stored for a longer period of time. Processing can extend availability season and promote widespread marketing of the items prepared from underutilized or neglected fruits and vegetables. Value addition of collected uncultivated foods by processing into edible forms prior to sale can be done (Harris and Mohammed, 2003). It would add value, reduce wastage and ensure better utilization. Processing technology to prepare products has been standardized for several underutilized fruits such as aonla, ber, jamun, karonda, imli, wood apple, etc. (Joshi and Jain, 2005). While some fruits are suitable for preparation of jam, jellies, juices, confectionary and preserved candies, the other can be used to make syrups, squashes, beverages and /or wine, sauces, chutneys and pickles or for canned, dehydrated or frozen products (Fig. 2). This process not only enhances the life of perishable products but also creates a good market relative to that in raw form. It helps to withdraw the surplus produce from the market in the post harvest season, stabilizes the prices and assists in maintaining a stock of fruits and vegetables to meet the demand in off-seasons. The processing of underutilized fruits and vegetables into squashes, juices, jams, jellies,

Table 2. Fruits and vegetable used for medicinal purpose in tribal communities

Botanical name	Part used	Remedies	Reference
Marsilea minuta	Leaves and twigs	Diabetes and gastrointestinal disorders	Anbarashan *et al.* (2011) Thirumalai *et al.* (2009)
Medicago sativa	Leaves	Night blindness	Meena and Yadav (2010)
Madhuca indica	Flowers and leaves	Cold, cough, diabetes and throat affection	Meena and Yadav (2010)
Grewia abutilifolia	Roots	Fractures	Meena and Yadav (2010)
Capparis deciduas	Flower and leaves decoction of stem	Pyorrhoea and rheumatism	Meena and Yadav (2010)
Aegle marmelos	Fruits	Constipation	Meena and Yadav (2010)
Centella asiatica	Whole plant	Increases memory	Meena and Yadav (2010); Sajem and Gosai (2006); Singh and Pandey (1998)
Holoptelea intergrifolia	Tender leaf paste / seeds	Skin diseases and anti-nematodal	Meena and Yadav (2010); Katewa and Guria (1997)
Pueraria tuberose	Tuber	Sexual debility, cooling agent, and quench thrust	Jain *et al.* (2008)
Opuntia elatior	Fruits / pulp of stem	Sexual sterility / Pain reliever / early recovery	Jain *et al.* (2008)
Curcuma amada	Roots	Rickets	Jain *et. al.* (2008)
Cassia tora	Seed paste, seed extraxct, leaf extract	Expulsion of guinea worm, asthma, in obesity	Jain *et al.* (2008) Sajem and Gosai (2006) Katewa *et al.* (2003)
Ficus religiosa	Fruit	Asthma	Parveen *et al.* (2007)
Tribulus terrestris	Whole plant	Gonorrhoea, gleet, spermatorrhoea, impotence	Parveen *et al.* (2007) Jain *et al.* (2003)
Chenopodium album	Leaves	Leaves Stomach pains A tea of the leaves and plant is used to relieve stomach pains	Parveen *et al.* (2007)
Ficus benghalensis	Fruit and latex	Spermatorrhoea	Parveen *et al.* (2007); Singh and Pandey (1998)
Bombax ceiba	Bark and flower and powdered root	Hydrocele, leucorrhoea, gonorrhoea and regularize	Jain *et al.* (2003)
Sterculia urens .	Bark powder; resin	Regularize menstrual disorders; leucoderma and peptic ulcer	Jain *et al.* (2003); Katewa and Guria (1997)
Luffa acutangula	Fruit extract	Jaundice	Katewa and Guria (1997)
Amorphophallus bulbifer	Crushed tuber	Antidote in animal bites	Katewa and Guria (1997)
Tamarindus indica.	Seed paste extract of fruits	Antidote; blood purifier and in jaundice	Singh and Pandey (1998)
Syzygium cumini	Fruits, stem bark	Diabetes, increases appetite; anti-dysentery, to relive headache	Singh and Pandey (1998)
Madhuca indica	Flower and leaves decoction of stem bark	Abdominal and chest pain due to cough and cold, blood purifier, gargled inspongy gum, tonsillitis and pharyngitis	Singh and Pandey (1998)
Ensete superbum	Sap of leaves and fruit powder	Raise uterus	Singh and Pandey (1998)
Diospyros melanoxylon	Powder of fruits and flower bark powder	Urinary and heart diseases, antidysenteric	Singh and Pandey (1998)
Dendrocalamus strictus	Decoction of leaves	Clear uterus	Singh and Pandey (1998)
Cissus quardrangularis L.	Internodes of stem	Bone fracture	Singh and Pandey (1998)
Coccinia grandis	Fruit	Cold, cough, diabetes and throat affection	Jain (1991)

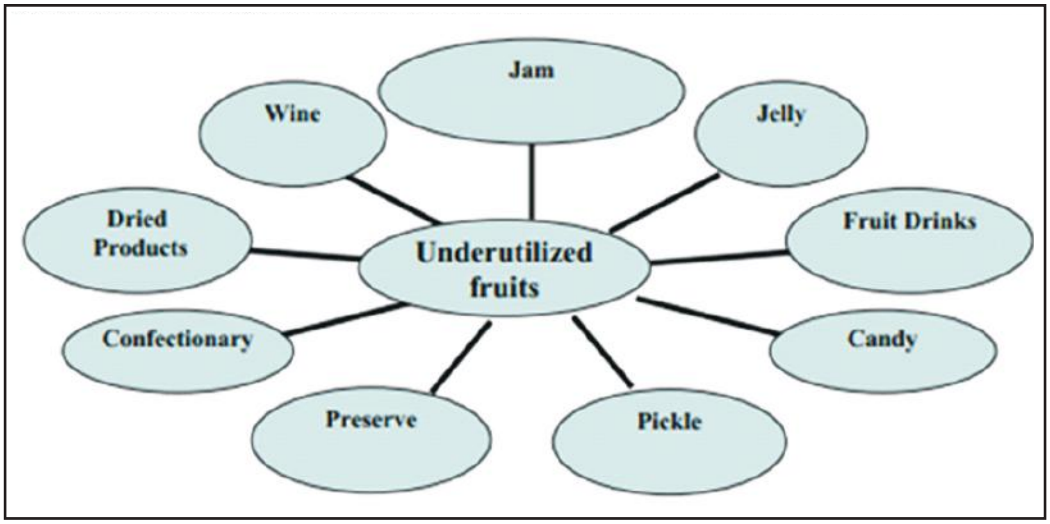

Fig. 2. Products that may be prepared from underutilized fruits

Table 3. Major processed products, which can be prepared from minor fruits

Processed products	Fruits used
Jam	Jamun, Karonda, Aonla, Mulberry, Soursop, Tamarind, Wood apple, etc.
Jelly	Tamarind, Jamun, Karonda, Tamarind, etc.
Preserved	Ber, Aonla, Ker, Sangri, Karonda, Bael, Karonda, Soursop, etc.
Candy	Aonla, Karonda, Tamarind, etc.
Confectionary	Amra, Aonla,Tamarind, etc.
Glazed fruits	Tamarind, Annanas, Aonla, etc.
Juice/syrup/ Beverage/squash	Aonla, Ber, Bael, Jamun, Karonda, Phalsa, Mulberry, Pomegranate, Soursop, Wood apple, Tamarind, etc.
Wine	Mahua, Jujube, Ber, Indian fig, Karonda, etc.
Chutney	Karonda, Woodapple, Aonla, etc.
Sauce	Karonda, Tamarind, Woodapple, Pomegranate, etc.
Pickle	Jujube, Tamarind, Ker, Lasora, Gonda, etc.
Dehydration	Aonla, Karonda, Ker, Bael, Ber, Custard apple, etc.
Frozen	Puree Bael, Karonda, Ker, Phalsa Tamarind, Custard apple, etc.
Canning	Ber, Aonla, Jamun, Ker, etc.

marmalades, pickles and fruit in syrup etc. offers a variety of ways of consuming fruits and vegetables (Table 3).

The popularity of such products is on increase. It is hard to think of the hot and long summer without a daily refreshing glass of some squash or juice. Jam and jelly, and fruit-in–syrup are being used by more and more people as dessert while jams and marmalades are finding way on to the breakfast tables of an ever greater number of people. Pickles and salads are becoming indispensable items for adding spice and flavor to the food.

At present, only small scale processing is being done to make processed products in spite of greater possibilities mainly because of the lack of a systematic approach to exploit the potential. Opportunities exist for their consumption in internal as well as international market by appropriate publicity of their nutritional and therapeutic values as “New Health Foods” or “High Value Foods”. Development of organised orcharding to produce quality raw material and collection chain for its uninterrupted supply in required quantities to the processing centres is required. To be able to manufacture commercial products for use in different sectors, plants species that are rich in different materials of economic values have already been identified. But there is need of concentrated research and development efforts to manufacture standard quality products for their wider use. Attention is required to identify proper genotypes, growing techniques for high recovery of the intended metabolites and isolation and processing techniques for product development followed by suitable pilot testing for commercial feasibility.

Commercial produces from underutilized fruits and vegetables: Almost every day of people consume and use an amazing variety of products prepared from the fruits and vegetables. The produce that the underutilized fruit trees yield are used to manufacture a variety of products such as sugars, starch, apices, gums, resins, essential oils, tannin and dyeing material, fibres, wax, etc. At present they are limited only to household use and consumption or are sold in local markets. Some of the products, however, are already being traded in the domestic as well as international markets.

Conclusion: Underutilized plants embedded with rich nutrient potentials along with ability to stand against adverse climatic conditions can prove to be boon to all concerns - growers, consumers and environmentalists, provided that they are tamed properly. The reason for the low utilization of underutilized fruits and vegetables is lack of information and non-viability of indigenous vegetable production like the major cultivated species.

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Heterosis for Fruit Quality Parameters in Tomato (*Solanum lycopersicum* L.)

M. V. Bharathkumar, A. T. Sadashiva[1], Sanjay Kumar and R. N. Thontadarya[2]

CCS Haryana Agricultural University, Hisar-125 004, India
[1]Indian Institute of Horticultural Research, Bengaluru-560 089, India
[2]College of Horticulture, UHS campus, Bengaluru-560 065, India
E-mail: bharathkumarmv809@gmail.com

Abstract: Line x Tester analysis was performed by employing nine tomato genotypes (6 lines and 3 testers) to develop 18 hybrids. These hybrids along with parental lines and commercial checks Arka Rakshak and Abhinav were evaluated to know the extent of heterosis exhibited to different nutritional and keeping quality traits along with the yield. Results revealed that the hybrids IIHR 2892 x IIHR 2852 and IIHR 2848 x IIHR 2852 exhibited standard heterosis of 30.67% and 21.24%, respectively over standard check Abhinav for fruit firmness. Standard heterosis of 86.50% has been recorded for total carotenoid in the hybrid combination IIHR2892 x IIHR2852 over the check Arka Rakshak. IIHR2892 x IIHR2852 have recorded standard heterosis for yield along with important fruit quality traits like acid, total carotenoids, lycopene, fruit firmness and fruit breadth.

Key Words: F_1 Heterosis, Hybrid, Line × Tester, Quality, Tomato

Tomato (*Solanum lycopersicum* L.) being the crop of importance for both culinary and processing purpose, it has been cultivated over large area around the world. Even though the primary objective of any breeding program and need of farmer is a high yielding cultivar/hybrid, the need for good quality fruit in tomato is of great importance owing to the reason being that high yielding hybrid with poor fruit quality and appearance will not be preferred in the market. At present, most of the research efforts in tomato are being concentrated on development of high yielding tomatoes coupled with multiple disease resistance. The growing health concerns among the people builds on the scope to incorporate superior nutritional characters like high lycopene, total carotenoids and ascorbic acid along with good keeping quality traits like pericarp thickness and fruit firmness in addition to high yield and disease resistance. Phenotypic superiority of F_1 hybrid offspring over its diverse parents is said to be heterosis (Shull, 1948). Heterosis for various fruit quality and yield characters has been reported by Yadav *et al*. (2013) and Paramappa *et al*. (2014) in solanaceous vegetables like tomato and brinjal. Moreover, vegetable hybrids that exploit high heterosis are known to perform better in their quality and yielding ability over the varieties developed by selection in various growing conditions (Singh, 2014). Hence, present investigation was carried out at Indian Institute of Horticulture Research, Bengaluru during 2013-14 and 2014-15 to assess the heterosis levels expressed by hybrids over their parents for fruit quality traits and also to identify best heterotic combinations for the same.

MATERIAL AND METHODS

Source materials for current study comprised of nine diverse genotypes (IIHR 977, IIHR 1816, IIHR 2848, IIHR 2850, IIHR 2891, IIHR 2892, IIHR 2852, IIHR 2853 and IIHR 2890) that were selected from IIHR collection according to their variability for different quality traits. Six lines (female) and three testers (male) were crossed in Line X Tester fashion at crossing block, division of vegetable crops, IIHR, Hesaraghatta, Bengaluru during *Rabi* of 2013-14 by transferring the pollen grain from male parent to the receptive stigma of emasculated female flower and bagging the same with the label. Evaluation of hybrids for various fruit quality parameters in comparison to their parents along with a popular public (Arka Rakshak) and private sector hybrids (Abhinav) as standard checks was taken up during summer 2014 in randomized block design with three replications. Each entry was represented by 40 plants spaced 100 cm apart between rows and 45 cm within row. Crop was raised by following package of practices recommended by IIHR for tomato crop. About 5 fruits from each replication of an entry were considered to record observation for quality traits like fruit length (cm), fruit breadth (cm), firmness (kg cm^{-2}), number of locules per fruit, pericarp thickness (mm), TSS (º Brix), ascorbic acid (mg/100 g), total carotenoids (mg/100 g) and lycopene (mg/100 g), and the average value obtained from 3 replications was employed for data analysis in statistical software Windostat version 8.0 to estimate the level of heterosis recorded by the hybrid progenies. Yield was recorded on whole plot basis. Heterosis values in negative direction were considered as desirable for the character number of locules per fruit, sine the number of locules is indirectly proportional to the firmness of the fruit. Sometimes more number of locules per fruit is preferred sine the juice content increases with the raise in number of locules.

RESULTS AND DISCUSSION

Analysis of variance for nine considered fruit quality traits (Table 1) revealed that mean sum of squares for parents and hybrids were significant for fruit length, fruit breadth, firmness, number of locules per fruit, pericarp thickness, TSS, total carotenoids and lycopene indicates presence of heterosis for these characters. Variance due to lines (females) and variance due to testers (males) was significant for all the traits except fruit firmness claiming the presence of sufficient variation among the male and female parents for most of the characters under study.

Out of 18 hybrids, significant positive heterosis for fruit length was observed only in the hybrid combination IIHR 2848 x IIHR 2853 over better parent and over standard checks (Arka Rakshak and Abhinav) with wide variation in range of heterosis as -22.94 to 12.56 per cent over better parent, -26.08 to 14.57% heterosis over standard check Arka Rakshak (SC 1) and -24.03 to 17.75% heterosis Abhinav (SC 2) was observed. The results obtained for fruit length are in line with the findings of Yadav *et al.* (2013). Only the cross combination IIHR2892 x IIHR2852 showed significant positive heterosis over better parent (23.99), whereas, about 8 combinations expressed significant heterosis over both SC 1 and SC 2 for fruit breadth with IIHR 2850 x IIHR 2853 expressing the highest heterosis per cent of and over SC 1 and SC 2 respectively. For fruit breadth, heterosis range of -27.52 to 23.99 over better parent, 1.08 to 43.78 over SC 1 and 4.39 to 48.49 over SC 2 was reported.

None of the hybrid combinations showed significant heterosis for fruit firmness over SC 1, whereas, the combination IIHR 2892 x IIHR 2852 expressed significant heterosis of 18.34% over better parent. Hybrids, namely IIHR 2848 x IIHR 2852 and IIHR 2892 x IIHR 2852 showed significant heterosis over SC 2 in desirable direction. Heterosis in the range of -31.84 to 18.34 %, -40.79 to 3.58 and -25.31 to 30.67 over BP, SC 1 and SC 2, respectively. Positive and significant heterosis over mid and better parents for fruit firmness was also reported by Shalaby (2013), while Solieman *et al.* (2013) recorded heterosis over mid-parent. Tomato fruits with least number of locules were reported to be having more firmness and transit survival ability, whereas fruits with more number of locules known to contain higher amount of juice and suits well for processing. Seven combinations were found to be heterotic in negative direction for number of locules per fruit with the hybrid IIHR 977 x IIHR

Table 1. ANOVA for various fruit quality traits

Source	Replication	Parents	Lines	Tester	Line x tester	Parent Vs. hybrids	Crosses	Error
Fruit length	0.14	1.77**	1.25**	3.62**	0.68*	0.85*	1.29**	0.16
Fruit breadth	0.09	3.95**	3.78**	6.065**	0.54	0.43	1.29**	0.24
Firmness	0.64	1.26*	1.03	0.96	3.02*	2.48*	2.054**	0.54
Locules	0.22	5.00**	1.65**	9.79**	12.19**	5.62**	2.24**	0.26
TSS	0.06	0.50**	0.27**	1.35**	0.01	0.56**	0.24**	0.08
Pericarp thickness	0.06	4.01**	2.66**	2.39**	13.97**	4.99**	3.27**	0.39
Ascorbic acid	0.57	64.58**	80.23**	1.054**	113.42**	0.34	21.88**	0.20
Total carotenoids	0.05	40.92**	27.29**	19.20**	152.78**	184.02**	80.46**	0.67
Lycopene	0.049	14.51**	9.76**	4.99**	57.32**	101.80**	35.11**	0.30
Yield per hectare	52.836	90.18	13.593	101.89	449.68**	27085.25**	483.27**	44.5

*significant at 5% level **significant at 1% level

Table 2. Heterosis (%) for fruit quality characters

Crosses	Fruit length			Fruit breadth			Fruit firmness			Number of locules fruit^{-1}			TSS		
	Heterosis % over			Heterosis % over			Heterosis % over			Heterosis % over			Heterosis % over		
	BP	SC-1	SC-2	BP	SC-1	SC-2	BP	SC-1	SC-2	BP	SC-1	SC-2	BP	SC-1	SC-2
IIHR 977 x IIHR852	-10.13 *	-2.39	0.31	8.74	3.43	6.82	0.54	-12	11.02	7.74	-3.42	16.62	-6.59	-3.04	-15.44 **
IIHR 977 x IIHR853	-19.04 **	-12.07 *	-9.63	-27.52 **	2.09	5.44	-20.76 **	-21.75 **	-1.29	-40.39 **	17.18	41.50 *	-3.65	-7.6	-19.42 **
IIHR 977 x IIHR890	-22.94 **	-16.30 **	-13.98 *	8.68	8.88	12.45	-5.98	-18.33 *	3.03	-25.99 **	27.64 *	54.12 **	-17.01 **	-2.13	-14.65 **
IIHR 1816 x IIHR852	-9.17	-7.64	-5.08	-18.39 **	1.08	4.39	-12.45	-23.37 **	-3.33	2.75	27.64 *	54.12 **	-14.52 **	-6.08	-18.09 **
IIHR 1816 x IIHR 2853	-4.8	-7.13	-4.55	-7.21	30.71 **	34.99 **	-20.68 **	-21.68 **	-1.19	-0.84	94.93 **	135.37 **	-15.70 **	-7.37	-19.22 **
IIHR 1816 x IIHR 2890	-15.85 **	-20.73 **	-18.53 **	-10.04	11.42	15.07	-31.84 **	-40.79 **	-25.31 **	-19.03 *	39.65 **	68.62 **	-17.53 **	-2.74	-15.18 **
IIHR 2848 x IIHR 2852	-8.76	-7.13	-4.55	-6.19	29.82 **	34.08 **	9.8	-3.89	21.24 *	5.35	34.47 *	62.37 **	-4.12	6.08	-7.49
IIHR 2848 x IIHR 2853	12.56 *	14.57 **	17.75 **	-7.39	30.46 **	34.73 **	-16.22 *	-17.27 *	4.37	-24.54 **	48.34 **	79.12 **	-13.05 **	-3.8	-16.10 **
IIHR 2848 x IIHR 2890	-13.71 **	-12.18 *	-9.74	-8.25	26.97 **	31.13 **	-8.56	-20.57 **	0.2	-6	62.11 **	95.75 **	-8.76	7.6	-6.16
IIHR 2850 x IIHR 2852	-4.66	-3.06	-0.37	-12.26 *	23.92 **	27.98 **	-20.06 *	-23.17 **	-3.08	27.19 *	53.52 **	85.37 **	6.37	10.41	-3.71
IIHR 2850 x IIHR 2853	0.57	-1.88	0.84	1.8	43.78 **	48.49 **	-15.06 *	-16.13 *	5.81	-7	82.82 **	120.75 **	-2.65	0.3	-12.52 **
IIHR 2850 x IIHR 2890	-17.69 **	-20.38 **	-18.17 **	-21.11 **	11.42	15.07	-10.68	-14.16	8.29	-24.07 **	30.95 *	58.12 **	-10.70 *	5.32	-8.15
IIHR 2891 x IIHR 2852	-0.15	1.53	4.35	9.4	3.43	6.82	-6.29	-17.98 *	3.47	3.93	-6.83	12.5	-5.02	1.98	-11.07 *
IIHR 2891 x IIHR 2853	-1.67	-4.08	-1.41	-22.25 **	9.52	13.11	-15.06 *	-16.13 *	5.81	-36.86 **	24.12	49.87 **	0.07	7.45	-6.3
IIHR 2891 x IIHR 2890	-12.01 *	-21.24 **	-19.06 **	11.02	11.23	14.88	-20.47 *	-30.92 **	-12.85	-3.96	65.63 **	100.00 **	-12.37 **	3.34	-9.87 *
IIHR 2892 x IIHR 2852	-15.53 **	-14.11 **	-11.73 *	23.99 **	26.90 **	31.06 **	18.34 *	3.58	30.67 **	37.22 **	65.63 **	100.00 **	-13.40 *	-10.11	-21.60 **
IIHR 2892 x IIHR 2853	-15.93 **	-17.98 **	-15.71 **	-13.69 *	21.57 **	25.56 **	-15.30 *	-16.37 *	5.51	-31.60 **	34.47 *	62.37 **	-6.85	-11.17 *	-22.53 **
IIHR 2892 x IIHR 2890	-7.7	-26.08 **	-24.03 **	5.83	8.31	11.86	-18.93 *	-29.58 **	-11.17	-22.03 **	34.47 *	62.37 **	-13.92 **	1.52	-11.46 *
SEm±		0.23			0.29			0.43			0.30			0.16	
CD (p=0.05)		0.67			0.82			1.22			0.85			0.46	
CD at 1%		0.90			1.10			1.64			1.14			0.62	

*, ** $p < 0.05$ and 0.01, respectively. BP = Better parent, SC-1 = Standard check 1 (Arka Rakshak), SC-2 = Standard check 2 (Abhinav)

Table 3. Heterosis (%) for fruit quality characters

Crosses	Pericarp thickness			Ascorbic acid			Total carotenoids			Lycopene			Yield ha^{-1}		
	Heterosis % over			Heterosis % over			Heterosis % over			Heterosis % over			Heterosis % over		
	BP	SC-1	SC-2	BP	SC-1	SC-2	BP	SC-1	SC-2	BP	SC-1	SC-2	BP	SC-1	SC-2
IIHR 977 x IIHR 2852	-22.92**	-10.22	15.12	46.49**	15.97 **	78.11 **	53.75 **	59.13 **	0.95	61.03 **	59.02 **	-1.14	60.92 **	-39.27 **	-7.70
IIHR 977 x IIHR 2853	-31.83**	-20.60**	1.8	93.76**	51.78 **	133.11 **	0.65	4.17	-33.92 **	1.56	0.29	-37.65 **	39.65 *	-26.94 **	11.03
IIHR 977 x IIHR 2890	-22.04**	-9.2	16.43	27.95**	-2.08	50.38 **	-49.63 **	-34.77 **	-58.62 **	-51.16 **	-41.48 **	-63.62 **	48.05 *	-35.06 **	-1.30
IIHR 1816 x IIHR 2852	-9.34	-2.89	24.51 **	-49.25 **	-15.17 **	30.29 **	55.08 **	42.88 **	-9.37 **	62.53 **	47.13 **	-8.53 *	166.61 **	0.63	52.93 **
IIHR 1816 x IIHR 2853	-15.90 *	-9.92	15.5	-50.40 **	-17.08 **	27.35 **	60.11 **	61.75 **	2.61	77.14 **	65.88 **	3.13	112.53 **	11.18	68.96 **
IIHR 1816 x IIHR 2890	-24.60**	-19.24**	3.55	-12.70 **	45.94 **	124.15 **	-27.19 **	-5.71	-40.19 **	-21.47 **	-5.9	-41.50 **	118.71 **	-4.06	45.80 **
IIHR 2848 x IIHR 2852	5.09	17.75 *	50.98**	-40.09 **	-7.83 *	41.55 **	-23.23 **	-29.27 **	-55.13 **	-24.06 **	-31.26 **	-57.26 **	90.50 **	-28.10 **	9.27
IIHR 2848 x IIHR 2853	-3.76	7.83	38.26**	-44.33 **	-14.36 **	31.53 **	5.40	6.48	-32.45 **	14.34 *	7.07	-33.44 **	63.74 **	-14.34	30.18 *
IIHR 2848 x IIHR 2890	-3.76	7.83	38.26**	-44.85 **	-15.17 **	30.29 **	-46.99 **	-31.35 **	-56.45 **	-46.83 **	-36.28 **	-60.39 **	56.74 **	-31.24 **	4.49
IIHR 2850 x IIHR 2852	-1.27	-0.72	27.29**	-42.43 **	-32.83 **	3.16	9.21	0.62	-36.17 **	11.34	0.79	-37.34 **	157.45 **	-2.83	47.67 **
IIHR 2850 x IIHR 2853	-5.46	-4.94	21.89*	-21.57 **	-8.50 **	40.53 **	-4.23	-3.24	-38.62 **	1.60	-4.86	-40.85 **	52.07 **	-20.45 *	20.90
IIHR 2850 x IIHR 2890	-11.13	-10.64	14.57	-30.40 **	-18.81 **	24.70 **	-62.22 **	-51.08 **	-68.97 **	-60.98 **	-53.24 **	-70.93 **	70.60 **	-25.17 **	13.72
IIHR 2891 x IIHR 2852	-16.44*	-20.60**	1.80	-1.05	-21.67 **	20.31 **	-17.90 **	-24.36 **	-52.02 **	-19.42 **	-27.06 **	-54.65 **	121.62 **	-16.35 *	27.12 *
IIHR 2891 x IIHR 2853	-13.4	-17.71*	5.51	40.96**	10.42 **	69.58 **	61.81 **	63.48 **	3.70	79.67 **	68.25 **	4.60	110.22 **	9.98	67.13 **
IIHR 2891 x IIHR 2890	-19.53**	-23.54**	-1.97	20.41**	-15.44 **	29.86 **	-19.34 **	4.45	-33.74 **	-13.56 **	3.57	-35.61 **	71.28 **	-24.87 **	14.18
IIHR 2892 x IIHR 2852	-9.82	-15.58*	8.24	2.74	5.33	61.77 **	102.43**	86.50 **	18.31 **	108.13**	88.40 **	17.13 **	155.31 **	-3.54	46.58 **
IIHR 2892 x IIHR 2853	-22.69**	-34.74**	-16.32	4.44	7.08 *	64.46 **	-10.95 *	-10.03	-42.93 **	-6.66	-12.59 *	-45.66 **	75.91 **	-7.97	39.86 **
IIHR 2892 x IIHR 2890	-11.86	-26.27 **	-5.46	10.08**	12.86 **	73.34 **	-43.50 **	-26.83 **	-53.58 **	-43.70 **	-32.54 **	-58.06 **	146.47 **	8.11	64.30 **
SEm±		0.36			0.26			0.48			0.32			4.44	
CD at 5%		1.04			0.74			1.36			0.91			12.72	
CD at 1%		1.39			1.00			1.83			1.23			17.08	

*, ** $p < 0.05$ and 0.01, respectively. BP = Better parent, SC-1 = Standard check 1 (Arka Rakshak), SC-2 = Standard check 2 (Abhinav)

Table 4. Range of heterosis and best heterotic hybrids for various fruit quality characters

Character	Mean range	Heterosis (%) range over			Number of crosses with significant heterosis in desirable direction over			Best heterotic hybrids over		
		BP	SC 1	SC 2	BP	SC 1	SC 2	BP	SC 1	SC 2
Fruit length (cm)	4.84 - 6.64	-22.94 – 12.56	-26.08 – 14.57	-24.03 – 17.75	1	1	1	IIHR2848xIIHR2853 (12.56)	IIHR2848xIIHR2853 (14.57)	IIHR2848xIIHR2853 (17.75)
Fruit breadth (cm)	5.31 - 7.55	-27.52 – 23.99	1.08 – 43.78	4.39 – 48.49	1	8	11	IIHR2892xIIHR2852 (23.99)	IIHR2850xIIHR2853 (43.78) IIHR1816xIIHR2853 (30.71)	IIHR2850xIIHR2853 (48.49) IIHR1816xIIHR2853 (34.99)
Firmness (kg cm^{-2})	5.02 - 8.78	-31.84 – 18.34	-40.79 – 3.58	-25.31 – 30.67	1	0	2	IIHR2892xIIHR2852 (18.34)	-	IIHR2892xIIHR2852 (30.67) IIHR2848xIIHR2852 (21.24)
Locules	3 - 6.28	-40.39 – 37.22	-3.42 – 94.93	12.5 – 135.37	8	0	0	IIHR977xIIHR2853 (-40.39) IIHR2891xIIHR2853 (-36.86)	-	-
TSS (^{0}B)	3.9 - 4.84	-17.53 – 6.37	-11.17 – 10.41	-22.53 - -3.71	0	0	0	-	-	-
Pericarp thickness (cm)	5.11 - 9.22	-31.83 – 5.09	-34.74 – 17.75	-16.32 – 50.98	0	1	6	-	IIHR2848xIIHR2852 (17.75)	IIHR2848xIIHR2852 (50.98) IIHR2848xIIHR2890 (38.26)
Ascorbic acid (mg $100g^{-1}$)	8.06 - 18.21	-50.40 – 93.76	-32.83 – 51.78	3.16 – 133.11	6	6	17	IIHR977xIIHR2853 (93.76) IIHR977xIIHR2852 (46.49)	IIHR977xIIHR2853 (51.78) IIHR1816xIIHR2890 (45.94)	IIHR977xIIHR2853 (133.11) IIHR1816xIIHR2890 (124.15)
Total carotenoids (mg $100g^{-1}$)	6.34 - 24.17	-62.22 – 102.43	-51.08 – 86.50	-68.97 – 18.31	5	5	1	IIHR2892xIIHR2852 (102.43) IIHR2891xIIHR2853 (61.81)	IIHR2892xIIHR2852 (86.50) IIHR2891xIIHR2853 (63.48)	IIHR2892xIIHR2852 (18.31)
Lycopene (mg $100g^{-1}$)	3.75 - 15.11	-60.98 108.13	-53.24 - 88.40	-70.93 - 17.13	6	5	1	IIHR2892xIIHR2852 (108.13) IIHR2891xIIHR2853 (79.67)	IIHR2892xIIHR2852 (88.40) IIHR2891xIIHR2853 (68.25)	IIHR2892xIIHR2852 (17.13)
Yield (t ha^{-1})	48.38-88.56	39.65 - 166.61	-39.27 – 11.18	-7.7 - 68.96	18	0	10	IIHR1816xIIHR2852 (166.61) IIHR2850xIIHR2852 (157.45)	-	IIHR1816xIIHR2853 (68.96) IIHR2891xIIHR2853 (67.13)

*Values in the parenthesis indicates values of heterosis

BP = Better parent, SC-1 = Standard check 1 (Arka Rakshak), SC-2 = Standard check 2 (Abhinav)

2853 being highly heterotic (-40.39), whereas none of the 18 combinations were found to be heterotic in negative direction over standard checks. Industries concentrating on tomato juice prefer fruits with more number of locules since they are reported as high juice yielders. About 14 and 16 hybrid combinations were heterotic for number of locules in positive direction over SC 1 and SC 2, respectively. However, none of the combinations was positively heterotic over better parent. Heterosis in the range of -40.39 to 37.22 over better parent, -3.42 to 94.93 over SC 1 and heterosis rage of 12.5 to 135.37 was observed for number of locules per fruit. Results obtained for number of locules per fruit is in accordance with the results of Solieman *et al*. (2013).

Increased TSS in tomato fruit may efficiently bring down the quantity of sugar required during processing and may also preferred as salad. For TSS, range of heterosis varied from -17.53 to 6.37 over better parent, -11.17 to 10.41 over SC 1 and -22.53 to -3.71 over SC 2. But none of the hybrids exhibited significant heterosis in desirable direction over BP, SC 1 and SC 2 for TSS. Similar results ranging from negative to positive heterosis for TSS over better parent and standard check was recorded by Yadav *et al*. (2013) and Kumar *et al.* (2013). Whereas, Shalaby (2013) obtained only negative heterosis over mid and better parents for total soluble solids The pericarp thickness is directly proportional to firmness of the fruit and hence positive heterosis is desired for this trait. Magnitude of heterosis for pericarp thickness varied between -31.83 to 5.09 over better parent, -34.74 to 17.75 over SC 1 and -16.32 to 50.98 over SC 2. Significant heterosis in desirable direction was observed only in the hybrid IIHR 2848 x IIHR 2852 (17.75%) over SC 1, whereas about 6 hybrids exhibited significant heterosis over SC 2 with the cross IIHR 2848 x IIHR 2852 (50.98%) exhibiting maximum significant heterosis. Joshi *et al.* (2005) and Solieman *et al*. (2013) also recorded positive heterosis for pericarp thickness over the mid parent.

The range of heterosis was between -50.40 to 93.76% over better parent and -32.83 to 51.78% over SC 1 with 6 hybrids exhibiting significant heterosis over both BP and SC 1. About 17 hybrids were significantly heterotic over SC 2. For ascorbic acid, cross combination IIHR 977 x IIHR 2853 exhibited maximum heterosis of 93.76, 51.78 and 133.11% over BP, SC 1 and SC 2, respectively. The results obtained are in line with the findings of Anita *et al*. (2005) and Solieman *et al*. (2013). Carotenoid is an important pigment that acts as antioxidant and also as source of vitamin A. The extent of heterosis for total carotenoids varied between -62.22 to 102.43, -51.08 to 86.50 and -68.97 to 18.31 over the better parent, SC 1 and SC 2, respectively. About 5 hybrids each exhibited significant heterosis over both better parent and SC 1, whereas, only one hybrid was found to be positively significant over SC 2. The hybrid IIHR 2892 x IIHR 2852 expressed maximum heterosis per cent of 102.43, 86.50 and 18.13 over BP, SC 1 and SC 2 respectively for total carotenoids.

Heterosis for lycopene ranged between -60.98 to 108.13, -53.08 to 88.40 and -70.93 to 17.13 over better parent, SC 1 and SC 2, respectively with 6 hybrids showing significant positive heterosis over BP and 5 hybrids with significant heterosis in desirable direction over SC 1. Only the hybrid combination IIHR 2892 x IIHR 2852 recorded significant standard heterosis of 17.13% over SC 2. Kurian and Peter (2001) and Kumar *et al.* (2013) observed highest significant heterobeltiosis for lycopene. Ultimate aim of any breeding program is to get high yield per unit area with acceptable quality, since farmers will not prefer the variety with low yield even though it has superior fruit quality characters. The extent of heterosis for yield per hectare ranged between 39.65 to 166.61, -39.27 to 11.18 and -7.7 to 68.96 over better parent, SC 1 and SC 2, respectively. Among all 18 hybrids that had shown heterosis over better parent and 10 hybrids that exhibited significant heterosis over SC 2, the combination IIHR 1816 x IIHR 2852 found to be the best heterotic one with heterosis per cent of 166.61 and 68.96 over better parent and SC 2, respectively. While none of the hybrids recorded significant heterosis in desirable direction over SC 1. Positive significant heterosis for fruit yield has been reported by Yadav *et al*. (2013); Amaefula *et al*. (2014) and Chauhan *et al*. (2014). Heterosis for all quality characters along with that of the yield was found in none of the hybrids evaluated. However, the combination IIHR2892 x IIHR2852 has showed significant standard heterosis in desirable direction for five quality characters like ascorbic acid, total carotenoids, lycopene, fruit firmness and fruit breadth along with that of yield per hectare and hence this hybrid can be further evaluated under various environmental conditions to examine its performance over the years for fruit quality and yield.

It's been a well known fact that hybrids cover most of the area in tomato for various traits. Since significant heterosis has been reported towards a desirable direction in the present study for most of the quality characters like lycopene, carotenoids, TSS, firmness and ascorbic acid along with that of the yield, hybrids in tomato can be exploited commercially.

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Effect of Sulphur on Growth, Yield and Economics of Onion (*Allium cepa* L)

Rama Kant Singh, Pankaj Kumar and S. B. Singh
Krishi Vigyan Kendra, Katihar, Bihar Agriculture University, Sabour-854 105, India
E-mail: rksbau555@gmail.com

Abstract: A field experiment was conducted at farmer's field of Katihar district during two consecutive years of 2013-14 and 2014-15 to investigate the effect of different doses of sulphur on growth and yield performance of onion. The soil is non-calcareous light gray in colour flood plain belongs to the alluvial Gangetic plain (Agro-climatic zone II) were significantly affected by different doses of sulphur. However, bulb diameter, neck diameter, and neck bulb ratio were not affected by different doses of sulphur application. Number of leaves plant^{-1} increased up to a certain growth stage and then declined. Dry weight of root, dry weight of bulb and total dry matter showed an increasing trend up to last stage of growth. Application of 10 kg 80% WDG S ha^{-1} showed the highest yield (242.25 q ha^{-1}). Application of 100, 50, 100 kg ha^{-1} of nitrogen, phosphorous, potash, 10 t ha^{-1} cowdung and 10 kg 80 % WDG S ha^{-1} might be an optimum combination for onion production.

Key Words: Dry Matter, Growth, Onion, Sulphur, Yield

The production of onion in the world is over 37 million tones on 7 million areas of land as per estimation of United Nations Food and Agriculture Organization. About 170 countries are cultivating onion among them India is one of the leading onion producers next to China in the world (Kabir, 2007). The demand and supply regulates the price fluctuations of onion in the agriculture market. To stabilize prices, there is need to enhance cultivated area, production and storage capacity. Sulphur is an essential nutrients, which plays an important role in its production and quality specially pungency and nutritive values. Onion face wide fluctuations both in their production and consumption price trends. Sulphur containing secondary compounds was not only of importance for nutritive value and flavors, but also for resistance against pests and diseases (Bell, 1981). Most of Indian soils are deficient in available sulphur as because its external supply is very instead of high requirements. This deficiency is becoming acute over time due to extensive use of sulphur free fertilizer, intensive crop production and poor sulphur status of soils. Non-application of sulphur in sulphur deficient soils has often resulted in low yield of onion. Sulphur deficient plants also had poor utilization of macro and micronutrients and significantly the onion bulb in maturity. The present research work was undertaken to investigate the effect of sulphur fertilization on growth, yield and yield attributes in onion.

MATERIAL AND METHODS

The experiment was conducted at Farmers field by Krishi Vigyan Kendra, Katihar, under Bihar Agriculture University, Sabour, Bhagalpur during two consecutive years of 2013-14 and 2014-15. It lies between Latitude 25°N to 26°N, Longitude 87°E to 88°E with an altitude of 32 m above MSL. The climate is sub-tropical and humid having average temperature (Max. and Min.), 42°C and 4°C, respectively and the average annual rainfall of the district is about 1298 mm.

The experimental soils were non-calcareous in nature belonging to the Alluvial tract under Agro-ecological zone-II lies between three major rivers Mahananda, Kosi and Ganga. The soil samples were collected from farmer's field before the experiment start on and after harvesting of the crop. The soil samples were collected from 15 cm depth and prepared a composite soil samples and processed. The physico-chemical properties of soil were analyzed by prescribed standard procedure. The soil texture varies from sandy loam to sandy clay, respectively. Available sulphur was determined by turbidetry method (Hunter, 1984).

The experiment was design in RBD with three treatments and ten replications. The unit plot size was 4.0m × 2.5m. The land was prepared in early November and gypsum were applied @400kg ha^{-1} in plot with soil test based nutrients recommendation. Details of treatment were T_1- Farmers use imbalance fertilizer (N 50 kg and P_2O_5 50 kg), T_2- 100 kg Nitrogen + 50 kg Phosphorus + 100 kg MOP + 400 kg gypsum as basal application and T_3- 100 kg nitrogen + 50 kg Phosphorus + 100 kg Murate of Potash + 10 kg sulphur (80% WDG ha^{-1}). All the fertilizers were applied as per treatments dose in each individual plot during the final land preparation and rest nitrogenous fertilizer were applied at different stages recommended in different treatments and 5 kg sulphur as basal and 5 kg sulphur 80 % WDG (Wettable Dispersible Granules) applied at 30 DAT in T_3 Plot. Onion seed var Super Black (Zirat) in nursery was shown on 18^{th} and 24^{th} November 2014 at the rate of 8 kg ha^{-1}. At 45 days after sowing the onion nursery were transplanted in main plot after application of treatments wise manure and fertilizers with a spacing of 20 cm x 15 cm on 03 and 09 January 2015. The growth and yield parameters of individual plant were recorded of 10 plants in each plot.

A total of five harvests (5 plants /replication /harvest) were received for recording data on some morpho-physiological attributes of onion only. The first crop sampling was done at 45 days after transplanting and subsequently at 10 days interval upto 85 DAT. The plants were separated into roots, bulbs, stems and leaves and the corresponding dry weights were recorded after oven drying at 80^0C for 72 hours. The total dry matter was calculated from the summation of dry weights of roots, bulbs, stems and leaves. Other morpho-physiological attributes of onion were also calculated by respective method. The following growth parameters were also computed using the formula given by Hunt (1978).

Absolute growth rate (AGR):

$$AGR = \frac{W_2 - W_1}{T_2 - T_1} \text{ gram plant}^{-1} \text{ day}^{-1}$$

Where; W_2 and W_1 are the dry mass (DM) at time T_2 and T_1, respectively.

RESULTS AND DISUSSION

Physico-chemical properties of soil: An inconsistent change in soil pH and ECes values was observed; organic carbon percentage was at beginning from 0.32 to 0.33 per cent in before transplanting and 0.33 to 0.37 per cent due to application of gypsum and sulphur with FYM. In onion field no appreciable rise of organic carbon was noted. The status of available nitrogen, phosphorous and potash was 187.2 to 189.4, 15.9 to 16.7 and 211.4 to 218.5 $kgha^{-1}$ and 166.4 to 179.6, 13.8 to 16.8 and 191.4 to 202.0 kg ha^{-1}, respectively at before transplanting and after harvesting of crop. NPK status decreases due to uptake by crops. The initial levels of sulphur were 6.65 to 6.72 ppm at harvesting it was varies from 6.48 to 6.87 ppm (Table 1).

S application leads to increase in the growth attributes and ultimately production and productivity of crop. Sulphur is applied as basal dose before transplanting of onion seedlings through gypsum, sulphur with 80% WDG @ 5 kg ha^{-1} and broadcasting the remaining sulphur with 80% WDG @ 5 kg ha^{-1}. Sulphur fertilizer might have promoted the availability of native soil sulphur as replicated by their uptake. Similar opinion was reported by Nasreen *et al.*(2007).

Effect of sulphur on plant height: Table 2 and 3 showed the positive relationship between plant height, fresh weight of leaves and bulb to age and sulphur doses upto 65 DAT, after that the relationship was inverse but number of leaves increase significantly at various growth stages. The effect of different levels of sulphur on plant height was found

Table 1. Effect of different treatments on physico-chemical properties of experimental soil

Treatments	pH		ECe		OC		N		P		K		S	
	(1 : 2.5)		(d Sm^{-1})		(%)		Available Nutrients (Kg ha^{-1})						(ppm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
T_1	6.94	6.86	0.273	0.290	0.32	0.33	187.2	166.4	15.9	13.8	218.5	191.4	6.65	6.48
T_2	6.97	7.03	0.277	0.318	0.33	0.37	189.4	179.6	16.7	16.8	211.4	200.4	6.68	6.88
T_3	6.98	7.01	0.278	0.279	0.31	0.36	187.2	178.0	16.1	14.6	213.0	202.0	6.72	6.87
CD (p=0.05)	NS	0.03	NS	0.02	NS	0.89	NS	1.3	NS	0.8	NS	1.8	NS	0.2

Table 2. Effect of different doses of sulphur on onion yield and economics

Treatments	Plant height (cm)	Bulb diameter (cm)	Neck Diameter (cm)	Neck bulb ratio	Fresh weight (qt ha^{-1})	Marketable yield (qt ha^{-1})	Yield damage (%)	Cost of cultivation (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net Income (Rs ha^{-1})	BC ratio
T_1	33.94	4.68	1.32	0.28	212.72	195.80	7.92	75532	176220	100688	2.33
T_2	37.58	4.90	1.36	0.28	230.66	215.24	6.68	78613	193716	115103	2.46
T_3	42.34	5.09	1.49	0.30	254.25	242.25	4.72	78714	218025	139311	2.77
CD (p=0.05)	4.6	0.6	0.04	NS	16.51	12.85	1.37	NS	NS	NS	NS

Table 3. Effect of different doses of sulphur on growth attributes of onion

Treatments	45 DAT					65 DAT					85 DAT				
	Plant Height (cm)	No of leaves plant^{-1}	Fresh weight (g plant^{-1}) Leaf	Fresh weight (g plant^{-1}) bulb	Absolute growth rate plant^{-1}	Plant Height (cm)	No of leaves plant^{-1}	Fresh weight (g plant^{-1}) Leaf	Fresh weight (g plant^{-1}) bulb	Absolute growth rate plant^{-1}	Plant Height (cm)	No of leaves plant^{-1}	Fresh weight (g plant^{-1}) Leaf	Fresh weight (g plant^{-1}) bulb	Absolute growth rate plant^{-1}
T_1	23.26	4.2	3.21	1.58	0.07	39.52	6.2	15.26	9.67	0.55	31.27	8.1	14.28	63.22	0.01
T_2	27.31	4.5	3.28	1.75	0.08	45.62	6.4	16.71	13.82	0.61	37.35	7.5	15.96	68.94	0.05
T_3	31.24	4.6	3.25	1.78	0.10	50.72	7.0	17.60	15.70	0.66	42.34	7.4	17.88	76.51	0.11
CD (p=0.05)	2.8	0.2	NS	NS	NS	3.2	0.6	0.6	2.4	0.6	6.2	0.7	2.6	4.9	NS

significant at various growth stages and fresh weight of leaves and bulb at 65 and 85 DAT. The increase in plant height, fresh weight of leaves and bulb upto 65 DAT and thereafter, decline observation at 85 DAT. Sulphur significantly stimulate plant height, fresh weight of leaves and bulb at 10 kg sulphur 80 % WDG in all growth period except 85 DAT at present study. Others nutrient are present in sufficient quantities in the soil, responses to sulphur may not be evident, and conversely, unless sulphur is provided in adequate amount, responses to nitrogen, phosphorus and potassium may be very little.

The average horizontal and vertical bulb diameter of onion was varies from 4.98 cm to 5.52 cm and 4.38 to 4.56 cm at 85 DAT (Table 4). The variability is due to effectiveness of sulphur which ultimately increased the nutrient availability for the crop. The effect of different levels of sulphur on neck diameter was significant at 65 and 85 DAT. The neck diameter value was observed higher at 65 DAT and then found continued decreasing trend upto 85 DAT. The data on neck diameter varied was found 1.49 cm with T_3 where, sulphur applied @ 10 kg ha^{-1} with 80 % WDG, 1.36 cm with T_2 where sulphur source was gypsum and 1.32 cm with T_1 where no sulphur was applied. The data related to neck bulb ratio have decreased. It is possible due to increased size of bulb at all growth stages. Smriti *et al*. (2002) also reported that S application increase the size of bulb, therefore neck bulb ratio was reported in decreasing trend.

The data related to fresh and marketable yield was presented in table 2. Different doses of sulphur application had a significant variation on fresh and marketable yield of onion. The maximum fresh yield 254.25 q ha^{-1} was observed with application of 10 kg sulphur ha^{-1} through 80 % WDG followed by T_2 (230.66 q ha^{-1}) and T_1 (212.71 q ha^{-1}). The maximum marketable yield (242.25 q ha^{-1}) was observed where land was fertilized with 10 kg sulphur ha^{-1} through 80 % WDG followed by T_2 and T_1 with same statistical rank (Table 2). Control treatment showed the minimum fresh and marketable yield. The highest neck bulb ratio (0.30) was observed with 10 kg sulphur ha^{-1} through 80 % WDG. On the other hand the sulphur dose at 10 kg sulphur ha^{-1} through 80 % WDG produced significantly highest yield and subsequently yield was reduced with T_2 and T_1 where no sulphur was applied. These findings are conformity to the findings of Meena and Singh (1998) showed that sulphur fertilization significantly enhance the yield. The results shows that the sulphur dose at 10 kg 80% WDG S ha^{-1} produced the highest yield of

Table 4. Effect of different doses of sulphur on neck and bulb diameter of onion

Treatments	Diameter (cm plant^{-1})														
	45 DAT					65 DAT					85 DAT				
	neck	bulb		bulb	Neck bulb ratio	neck	bulb		bulb	Neck bulb ratio	neck	bulb		bulb	Neck bulb ratio
		horizontal	vertical				horizontal	vertical				horizontal	vertical		
T_1	0.71	0.99	1.48	1.24	0.57	1.33	2.95	2.39	2.67	0.50	1.32	4.98	4.38	4.68	0.28
T_2	0.73	0.93	1.50	1.22	0.60	1.41	3.12	2.45	2.79	0.51	1.36	5.34	4.45	4.90	0.28
T_3	0.73	0.98	1.51	1.25	0.59	1.48	3.34	2.50	2.92	0.51	1.49	5.52	4.56	5.04	0.30
CD (p=0.05)	NS	NS	NS	NS	NS	0.6	0.4	NS	0.8	NS	0.4	0.02	0.08	0.3	NS

onion. The highest yield was also reported by Nasreen *et al.* (2003); Nasreen and Huq (2005). Sulphur fertilizer might have promoted the availability of native soil S as reflected by their uptake. Similar opinion was reported by Nasreen *et al.* (2007). The influence of different sources of sulphur and their interaction effect on yield damage was found to be significant and presented in table 2. It is clear from the data that in sulphur applied plots the percentage loss of onion is low. The minimum yield losses (4.72 %) were recorded in T_3 where 10 kg sulphur ha^{-1} applied through 80 % WDG in comparison to T_1 where no sulphur applied.

For the dry weight of root, trend was significantly increased up to 85 DAT. At 85 DAT the highest dry weight of root plant^{-1} (0.44 g) was recorded with the application of 10 kg 80 % WDG S ha^{-1} and the minimum (0.24 g) was recorded in without sulphur treated plot (Table 5). At 85 DAT the highest dry weight of bulb (7.34 g) was found in the plants grown with 10 kg 80 % WDG S ha^{-1} and the lowest (5.04 g) without S application, which was statistically significant. This result is agreed with the findings of Jaggi (2004) and Wiles (1994). There was a significant effect of sulphur on dry weight of root at 45, 65 and 85 DAT respectively. There was a significantly increasing trend observed in dry weight of root per plant in respect of increasing days after transplanting (table 5). The dry weight of leaf was significantly higher at 10 kg 80% WDG S ha^{-1} in comparison of other doses. On the other hand, control plot (no sulphur application) had the lowest leaf dry weight in all DATs. The dry weight of root, bulb and leaf was increased when the dose was increased through application of sulphur in onion. Meena and Singh (1998); Smriti *et al.* (2002); Nasreen *et al.* (2007) also found enhanced the dry weight of onion with S application.

Total dry matter production of onion depends on the size of the photosynthetic system and the length of growth period, during which photosynthesis continues. The total dry matter increased up to 10 kg 80% WDG S ha^{-1} and then decreased where on application of S. It was observed that TDM increased significantly with the advancement of time. At 85 DAT, the highest TDM (11.73 g) was found in the plants grown with 10 kg 80% WDG S ha^{-1} and the lowest (8.40 g) was found in no application of sulphar (table 5). The total dry matter increased up to 10 kg 80% WDGS ha^{-1} and then it decreased with other levels of S application. This result is agreed with the findings of Jaggi (2004). The highest total dry matter was found in the plants grown with 10 kg 80% WDG S ha^{-1} and the lowest in without application

Table 5. Effect of different doses of sulphur on dry weight of onion

Treatments	Dry weight (gram plant^{-1})											
	45 DAT				65 DAT				85 DAT			
	root	leaf	bulb	total	root	leaf	bulb	total	root	leaf	bulb	total
T_1	0.15	0.36	0.15	0.66	0.18	1.65	0.98	2.81	0.24	3.12	5.04	8.40
T_2	0.17	0.38	0.17	0.72	0.22	1.91	1.25	3.38	0.31	3.44	6.22	9.97
T_3	0.21	0.37	0.17	0.75	0.40	2.02	1.6	4.01	0.44	3.95	7.34	11.73
CD (p=0.05)	NS	0.35	NS	0.04	0.8	0.8	0.4	0.8	0.1	0.21	1.26	1.1

of S. The highest total dry matter obtained for onion was also reported by Nasreen *et al.* (2003).

Absolute growth rate (AGR) is the increase dry matter unit^{-1} of time plant^{-1}and it represents the efficiency of a plant as producer of new materials (Table 3). It was observed that there was a positive relationship between AGR and plant age until 65 DAT, after that the relationship was inverse. The effect of different levels of sulphur on AGR was found significant at all growth stages. The AGR showed the highest value at 65 DAT and continued to decline till 85 DAT. Sulphur significantly stimulated absolute growth rate in onion at 10 kg 80% WDG S ha^{-1} in all growth period except 85 DAT at the present study (Table 3).

Effect of different doses of sulphur on yield and yield contributing and B C ratio: The maximum fresh weight (254.25 kg ha^{-1}) was observed with the application of 10 kg 80 % WDG S ha^{-1} followed by 230.66 kg ha^{-1} with T_2 and 212.72 kg ha^{-1} with without sulphur applicated plot T_1. The highest marketable yield (242.25 kg ha^{-1}) was found where land was fertilized with 10 kg 80 % WDG S ha^{-1} followed by 215.24 kg ha^{-1} and 195.80 kg ha^{-1} with same statistical rank (Table 2). Control treatment showed the minimum fresh and dry weight. The highest bulb diameter (5.04 cm) was observed with application of 10 kg 80 % WDG S ha^{-1}. The highest neck diameter (1.49 cm) was observed with 10 kg 80 % WDG S ha^{-1} and the highest neck bulb ratio (0.30) was observed with 10 kg 80 % WDG S ha^{-1}. A response curve on the effect of different doses of sulphur on yield of onion was constructed at final harvest. The sulphur dose at 10 kg 80 % WDG S ha^{-1} produced significantly highest yield and subsequently yield was reduced with T_2 and T_1. These results reflect the conformity of the findings of Ullah *et al.* (2008).

The cost of cultivation of onion varied from Rs.75532 (T_1) to Rs.78754 per ha (T_3). The cost of cultivation increased in plot T_3 only due to use of sulphur. The data presented in table 2 showed that the gross income of onion was calculated varied from Rs. 218025 to Rs.176220 per ha. The maximum gross return was found Rs.218025 with treatment T_3 (10 kg 80 % WDG S ha^{-1}) minimum Rs.176220 with T_1 (no application of S). It is clear with our findings that the maximum return with T_3 might be due to highest yield of green pod per ha. It is possible due to the application of sulphur and inorganic fertilizer due to that the availability of nutrients is increased and the total production was also increased due to that the gross return was increased.

It is clear from the data presented in table 2 that the net income (Rs. 139311) was more profitable with the treatment T_3. The highest BC ratio 2.77 recorded in 3rd treatment shows the farmer friendly trend of these findings.

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Effect of Simulated Transportation on Physiological Properties of Ber (Ziziphus *mauritiana*) cv. Umran Stored Under Ambient Storage Conditions

Preeti, R. K. Goyal and Manoj Bhanukar
Department of Horticulture, CCS Haryana Agricultural University, Hisar-125 004, India
E-mail:parmar.preeti80@gmail.com

Abstract: The experiment was carried out to evaluate the effect of simulated transportation by providing different levels of vibration and time duration on physiological properties of ber fruits cv. Umran during transportation and storage under ambient conditions. The mechanical injury, PLW and decay loss increased with increased intensity, duration of vibration and days of storage while the firmness and total chlorophyll content of the fruits decreased. Based upon above parameters among various levels of simulation vibration and duration of vibration, fruits without simulation vibration were best in maintaining their physiological attributes followed by the fruits simulated at vibration of 50 rpm for 3 and 6 hours.

Key Words: Ber, Nylon netted bags, Simulation vibration, Umran

Ber (*Ziziphus mauritiana*) is not being marketed to any far extent places where it is not grown in the absence of proper post-harvest handling technology including transportation and storage. Inadequate means of transportation cause losses due to bruises, abrasions, cuts and punctures, which reduce the quality of fruits for marketing. During storage period, peel colour changes were observed due to abrasion and impact damage which directly influenced the visual quality. Browning of the damaged regions occurs due to oxidation of poly phenols (enzyme activity) giving an unpleasant appearance to the consumer (Maia *et al.*, 2011). During the transportation process the vehicles transmit vibrations and jerks into the packaging boxes that cause damages to the fruits. Thakur *et al.* (2005) also reported that along the post harvest handling and distribution channels, fruit firmness decreased due to metabolic activities. Zhou *et al.* (2007) reported that fruits exposed to vibration stress exhibited a faster softening and this continues during storage under ambient temperature. Understanding the behaviour of the produce under static and dynamic loads provides useful information in reducing mechanical damage and enhancing quality of the fresh produce during transportation, because damage to fresh produce due to mechanical forces is among the most important causes of losses of quality (Dewulf *et al.,* 1999).

Therefore, during long distance transportation there is needed to standardize the speed of the vehicles so that the shelf life of the fruits can be increased. In the present studies, attempts were made to know the impact of transportation on physiological properties of ber by providing simulated transportation at different frequency levels for different time durations and on that basis the frequency of vibrations were standardized.

MATERIAL AND METHODS

The experiment was carried out at CCS Haryana Agricultural University, Hisar. Laboratory vibration tester powered with 3HP electric motor was used to provide simulation vibration with required time as per treatments. The frequency and time of which were adjusted by the frequency and time adjusting knobs respectively, as per requirement. The ber fruits of cultivar Umran were selected after harvesting and packed in nylon netted bags. Approx. 4kg fruits were packed in each of the nylon netted bags and were subjected to simulation vibration at three levels *i.e.* 50,100 and 200 rpm for 3 and 6 hour durations. The physiological parameters were recorded at alternate days up to 8^{th} day of storage after simulation vibration and fruits were stored at ambient temperature (26±3°C). A control (without any simulated vibration *i.e.* 0 rpm) was also taken for comparing with simulated vibration treated fruits. The seven treatments were replicated four times.

The firmness of fruits was measured with the help of penetrometer fitted with a cylindrical plunger. The chlorophyll content of fruits was estimated by the method given by Wellburn (1994).

PLW (%) = Initial weight of fruits – Final weight of fruits/Initial weight of fruits X 100

Decay loss (%) = Weight of decayed fruits/Initial weight of fruits X 100

Mechanical injury (%) = Weight of the injured fruits/Initial weight of the fruits at the time of packing X 100

RESULTS AND DISCUSSION

Mechanical injury: The minimum injury was recorded in the fruits simulated at vibration of 50 rpm (5.17%) and the maximum (15.10%) at vibration of 200 rpm (Table 1). The magnitude of mechanical injury also increased significantly with increased duration of vibration. Minimum mechanical injury (6.63%) was observed in the fruits on which simulation vibration was given for 3 hour duration, while the maximum (8.18%) at simulation vibration for 6 hours. The injury might be due to improper handling of the fruits during loading efforts and jerks transmitted to the fruits during transportation. Similar results were reported by Singh and Thakur (2003).

Physiological loss in weight (%): The PLW increased significantly with increased intensity of vibration. On 2nd day minimum PLW (4.13%) was observed in the fruits with no simulation vibration (0 rpm) followed by the fruits simulated at vibration of 50 rpm (5.61%). The maximum PLW (10.15%) was observed at vibration of 200 rpm. Likewise, the PLW also increased significantly with increased duration of vibration. On the same day minimum PLW (6.15%) was observed at simulation vibration for 3 hours, while maximum (7.44%) at vibration for 6 hours (Table 2). Similar trend was observed on 4th, 6th and 8th day. This might be due to the increased rate of respiration and transpiration with increased intensity of vibration. As a result more amount of water transpired from the fruits. PLW also increased with increase in duration of vibration. Increase in PLW with storage has also been reported in ber by Yadav *et al.* (2005). The minimum was observed on 2nd day, while the maximum on 8th day of storage in all the treatments.

Table 1. Effect of simulation transportation on mechanical injury (%)

Simulation period (Hours)	Simulation vibration (rpm)				Mean
	0	50	100	200	
3	0(3.24)	4.22(8.28)	8.39(9.82)	13.89(11.14)	6.63 (8.20)
6	0(3.24)	6.13(9.09)	10.25(10.33)	16.32(11.61)	8.18 (8.57)
Mean	0(3.24)	5.17(8.68)	9.32(10.07)	15.10(11.37)	
CD (p=0.05)	H=0.06	S=0.09	H x S= 0.12		

Parentheses are angular transformed values

Table 2. Effect of simulation transportation on physiological loss in weight (%)

Simulation period (Hours)		Simulation vibration (rpm)				Mean
			2nd day			
		0	50	100	200	
3		4.13	4.97	6.56	8.95	6.15
6		4.13	6.24	8.02	11.36	7.44
Mean		4.13	5.61	7.29	10.15	
CD (p=0.05)	H=0.60	S=0.85	H x S= NS			
			4th day			
3		7.01	8.22	10.72	13.44	9.85
6		7.01	10.13	12.42	15.90	11.36
Mean		7.01	9.17	11.57	14.67	
CD (p=0.05)	H=0.84	S=1.19	H x S= NS			
			. th day s			
3		10.12	12.50	15.52	18.56	14.17
6		10.12	14.35	17.78	21.36	15.90
Mean		10.12	13.42	16.65	19.96	
CD (p=0.05)	H=1.34	S=1.89	H x S= N			
				8th day		
3		15.21	17.94	20.56	24.05	19.44
6		15.21	19.81	23.94	28.90	21.96
Mean		15.21	18.87	22.25	26.48	
CD (p=0.05)	H=1.01	S=1.43	H x S=2.03			

Decay loss (%): The decay loss increased significantly with increased intensity of vibration. On 2nd day of storage, no decay loss was observed in the fruits without simulation vibration and those simulated at vibration of 50 rpm significantly low as compared to 100 and 200 rpm (Table 3). This loss also increased significantly with increased duration of vibration. On 4th day of storage, the minimum decay loss was observed in fruits without simulation vibration followed by the fruits simulated at vibration of 50, 100 and 200 rpm. This loss also increased significantly with increased duration of vibration. A similar trend was observed on 6th and 8th day of storage. This might be due to the fact that increase in intensity of vibrations resulted in more mechanical damage to the fruits which provided favorable conditions for growth of micro-organisms. The decay loss in the ber fruit increased after transportation (Lal and Fageria, 2004) but there was no decay loss immediately after transportation (Yadav *et al.*, 2005). The decay loss was significant maximum in 200 ppm vibration for 6 hours on 2nd, 4th, 6th and 8th day of storage.

Fruit firmness (kg cm^{-2}): The data revealed that the firmness of the fruits decreased significantly with increased intensity and duration of vibration. Maximum fruit firmness was observed in the fruits without simulation vibration followed by those fruits simulated at vibration of 50 rpm and minimum was observed in the fruits simulated at vibration of 200 rpm. The maximum firmness was recorded in the fruits rendered simulation vibration for 3 hours while minimum was observed in the fruits given simulation vibration for 6 hour. The data in the Table 4 indicated that it also decreased significantly with increased period of storage. This might be due to loss of moisture. The interaction shows maximum fruit firmness in the fruits without simulation vibration while minimum was recorded on 8th day in the fruits simulated at vibration of 200 rpm for 6 hours. The results are in conformity with Goukh and Bashir (2003) in guava and Kaur *et al.* (2013) in pear.

Total chlorophyll content: The results presented in Table 5 depicted that the total chlorophyll content decreased significantly with increased intensity of vibration. Maximum retention of chlorophyll content (0.50 mg/100cm^2) was observed in the fruits without simulation vibration followed by the fruits simulated at vibration of 50 rpm (0.46 mg/100cm^2), while the minimum (0.30 mg/100cm^2) was observed in the fruits simulated at vibration of 200 rpm. The total chlorophyll content also decreased significantly with increased duration of vibration. Maximum retention of chlorophyll content (0.42 mg/100cm^2) was found in the fruits given simulation vibration for 3 hours, while the minimum (0.39 mg/100cm^2) was found

Table 3. Effect of simulation transportation on decay loss (%)

Simulation period(Hours)		Simulation vibration (rpm)				Mean
		0	50	100	200	
2nd day						
3		0 (3.24)	0 (3.24)	0.63(5.29)	2.32 (7.16)	0.74 (4.73)
6		0 (3.24)	0 (3.24)	2.17 (7.02)	4.35 (8.32)	1.63 (5.46)
Mean		0 (3.24)	0 (3.24)	1.4 (6.16)	3.34 (7.74)	
CD (p=0.05)	H=0.16	S=0.23	H x S= 0.32			
*The data in parentheses are angular transformed values.						
4th day						
3		5.68	6.31	9.70	14.59	9.07
6		5.68	8.36	11.45	17.37	10.72
Mean		5.68	7.33	10.57	15.98	
CD (p=0.05)	H=0.60	S=0.84	H x S= 1.19			
6th day						
3		12.84	15.15	19.82	29.10	19.23
6		12.84	18.42	22.75	33.74	21.94
Mean		12.84	16.78	21.29	31.42	
CD (p=0.05)	H=1.17	S=1.65	H x S= 2.33			
8th day						
3		20.55	28.38	37.01	51.09	34.26
6		20.55	31.89	41.68	55.78	37.47
Mean		20.55	30.14	39.34	53.44	
CD (p=0.05)	H=1.80	S=2.55	H x S = NS			

in the fruits given simulation vibration for 6 hours. The interaction suggested that, total chlorophyll content was found maximum (0.50 mg/100cm^2) in the fruits without simulation vibration and minimum (0.28 mg/100cm^2) in the fruits simulated at vibration of 200 rpm for 6 hours. Total chlorophyll content decreased with increased period of storage (Table 6). Maximum chlorophyll content (0.80 mg/100cm^2) was found on zero day followed by 2nd day (0.59 mg/100cm^2) and minimum (0.10 mg/100cm^2) on 8th day of storage while in the interaction, maximum (0.80 mg/100cm^2) retention of total chlorophyll content was found on day zero and it was minimum (0.09 mg/100cm^2) on 8th day in the fruits given simulation vibration for 6 hours (Table 7). The change in total chlorophyll content on account of interaction of duration of vibration, intensity of vibration and days of storage was not significant (Table 8). Similar changes in total chlorophyll content had been found in ber (Sharma *et al.,* 2000) and in apple (Vursavus and Ozguven, 2004).

Table 4. Effect of simulation transportation on fruit firmness (kg cm^{-2})

Simulation Period (Hours)	Simulation vibration (rpm)				Mean
	0	50	100	200	
3	8.5	7.8	6.9	5.8	7.2
6	8.5	7.5	6.4	5.2	6.9
Mean	8.5	7.6	6.6	5.5	
C.D (p=0.05)	H= 0.1	S=0.1	H x S= 0.2		

Simulation Vibration (rpm)	Days of storage					Mean
	0	2	4	6	8	
0	9.9	9.3	9.0	7.6	6.5	8.5
50 rpm	9.6	9.0	8.3	6.2	5.0	7.6
100 rpm	9.3	7.8	7.3	5.2	3.6	6.6
200 rpm	9.1	6.5	5.9	3.9	2.2	5.5
Mean	9.5	8.2	7.6	5.7	4.3	
CD (p=0.05)	S= 0.1	D= 0.1	S x D= 0.3			

Days of storage	Simulation period and vibration							
	3 Hours				6 Hours			
	0 rpm	50rpm	100rpm	200rpm	0 rpm	50rpm	100rpm	200rpm
0	9.9	9.7	9.5	9.2	9.9	9.4	9.1	8.9
2	9.3	9.1	8.1	7.0	9.3	9.0	7.6	6.1
4	9.0	8.5	7.5	6.3	9.0	8.0	7.0	5.4
6	7.6	6.3	5.3	4.2	7.6	6.2	5.0	3.6
8	6.5	5.2	3.9	2.5	6.5	4.7	3.2	1.8
CD (p=0.05)	H= 0.1	S=0.1	D= 0.1		H x S x D = 0.2			

Table 5. Effect of simulation transportation (duration of vibration and simulation vibration) on total chlorophyll content (mg/100cm^2)

Simulation Period (Hours)	Simulation vibration (rpm)				Mean
	0	50	100	200	
3	0.50	0.47	0.38	0.32	0.42
6	0.50	0.44	0.36	0.28	0.39
Mean	0.50	0.46	0.37	0.30	
CD (p=0.05)	H= 0.01	S= 0.01	H x S=0.01		

Table 6. Effect of simulation transportation (duration of vibration and days of storage) on total chlorophyll content (mg/100cm^2)

Simulation period	Days of storage					Mean
	0	2	4	6	8	
3	0.80	0.61	0.34	0.23	0.11	0.42
6	0.80	0.57	0.31	0.20	0.09	0.39
Mean	0.80	0.59	0.33	0.21	0.10	
CD (p=0.05)	H= 0.01	D= 0.01	H x D=0.01			

Table 7. Effect of simulation transportation (simulation vibration and days of storage) on total chlorophyll content (mg/100cm^2)

Simulation Vibration (rpm)	Days of storage					Mean
	0	2	4	6	8	
0	0.80	0.69	0.46	0.35	0.19	0.50
50	0.80	0.63	0.40	0.30	0.14	0.46
100	0.80	0.56	0.30	0.13	0.05	0.37
200	0.80	0.46	0.14	0.07	0.02	0.30
Mean	0.80	0.59	0.33	0.21	0.10	
CD (p=0.05)	S= 0.01	D= 0.01	S x D=			

Table 8. Effect of simulation transportation (duration of vibration, simulation vibration and days of storage) on total chlorophyll content (mg/100cm^2)

Days of storage	Simulation period and vibration							
	3 Hours				6 Hours			
	0 rpm	50rpm	100rpm	200rpm	0 rpm	50rpm	100rpm	200rpm
0	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
2	0.69	0.65	0.59	0.49	0.69	0.61	0.54	0.42
4	0.46	0.43	0.31	0.16	0.46	0.38	0.29	0.12
6	0.35	0.32	0.15	0.09	0.35	0.28	0.11	0.05
8	0.19	0.16	0.06	0.03	0.19	0.11	0.04	0.02
CD (p=0.0 5)	H= 0.01	S= 0.01	D= 0.01	H x S x D = NS				

CONCLUSION

There was significant increase in the mechanical injury, physiological loss in weight, decay loss and decrease in firmness and total chlorophyll content with increased intensity, duration of vibration and period of storage. The simulation vibration given to the fruits at 50 rpm for 3 hours was found most effective in controlling the mechanical injury, PLW, decay loss and the maximum level of these losses was observed in the fruits simulated at vibration of 200 rpm for 6 hours. The fruits with no simulation vibration were found more firm and maximum chlorophyll content followed by the fruits simulated at vibration of 50 rpm for 3 hours.

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Effect of Planting Time and Paclobutrazol on Growth and Seed Yield of Onion (*Allium cepa* L.)

Naval Kishor Kamboj, M. K. Rana and Chandanshive Aniket Vilas

Department of Vegetable Science, CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: kamboj.naval@gmail.com

***Abstract*:** An field experiment was carried out to investigate the effect of planting time and paclobutrazol levels on growth and seed yield of onion. The growth and seed yield of onion significantly influenced by different planting time and paclobutrazol concentrations used. The treatment combination first week of October and paclobutrazol 500 ppm performed best for number of umbels per plant, number of seeds per umbel and seed yield per hectare.

***Key Words*:** Onion, Planting time, Paclobutrazol, Seed yield

Onion (*Allium cepa* L.), a member of Alliaceae family, is one of the most important commercial vegetable crop grown in almost all parts of the world and believed to be originated from Central Asia comprising Iran, Afghanistan, Pakistan, Tadzhikistan and Uzbekistan. India is the second largest producer of onion bulbs in the world. As the area under onion crop is increasing, the demand for quality seed is also increasing fast. Among the various cultural practices followed for the production of onion seed, planting time is one of the most important factors that greatly influence the growth and seed yield of onion. There is a wide range of planting time, which may affect the yield and quality of seed due to varying climatic conditions at different stages of crop growth. The variation in planting time also affects the plant vigour and spread, which further affect the seed yield. In addition, growth regulators are also used to overcome the factors limiting the growth and yield to harness maximum benefit from seed production. Paclobutrazol is a triazole derivate and inhibits gibberellin biosynthesis and abscisic acid catabolism. Additionally, growth retardants have been shown to promote earlier flowering and increase the number of flowers in some plants (Banko and Bir, 1999). Considering the above facts, the present study was carried out to investigate the effects of planting time and paclobutrazol on growth and seed yield of onion cultivar Hisar-2.

MATERIAL AND METHODS

The experiment was carried out CCS Haryana Agricultural University, Hisar (Haryana) during Rabi season of 2013-14 and 2014-15. The experiment was laid out in randomized block design (factorial) with three replications of each treatment. The bulbs of Hisar-2 variety of onion were planted in a plot, having size 3.6x3.6 m at a plant spacing of 45x45 cm. There were 12 treatment combinations comprising of three planting time (first week of October, third week of October and first week of November) and four levels of paclobutrazol (Control, paclobutrazol at 500, 750 and 1000 ppm application). The observations were recorded on days to sprouting initiation and sprouting completion, number of shoots per plant, length of leaves (cm), length of flower stalk (cm), umbel diameter (cm), number of umbels per plant, number of seeds per umbel and seed yield per hectare (kg). The paclobutrazol was applied as foliar spray 45 days after planting. The crop was fertilized with rotten FYM @ 200 qha^{-1} at the time of field preparation. The inorganic fertilizers in the form Urea DAP and MOP were applied @ 100 kg nitrogen, 50 kg phosphorus and 50 kg potash ha^{-1} in individual plots before the planting of bulbs. Half of the recommended dose of nitrogen and whole dose of phosphorus and potash were applied as basal dose. Rest half of the nitrogen was applied at the time of flowering as top dressing. All the cultural practices as recommended in Package of Practices for Vegetable Crops were followed from time to time to ensure a healthy crop stand. Data on different yield contributing characters were recorded.

RESULTS AND DISCUSSION

Effect of planting time: The days taken to sprouting initiation and sprouting completion differed significantly with different planting dates during both the years. The minimum number of days to sprouting initiation (4.58 and 4.33) and sprouting completion (6.67 and 6.25) was taken by the crop planted on first week of October during 2013-14 and 2014-15, respectively (Table 1). This might be due to higher soil temperature in early planting, resulting in early sprouting of the bulbs. The results are in close conformity with the findings of Helaly and Karam (2012) who found that earlier planting significantly decreased the number of days to sprouting initiation and completion in onion. All the planting dates differed significantly from each other with respect to number

Table 1. Effect of planting time and paclobutrazol on growth and seed characters of onion

Treatments	Days to sprouting initiation		Days to sprouting completion		Number of shoots per plant		Length of leaves (cm)		Length of flower stalk (cm)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Planting time										
D_1:First week of October	4.58	4.33	6.67	6.25	5.52	5.95	55.73	58.49	103.04	107.47
D_2: Third week of October	4.75	4.50	6.83	6.33	5.40	5.73	53.68	55.88	100.28	104.68
D_3:First week of November	5.50	5.08	8.25	7.17	5.24	5.48	51.94	53.07	95.96	101.24
CD (p=0.05)	0.60	0.51	0.45	0.56	0.13	0.21	0.75	0.89	1.27	1.60
Paclobutrazol										
G_1: Control	4.78	4.56	7.22	6.44	5.52	5.74	55.76	57.64	103.70	107.48
G_2: Paclobutrazol 500 ppm	4.67	4.33	7.00	6.22	5.66	5.96	55.14	56.81	101.57	105.32
G_3: Paclobutrazol 750 ppm	5.11	4.78	7.22	6.67	5.30	5.69	53.52	55.62	98.79	102.58
G_4: Paclobutrazol 1000 ppm	5.22	4.89	7.56	7.00	5.09	5.49	50.70	53.18	94.66	99.81
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.87	1.03	1.47	1.85

of shoots per plant. The highest mean number of shoots per plant (5.52 and 5.95) was registered with first week of October planting during the year 2013-14 and 2014-15, respectively. The results corroborate the findings of Ud-Deen (2008), Mohanty (2011), Hamma (2013), Ashagrie *et al.* (2014), Mehri *et al.* (2015) and Mollah *et al.* (2015), who observed that the number of shoots per plant decreased significantly with the delay in planting of onion bulbs. The length of leaves increased with the advancement of planting date. The crop planted in first week of October had the maximum length of leaves (55.73 and 58.49 cm), during the year 2013-14 and 2014-15. These results are in agreement with those of Ashagrie *et al.* (2014) and Mehri *et al.* (2015), who recorded the maximum length of leaves when the crop was planted at the earliest, while the delay in planting gradually reduced the length of leaves due to the reduction in growth period. Significant variation was observed in length of flower stalk due to different planting dates. The planting date first week of October produced the maximum length of flower stalk (103.04 and 107.47 cm), during 2013-14 and 2014-15, respectively. Similar effect of planting time on length of flower stalk was reported by Ud-Deen (2008), Helaly and Karam (2012) and Mehri *et al.* (2015). The umbel diameter decreased significantly with the delay in planting time. The maximum diameter of umbel (6.17 and 6.59 cm) was recorded under first week of October planting date (D_1) during the year 2013-14 and 2014-15, respectively. The results are in agreement with the findings of Helaly and Karam (2012), who recorded the maximum umbel diameter with early planting of the crop during mid of November as compared to mid of December and mid of January. The different planting dates remarkably played an incredible role in increasing the number of umbels per plant during both the years. The maximum number of umbels per plant was observed in crop planted on first week of October. This might be because of low temperature and long day conditions received by the October planted crop during December-January since by this time, the plants reached to a stage of good growth, which might have contributed the highest number of umbels per plant. The results confirm the findings of Malik *et al.* (1999), Helaly and Karam (2012) and Mehri *et al*. (2015), who obtained the maximum number of umbels per plant from early planted crop and the minimum from late planted crop. All the planting dates differed significantly with respect to number of seeds per umbel. The uppermost mean value for number of seeds per umbel was under first week of October planting date, while the lowest mean value was recorded under first week of November planting date. This might be due to the reason that the November planted crop resulted in poor plant growth and delayed bolting and high temperature at umbel forming stage might have reduced the number of seeds per umbel. Malik *et al.* (1999) and Ashagrie *et al.* (2014) have also reported the similar results that early planted crop produced the maximum number of seeds per umbel. The seed yield per hectare decreased significantly with the delay in planting time. The highest seed yield per hectare (844.84 and 926.08 kg) was registered with first week of October planting, during the year 2013-14 and 2014-15, respectively, which might be due to the cumulative contribution of all the yield-contributing characters influenced by comparatively favourable temperature and day length. Similar effect of planting time on seed yield was reported by Ud-Deen (2008), Helaly and Karam (2012), Ashagrie *et al.* (2014) and Mehri *et al.* (2015), who obtained the maximum seed yield per hectare by planting the crop early.

Effect of paclobutrazol: All the levels of paclobutrazol were statistically non-significant with respect to days to sprouting initiation, sprouting completion, number of shoots per plant and umbel diameter (Table 2). The effect of paclobutrazol levels with respect to length of leaves differed significantly during both the years. The maximum mean length of leaves was measured under no application of paclobutrazol and the minimum length of leaves in plots where paclobutrazol was sprayed @ 1000 ppm. The primary mode of paclobutrazol action was inhibition of the gibberellins biosynthesis . Reduced gibberellins synthesis in response to paclobutrazol treatment might have resulted in a reduced cell proliferation, leading to a reduction in length of leaves. The length of flower stalk decreased significantly with the increase in level of paclobutrazol. The maximum length of flower stalk was with no application of paclobutrazol, whereas, the minimum length of flower stalk was with application of paclobutrazol 1000 ppm. The results corroborate the findings of Ashrafozzaman *et al*. (2009), who reported that the length of flower stalk decreased with the increase in level of paclobutrazol in onion. All the treatments of paclobutrazol differed significantly with respect to number of umbels per plant during both the years. The maximum number of umbels per plant (11.92 and 12.41) was obtained from the crop sprayed with paclobutrazol 500 ppm during both the years, respectively. The results are similar to the findings of Ashrafozzaman *et al*. (2009), who noticed the significant decline in number of umbels per plant with increasing levels of paclobutrazol. All the paclobutrazol levels differed significantly during both the years with respect to number of seeds per umbel. The maximum number of seeds per umbel was recorded with paclobutrazol 500 ppm. The significant effect of paclobutrazol in increasing number of flowers and seed has been experimentally substantiated by Singh *et al.* (1999). The levels of paclobutrazol differed significantly from

Table 2. Effect of planting time and paclobutrazol on growth and seed characters of onion

Treatments	Umbel diameter (cm)		Number of umbels plant^{-1}		Number of seeds umbel^{-1}		Seed yield ha^{-1} (kg)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Planting time								
D_1:First week of October	6.17	6.59	12.08	12.48	541.63	579.70	844.84	926.08
D_2: Third week of October	5.72	6.18	11.54	11.95	507.08	538.27	759.66	835.38
D_3:First week of November	4.94	5.44	10.64	11.02	425.51	461.43	578.18	671.64
CD (p=0.05)	0.17	0.28	0.21	0.37	12.15	16.37	56.52	73.57
Paclobutrazol								
G_1: Control	5.71	6.20	11.39	11.69	513.10	544.74	770.91	846.63
G_2: Paclobutrazol 500 ppm	5.76	6.20	11.92	12.41	526.79	562.76	834.56	930.58
G_3: Paclobutrazol 750 ppm	5.51	5.96	11.57	11.91	472.07	509.01	685.31	776.61
G_4: Paclobutrazol 1000 ppm	5.46	5.92	10.80	11.26	453.67	489.34	619.47	690.31
CD (p=0.05)	N.S.	N.S.	0.24	0.42	14.03	18.91	65.26	84.95

Table 3. Interaction effect of planting time and paclobutrazol on growth and seed characters of onion

Treatment combinations	Length of leaves (cm)		Length of flower stalk (cm)		Number of umbels plant^{-1}		Number of seeds umbel^{-1}		Seed yield ha^{-1} (kg)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
D_1G_1	58.00	60.47	12.03	12.33	556.93	595.87	893.81	961.30	106.10	112.03
D_1G_2	57.40	59.33	12.70	13.17	571.17	610.23	954.72	1065.01	104.57	109.67
D_1G_3	55.20	57.80	12.17	12.53	525.00	560.47	808.22	879.66	102.30	106.13
D_1G_4	52.30	56.37	11.40	11.90	513.40	552.23	722.62	798.34	99.20	102.03
D_2G_1	55.63	57.57	11.53	11.80	516.17	546.60	801.63	872.42	103.67	107.43
D_2G_2	55.10	57.07	11.93	12.36	526.73	554.00	879.00	941.55	101.90	105.07
D_2G_3	53.53	56.47	11.67	12.03	498.37	533.90	699.58	801.63	99.27	103.13
D_2G_4	50.43	52.43	11.03	11.60	487.07	518.57	658.43	725.92	96.30	101.10
D_3G_1	53.63	54.90	10.60	10.93	466.20	491.77	617.28	706.16	101.33	103.91
D_3G_2	52.93	54.03	11.14	11.70	482.47	524.03	669.95	785.17	98.23	101.23
D_3G_3	51.83	52.60	10.87	11.17	392.83	432.67	548.14	648.55	91.80	100.07
D_3G_4	49.37	50.73	9.97	10.27	360.53	397.23	477.36	546.66	88.47	98.30
CD (p=0.05)	1.51	1.79	0.41	0.73	24.29	32.75	113.04	147.14	2.54	3.20

each other with respect to seed yield per hectare during both the years. The seed yield per hectare decreased remarkably with the increase in paclobutrazol level. The maximum seed yield per hectare (834.56 and 930.58 kg) was obtained from the crop, which was sprayed with paclobutrazol @ 500 ppm in 2013-14 and 2014-15, respectively. These results concur with earlier reports of Ashrafozzaman *et al*. (2009), who observed that seed yield per hectare decreased remarkably with the increase in paclobutrazol levels.

The interaction of planting time with paclobutrazol levels were statistically non-significant with respect to days to sprouting initiation, sprouting completion, number of shoots per plant and umbel diameter during both the years (Table 3). However, the interaction effect with respect to length of leaves and flower stalk was statistically significant during both the years. The treatment combination first week of October - without chemical treatment showed the maximum length of leaves and length of flower stalk. The interaction effect of planting dates and paclobutrazol levels concerning the number of umbels per plant was statistically significant and showed the same trend. The combined effect of planting time and paclobutrazol levels concerning the number of seeds per umbel differed significantly during both the years of experimentation. The maximum number of seeds per umbel was recorded with combination of first week of October planting and paclobutrazol 500 ppm. The more number of seeds per umbel in early-planted crop might be due the production of large sized umbels due to the availability of longer low temperature period to the crop, which is prerequisite for better development of the crop. The crop planted on first week of October and sprayed with paclobutrazol 500 ppm resulted in the maximum seed yield per hectare.

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Post-Harvest Keeping Quality of Gladiolus (*Gladiolus* Spp.) in Relation to Pulsing Treatment and Refrigerated Storage

Avneet Kaur, Kushal Singh and Nirmaljit Kaur
Punjab Agricultural University, Ludhiana-141004, India
E-mail: avneetkhalsa08@gmail.com

Abstract: Keeping quality of cut flowers like *Gladiolus* is improved by giving pulsing treatment and refrigerated storage. Two cultivars viz. White Prosperity and Nova Lux were harvested at tight bud stage and treated for 20 h with the solution containing sugars (20 %) in combination with aluminium sulphate (400 µg ml^{-1}) and GA_3 (50 µg ml^{-1}). Relative water content did not show any significant change with respect to pulsing treatment or storage Percent increase in fresh weight and rachis length increased with the increase in storage duration. Percent increase in rachis length was more in cv. White Prosperity than cv. Nova Lux. Increase in storage duration cause decrease in size of floret and water absorption in spikes being higher in spikes given pulsing treatment with sucrose, aluminium sulphate and gibberellic acid. Sucrose in combination with aluminium sulphate and gibberellic acid was found most effective.

***Key Words*: ***Gladiolus*, Keeping quality, Pulsing treatment, Refrigerated storage

Gladiolus is a corm propagated plant belonging to family *Iridaceae*. It is very popular among cut flowers due to its varying form, texture, colour and colour combinations.

For the maintenance of cut flowers for longer durations, they must be free of any deterioration or decaying organisms. The germicides or antimicrobial agents such as aluminium sulphate, silver thiosulphate (STS), 8-hydroxyquinoline (8-HQS) etc. are added to the preservatives that prevent the blockage of spikes and easy uptake of solution. Al-Humaid (2005) reported that addition of antimicrobial agents to the sugars increased the vase life and improved the spike quality in *Gladiolus* cultivars. In *Antirrhinum majus*, the vase life was increased with addition of preservative solutions containing sugars and antimicrobial agents (Asrar, 2012). The flower longevity and post-harvest characteristics were maintained in *Rosa hybrid* by adding aluminium sulphate and sugars to preservative solutions (Gebremedhin *et al.,* 2013).

Gibberellic acid acts as senescence-delaying plant growth hormone that maintains flower turgidity and increases flower quality. Gibberellic acid influences the various growth processes hence could affect floret opening (Wu *et al.,* 2012). It plays important role in increasing vase life of cut flowers by improving water relation and carbohydrates status. The maintenance of water status may be either by increasing water uptake or by reducing rate of transpiration (Eason, 2002). Saeed *et al.* (2013) reported that in cut *Gladiolus* spikes gibberellic acid increased vase life, floret opening and floret size and delayed the flower senescence. Refrigerated (cold) or low temperature storage has many advantages in keeping the flowers fresh and maintaining their continuous supply in the market. The cold storage of flowers reduces the rate of respiration, water loss and growth of microorganisms and production of ethylene (Redman *et al.,* 2002). Hence, it delays the flower senescence and increase the shelf life. Both wet and dry storage techniques could be applied for the maintenance of flowers (Gast *et al.,* 1994). In market, cut flowers are transported from one place to the other, so their maintenance is the pre-requisite that could be assured by refrigerated storage. Tshwenyane *et al.* (2014) observed that refrigerated storage of *Chrysanthemum* cut flowers increases the flower longevity than the non-refrigerated storage during the transportation. At present, gladiolus cut flowers are in the increasing demand in the market due to their elegant attractive spikes of the different shades. In view of above, the current studies were conducted to develop the suitable treatments for the refrigerated storage of gladiolus spikes and for the maintenance of spikes for longer duration after harvesting.

MATERIAL AND METHODS

The spikes of cultivars White Prosperity and Nova Lux were harvested at tight bud stage and given pulsing treatment with solutions containing sucrose, glucose and fructose (20%) in combination with aluminium sulphate (400 µg ml^{-1}) and gibberellic acid (50 µg ml^{-1}). Under continuous illumination of 1000 lux intensity and at 23±2°C temperature, treatment was given by dipping the basal portions of spikes in pulsing solutions for 20 hours. After the pulsing treatment, spikes were grouped in bundles of 3 each, loosely tied at the base and stored in vertical position in the cool chamber (4±0.5ºC; 90-95% R.H.) for 6, 12 and 18 days. Florets from middle portion were taken for estimating the relative water content. The keeping quality parameters were observed by placing the spikes in the distilled water in an air-conditioned laboratory (22$\pm$3°C) and 16 h light duration of 1000 Lux intensity provided by 40 watt white fluorescent tubes.

The relative water content was calculated according to the method of Chakrabarty *et al.* (2009):

Where FW is fresh weight, DW is dry weight and TW is turgor weight of the florets. RWC=[(FW-DW)/ (TW-DW)]*100

Per cent increase in fresh weight, rachis length and size of fully expanded floret/floret size was also recorded. Water/solution absorption per spike was estimated as total volume of water absorbed by the spike till wilting of the last open floret was measured in ml and expressed as water absorbed per spike.

RESULTS AND DISCUSSION

Relative water content (RWC): Pulsing treatments as well as refrigerated storage did not show any significant effects on RWC of florets which may ascribe to the turgidity level of the florets that remained same. Wet refrigerated storage is known to decrease loss of water as well as provide water for continuous absorption by the spikes (Nowak and Rudnicki, 1990). RWC of florets of was slightly higher in cv. Nova Lux than that in White Prosperity (Table 1).

Increase in fresh weight: The spikes showed continuous increase in per cent fresh weight during the storage period of up to 18 days in both the cultivars. This could be attributed to the absorption of water and expansion of florets during the storage. Pulsing treatments with sugars tended to increase per cent increase in fresh weight over the control as well as the spikes treated with solution of aluminium sulphate alone as well as in combination with GA_3. The maximum per cent increase in fresh weight was observed in spikes pulse-treated with sucrose (20%) plus aluminium sulphate, 400 µg ml^{-1} (23.29) and sucrose plus aluminium sulphate plus GA_3, 50 µg ml^{-1} (22.99). Among cultivars, there were no significant differences in gain in per cent fresh weight of the spikes.

Increase in rachis length: The spikes exhibited an increase in the rachis length in vase with increase in storage duration. Spikes treated with sucrose in combination with aluminium sulphate and GA_3 showed maximum per cent increase in rachis length (Table 3). The increase in rachis length of the spikes in spikes treated with glucose or fructose in combination with aluminium sulphate was slightly higher than the control. Addition of GA_3 to the glucose or fructose further increased rachis length during storage. Aluminium sulphate alone or in combination with GA_3 did not increase rachis length over the control. The slight increase in rachis length by

Table 1. Effect of sugars, aluminium sulphate and GA_3 on relative water content of florets of gladiolus cultivars after storage for varying durations

Treatment	White Prosperity					Nova Lux					Overall Mean
	0 day	6 day	12 day	18 day	Mean	0 day	6 day	12 day	18 day	Mean	
T_1-Sucrose 20% + Aluminium sulphate, 400 µg ml^{-1}	96.00	95.72	96.57	97.67	96.49	96.67	97.49	97.99	97.20	97.34	96.91
T_2-Sucrose 20% + Aluminium sulphate, 400 µg ml^{-1}+GA_3, 50 µg ml^{-1}	95.86	95.05	98.00	91.78	95.17	96.97	98.27	96.50	92.62	96.09	95.63
T_3-Glucose 20% + Aluminium sulphate, 400 µg ml^{-1}	96.31	95.87	96.72	97.96	96.71	97.75	98.66	97.73	95.33	97.37	97.04
T_4-Glucose 20% + Aluminium sulphate, 400 µg ml^{-1}+GA_3, 50 µg ml^{-1}	95.76	93.65	93.98	97.61	95.25	97.71	98.84	98.61	98.19	98.34	96.79
T_5-Fructose 20% + Aluminium sulphate, 400 µg ml^{-1}	96.65	92.13	91.26	98.07	94.53	95.65	98.89	94.43	98.27	96.81	95.67
T_6-Fructose 20% + Aluminium sulphate, 400 µg ml^{-1}+GA_3, 50 µg ml^{-1}	96.20	94.78	96.91	98.42	96.58	97.74	98.56	98.56	97.89	98.19	97.38
T_7-Aluminium sulphate, 400 µg ml^{-1}	96.48	94.58	91.42	97.79	95.07	97.63	94.68	98.65	97.91	97.22	96.14
T_8-GA_3, 50 µg ml^{-1}+Aluminium sulphate, 400 µg ml^{-1}	95.93	94.16	97.39	97.75	96.31	97.67	95.64	94.01	94.72	95.51	95.91
T_9-Control	97.03	96.32	96.66	95.34	96.34	98.26	99.03	95.67	98.32	97.82	97.08
Mean	96.25	94.69	95.43	96.93	95.83	97.34	97.78	96.90	96.72	97.19	96.51

Mean values for storage duration:0 day=96.79; 6 day=96.23; 12 day=96.16; 18 day=96.82

CD (p=0.05) Cultivars (A)=NS; Storage duration (B)=NS; Treatments (C)=NS; AxB=NS; AxC=NS; BxC=NS; AxBxC=NS

Table 2. Effect of sugars, aluminium sulphate and GA_3 on per cent increase in fresh weight in spikes of gladiolus cultivars after storage for varying duration

Treatment*	White Prosperity				Nova Lux				Overall
	6 day	12 day	18 day	Mean	6 day	12 day	18 day	Mean	Mean
T_1	11.74 (20.02)	25.72 (30.44)	31.53 (34.10)	23.00 (28.19)	12.59 (20.70)	28.53 (32.27)	29.65 (32.97)	23.59 (28.65)	23.29 (28.42)
T_2	10.09 (18.51)	26.68 (31.02)	29.22 (32.67)	22.00 (27.40)	10.79 (19.16)	29.10 (32.63)	32.09 (34.48)	23.99 (28.76)	22.99 (28.08)
T_3	6.67 (14.95)	19.91 (26.48)	22.54 (28.32)	16.37 (23.25)	8.34 (16.72)	19.90 (26.42)	26.27 (30.76)	18.17 (24.63)	17.27 (23.94)
T_4	8.74 (17.18)	21.79 (27.78)	25.20 (30.09)	18.57 (25.02)	9.57 (17.97)	26.26 (30.81)	28.01 (31.93)	21.28 (26.90)	19.93 (25.96)
T_5	8.24 (16.67)	15.10 (22.85)	17.79 (24.84)	13.71 (21.45)	8.62 (17.06)	18.32 (25.31)	24.31 (29.50)	17.08 (23.96)	15.40 (22.71)
T_6	8.52 (16.93)	17.89 (24.88)	23.17 (28.71)	16.53 (23.51)	9.15 (17.59)	16.69 (24.00)	22.94 (28.53)	16.26 (23.37)	16.39 (23.44)
T_{7}-	4.63 (12.36)	13.91 (21.84)	17.10 (24.39)	11.88 (19.53)	3.91 (11.39)	13.39 (21.29)	14.09 (22.02)	10.46 (18.23)	11.17 (18.88)
T_{8}-	5.22 (13.18)	12.59 (20.64)	14.85 (22.61)	10.89 (18.81)	3.64 (10.93)	14.06 (21.96)	15.82 (23.40)	11.17 (18.76)	11.03 (18.79)
T_{9}-	4.51 (12.25)	16.06 (23.60)	18.72 (25.61)	13.10 (20.49)	3.01 (9.98)	10.60 (18.99)	14.62 (22.43)	9.41 (17.13)	11.25 (18.81)
Mean	7.59 (15.78)	18.85 (25.50)	22.23 (27.93)	16.22 (23.07)	7.73 (15.72)	19.65 (25.96)	23.09 (28.45)	16.82 (23.38)	16.52 (23.22)

Mean values for storage duration: 6 day=7.66 (15.75); 12 day=19.25 (25.73); 18 day=22.66 (28.19)

CD (p=0.05) Cultivars (A)=NS; Storage duration (B)=0.72; Treatments (C)=1.25; AxB=NS; AxC=1.76; BxC=2.16; AxBxC=NS

*Check table 1 for treatment details; Figures in parentheses are arc sine transformed values

Table 3. Effect of sugars, aluminium sulphate and GA_3 on per cent increase in rachis length in spikes of two gladiolus cultivars after storage for varying durations

Treatment	White Prosperity				Nova Lux				Overall Mean
	6 day	12 day	18 day	Mean	6 day	12 day	18 day	Mean	
T_1	8.48 (16.88)	19.45 (26.12)	23.89 (29.22)	17.27 (24.07)	2.64 (9.13)	6.24 (14.10)	6.60 (14.85)	5.16 (12.69)	11.22 (18.38)
T_2	6.55 (14.77)	28.36 (32.15)	29.63 (32.96)	21.51 (26.63)	2.34 (8.55)	7.05 (15.21)	13.12 (21.18)	7.50 (14.98)	14.51 (20.80)
T_3	5.08 (12.84)	15.76 (23.34)	18.91 (25.75)	13.25 (20.64)	1.57 (7.19)	5.11 (13.06)	6.03 (14.12)	4.24 (11.46)	8.74 (16.05)
T_4	7.25 (15.57)	18.69 (25.60)	22.79 (28.48)	16.25 (23.22)	2.09 (8.20)	8.99 (17.35)	11.29 (19.47)	7.46 (15.01)	11.85 (19.11)
T_5	5.24 (12.98)	15.13 (22.84)	17.45 (24.63)	12.61 (20.15)	2.37 (8.61)	7.08 (15.40)	5.00 (12.90)	4.82 (12.30)	8.71 (16.23)
T_6	6.55 (14.82)	16.46 (23.91)	21.28 (27.45)	14.76 (22.06)	2.19 (8.41)	8.57 (16.96)	11.13 (19.46)	7.30 (14.94)	11.03 (18.50)
T_7	5.10 (13.02)	16.11 (23.61)	16.14 (23.62)	12.45 (20.08)	1.28 (6.47)	2.47 (8.96)	1.97 (8.03)	1.91 (7.82)	7.18 (13.95)
T_8	7.11 (15.40)	15.47 (23.13)	18.54 (25.44)	13.71 (21.32)	1.70 (7.39)	6.59 (14.82)	3.38 (10.54)	3.89 (10.92)	8.80 (16.12)
T_9	5.38 (13.26)	15.74 (23.34)	18.68 (25.59)	13.27 (20.73)	1.92 (7.93)	1.35 (6.66)	1.87 (7.77)	1.71 (7.45)	7.49 (14.09)
Mean	6.30 (14.39)	17.91 (24.89)	20.81 (27.01)	15.01 (22.10)	2.01 (7.99)	5.94 (13.61)	6.71 (14.26)	4.89 (11.95)	9.95 (17.02)

Mean values for storage duration: 6 day=4.15 (11.19) ; 12 day=11.92 (19.25) ; 18 day=13.76 (20.63)

CD (p=0.05) Cultivars (A)=0.57; Storage duration (B)=0.69; Treatments (C)=1.21; AxB=0.98; AxC=1.70; BxC=2.08; AxBxC=2.94

*Check table 1 for treatment details; Figures in parentheses are arc sine transformed values

Table 4. Effect of sugars, aluminium sulphate and GA_3 on floret size in spikes of gladiolus cultivars after storage

Treatment*	White Prosperity					Nova Lux					Overall
	0 day	6 day	12 day	18 day	Mean	0 day	6 day	12 day	18 day	Mean	Mean
T_1	9.39	9.39	8.05	7.28	8.53	8.28	7.82	7.50	6.41	7.50	8.01
T_2	9.72	9.50	8.50	8.28	9.00	8.44	8.03	8.55	6.89	7.98	8.49
T_3	8.72	8.28	8.00	7.17	8.04	7.50	8.23	7.67	6.27	7.42	7.73
T_4	9.17	9.00	7.50	7.17	8.21	8.50	8.33	6.39	6.41	7.41	7.81
T_5	8.17	7.56	6.83	6.56	7.28	7.15	7.23	6.67	5.33	6.59	6.94
T_6	9.06	8.05	8.00	6.28	7.85	8.37	7.91	5.92	5.89	7.02	7.43
T_7	6.33	6.72	5.78	5.00	5.96	6.49	5.50	4.53	4.28	5.20	5.58
T_8	6.00	6.67	6.06	4.89	5.90	6.17	5.71	5.00	5.72	5.65	5.78
T_9	6.00	5.83	5.56	4.33	5.43	5.72	5.48	4.48	4.45	5.03	5.23
Mean	8.06	7.89	7.14	6.33	7.35	7.40	7.14	6.30	5.74	6.64	6.48

Mean values for storage duration:0 day=7.73; 6 day=7.51; 12 day=6.72; 18 day=6.03

CD (p=0.05) Cultivars (A)=0.16; Storage duration (B)=0.22; Treatments (C)=0.34; AxB=NS; AxC=NS; BxC=NS; AxBxC=0.96

*Check table 1 for treatment details

GA_3 when used in combination with sugars indicates that sugars provide energy for the process and maintain high metabolic rate during storage (Taiz and Zeiger 2006). Per cent increase in rachis length during storage was significantly higher in cv. White Prosperity than in Nova Lux.

Size of fully expanded floret (2nd floret)/floret size: The treatment with sugars before storage improved floret size. Floret size was maximum in treatments with sucrose, aluminium sulphate and GA_3. GA_3 treatment was not effective when used along with aluminium sulphate. It indicates that effect of GA_3 in increasing floret size requires energy which is supplied by sugars in the solution. Floret size decreased with increase in the duration of storage being maximum in control (unstored spikes). Floret size was slightly higher in cv. White Prosperity than in Nova Lux (Table 4).

Water absorption per spike: The spikes exhibited the minimum amount of water absorption (30.85 ml). The spikes pulse-treated with aluminium sulphate or aluminium sulphate in combination with GA_3 showed slightly higher uptake of water i.e. 33.82 and 34.19 ml, respectively. Spikes subjected to pulsing solutions containing sugars improved solution uptake significantly over the control. Maximum solution absorption/spike was exhibited by pulsing treatment with sucrose plus aluminium sulphate plus GA_3. Water/solution absorption decreased with increase in the storage duration and was minimum (25.66 ml) in spikes subjected to storage for 18 days (Table 5).

CONCLUSION

The keeping quality of gladiolus spikes can be improved by treatment with the pulsing solution prior to the refrigerated storage. The refrigerated storage provides the conditions that lower the rate of respiration, senescence and loss of water in the cut flowers. To maintain and increase the shelf life of the cut flowers, exogenous application of food source mainly sucrose holds considerable importance. Gibberellic acid synergises the effect of sugars, hence, increases the keeping quality. Effect of decaying organisms and resistance to water uptake in the spikes could be prevented by adding antimicrobial agents to the pulsing solution. Pulsing treatment and refrigerated storage are the two important means to fulfill the exceeding demand, regular market supply and long distance transport of cut flowers.

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Table 5. Effect of sugars, aluminium sulphate and GA_3 on water/solution absorption/spike of two gladiolus cultivars after storage

Treatment	White Prosperity					Nova Lux					Overall
	0 day	6 day	12 day	18 day	Mean	0 day	6 day	12 day	18 day	Mean	Mean
T_1	66.33	58.89	31.89	25.11	45.55	70.78	61.44	40.00	22.50	48.68	47.11
T_2	68.22	63.89	35.67	31.34	49.78	75.00	68.33	45.22	30.67	54.80	52.29
T_3	60.66	60.11	32.56	30.67	46.00	59.11	60.67	44.56	25.67	47.50	46.75
T_4	65.55	62.11	33.67	29.44	47.69	65.11	65.22	42.56	22.00	48.72	48.20
T_5	57.33	57.56	27.89	27.22	42.50	61.89	60.42	32.22	27.33	45.46	43.98
T_6	63.44	56.67	35.00	32.78	46.97	61.56	69.00	35.55	27.89	48.50	47.73
T_7	46.45	37.00	23.22	22.56	32.31	48.11	44.00	27.22	22.00	35.33	33.82
T_8	46.78	39.11	20.89	21.11	31.97	45.22	43.11	31.56	25.78	36.42	34.19
T_9	46.67	28.22	18.45	19.22	28.14	45.00	39.78	30.78	18.67	33.56	30.85
Mean	57.94	51.51	28.80	26.60	41.21	59.09	56.88	36.63	24.72	44.36	42.78

Mean values for storage duration:0 day=58.51; 6 day=54.19 ; 12 day=32.71; 18 day=25.66

CD (p=0.05) Cultivars (A)=1.05; Storage duration (B)=1.49; Treatments (C)=2.24; AxB=2.11; AxC=NS; BxC=4.48; AxBxC=NS

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Mass Multiplication and Genetic Fidelity Assessment of *Asparagus adscendens* Roxb.

Anish Kumar Sharma, Vikrant Gautam, Hukum Chand, Jyotsana Pandit[1] and S. V. Bhardwaj

Department of Biotechnology, [1]Department of Environmental Science,
Dr Y S Parmar University of Horticulture and Forestry, Solan-173 230, India
E-mail: janish.sharma28@gmail.com

Abstract: Maximum establishment of cultures was obtained on MS medium supplemented with 0.2 mg l^{-1} BAP and 0.2 mg l^{-1} Kn. Multiplication rate of 3.50 in rhizome explants was obtained on full strength MS medium with 0.2 mg l^{-1} BAP and 0.2 mg l^{-1} Kn after 8 weeks on multiplication medium. High frequency of rooting was obtained in regenerated shoots (63.80%) on half strength MS medium supplemented with 1.0 mg l^{-1} IBA and 0.3 mg l^{-1} ancymidol after 15 days of inoculation into rooting medium. Rooted plantlets were hardened in potting mixture showing 66 % survival. Hence, protocol for *in vitro* mass multiplication of *A. adscendens* using rhizome explant has been developed which can be used for conservation of this endangered plant species.

Key Words: *Asparagus adscendens,* Direct regeneration, Rhizome explants

The genus, *Asparagus* comprises 150 species and consists of herbs, shrubs and vines which are widespread world over. There are some interesting wild species and *Asparagus adscendens* Roxb. is one of them and this plant have medicinal usage. The plant is not commercially grown, so availability of planting material is scanty. Because of its significant properties, it has been over exploited, which in turn has led to its inclusion in the list of threatened plant species. The plant is normally propagated through seeds and rhizomes. It can also be propagated vegetatively, but this is a slow process that results in very less number of new propagules (Tewari, 2000).

Keeping in mind the economical and medicinal value of this plant, the availability of genetically superior and uniform planting material is essential. This can be achieved by using tissue culture techniques. *In vitro* propagation is the only means for mass multiplication of existing stocks of germplasm. It also helps in the conservation of important elite or rare plant species; those are threatened with the danger of extinction. Unlike other extensively studied *Asparagus* species, there is single report of *in vitro* micro-propagation of *A. adscendens* using nodal explant (Mehta and Subramanian, 2005) but still there is no report on micro-propagation using rhizome explants. Hence, the study was taken to develop a protocol for *in vitro* propagation of *A. adscendens* using rhizome explants. There is a large literature available on the use of different explants as a source for *in vitro* propagation of different *Asparagus* species (Mehta and Subramanian 2005; Kumar and Vijay 2009; Singh *et al*., 2013). There is not even a single report of rhizomes being used as explants for micro-propagation in the concerned as well as related *Asparagus* species. In present studies, mature plants were used as a source material for obtaining rhizome explants. To our knowledge this is first report for multiplication of *Asparagus adscendens* Roxb. from rhizome explants.

MATERIAL AND METHODS

Collection and sterilization of rhizome plants of *Asparagus adscendens* Roxb. were collected from wild as well as from the Department of Forest Products and maintained in the glasshouse of Department of Biotechnology, UHF, Nauni.

The rhizomes were excised from tuberous roots and were washed with tap water and then placed in a sterile beaker with few drops of detergent (Tween20) for 5 minutes and was shaken vigorously. Then explants were again washed with running tap water for 30 minutes to remove any traces of detergent. The explants were finally treated with different concentrations of NaOCl, bavistin, mancozeb and $HgCl_2$. To find out the best treatment for sterilization of explants, either single or a combination of above mentioned sterilants/fungicides was used. Rhizome explants were inoculated on Murashige and Skoog's (1962) (MS) medium supplemented with varying concentrations of 6-Benzylaminopurine (BAP) alone as well as in combination with Kinetin (Kn). Medium was solidified with 0.6 % agar. The rhizome explants, which turned green and showed little growth after 1-2 weeks were selected for transfer to fresh medium of same composition, for further growth.

Shoot multiplication in rhizome explants: After the establishment of cultures, cultures were transferred to shoot multiplication medium. Rhizome explants multiplied through adventitious shoot bud formation. MS medium supplemented with different concentration of BAP and Kn were used for shoot multiplication. The serial sub-culturing was performed after 5 weeks by separating and transferring shoots into fresh medium. All the experiments were repeated thrice with 20 explants for each treatment.

***In vitro* rooting of micro-shoots:** Healthy micro-shoots with 3 to 4 cm in length were transferred to rooting medium**.** Half strength MS medium supplemented with IBA was used for root induction. Effects of anti gibberellins compound (ancymidol) on root induction were also studied. The plantlets with roots were washed with distilled water and treated with bavistin (an antifungal agent) to prevent fungal infection before transferring to a mixture of autoclaved coco-peat and 1% organic manure in small polycups for further development and acclimation.

Culture conditions: All the cultures were kept in a temperature controlled room maintained at 26 ± 2°C. Photoperiod was kept at 16 hours light and 8 hours dark. Dark conditions were maintained by wrapping the culture vessels with carbon paper or keeping the cultures in a closed cardboard box.

Assessment of genetic fidelity: To check the genetic similarity of in vitro grown plant with mother plant molecular studies were done using RAPD and ISSR markers. A total of 10 RAPD and 10 ISSRs marker were used for screening. Genomic DNA was isolated from fresh leaves of mother plant and 10 randomly selected *in vitro* grown plants using CTAB method (Doyle and Doyle, 1987). PCR amplification was carried out in 25 ìL volume. The reaction mixture consisted of 1x Taq buffer A, 1U of Taq DNA polymerase, 0.8 mM dNTP, 0.3 ìM of primer, 1.5mM $MgCl_2$, and 50 ng of DNA sample. The amplification was performed using a thermal cycler (Eppendorf). The program consisted of initial denaturation at 94°C for 10 min followed by 35 cycles of denaturation at 94°C for 30 seconds, annealing at 37°C for 30 seconds in case of RAPD markers and specific for ISSRs, extension at 72°C for 2 min, and at a final extension cycle of 10 min at 72°C. The amplified products were checked in a 1.2% agarose gel stained with 0.5 ìg mL^{-1} of ethidium bromide and documented by a gel documentation system.

RESULTS AND DISCUSSION

The explants were surface sterilized for establishment of uncontaminated cultures and the treatment T_4 was found most effective in containing contamination (Table 1). This treatment resulted in 88.33 per cent uncontaminated cultures. Different response of media-explant interaction was observed during direct shoot regeneration from *A. adscendens* Roxb. Murashige and Skoog (1962) medium supplemented with vitamins, 3 per cent sucrose as a carbon source and various growth regulators was used as the basal medium for micro-propagation. Medium was gelled with 0.6 per cent agar. Literature is full of reports on usage of basic MS medium for culturing *Asparagus* species.

It is well known that cytokinins and auxins are necessary for the growth and organ differentiation. Cytokinin mediated shoot initiation in tissue culture is extensive and among the cytokinins, BAP is the most widely used one for shoot multiplication. *Asparagus* explants also had an absolute requirement of cytokinins (BAP, Kn) for the establishment and multiplication. Here the optimum concentration for establishment and proliferation of rhizome explant cultures was 0.2 mg l^{-1} BAP with 0.2 mg l^{-1}Kn which showed highest number of explants inducing shoots (9.00), number of shoots per explants (4.67) (Table 2; Fig. 1b,c) with multiplication rate of 3.50 per cent (Table 3, Fig. 1d). Mehta and Subramanian (2005) reported use of 0.27 µM NAA and 0.46 µM Kn in MS medium for shoot multiplication of *A. adscendens*. Rasheed and Yaseen (2013) also observed regeneration and proliferation of microshoots in *Asparagus densiflorus* in medium supplemented with BA (2 mg l^{-1}). Ghosh and Sen (1994) obtained maximum number (62–65) of shoots from *Asparagus cooperi* shoot tip explants of 20 days old spear in the medium containing 2.0 mg dm^{-3} of BAP,

Table 1. Effect of sterilants on surface sterilization of rhizome explants

Treatment	NaOCl (3%v/v)	Bavistin (2%w/v) + Mancozeb (2%w/v)	$HgCl_2$ (0.1% w/v)	Mean survival rate (%)
T_1	30 sec	5 min	30 sec	21.67
T_2	1 min	10 min	1 min	41.67
T_3	1.5 min	15 min	1.5 min	68.33
T_4	2 min	20 min	2 min	88.33
T_5	2.5 min	25 min	2.5 min	83.33
CD(p=0.05)		5.25		

80 mg dm^{-3} of adenine and 0.02 mg dm^{-3} of á-naphthalene acetic acid after 60 days of culture.

After scrutinizing literature carefully it was observed that high root induction in *Asparagus sp.* was obtained using IBA, NAA and IAA (Mehta and Subramanian, 2005; Jain and Kumar, 2013). High frequency of rooting 63.80% was obtained in regenerated shoots of length 3-4 cm on half strength MS medium supplemented with 1.0 mg l^{-1} IBA and 0.3 mg l^{-1} ancymidol after 15 days of inoculation into rooting medium (Table 4; Fig.1e). Sharan *et al*. (2011) also observed 66% rooting of elongated shoots in Asparagus racemosus by giving it a preculture treatment with MS medium augmented with Indole Butyric Acid (7.35 ìM) for 48 h and then transfer to MS medium with 15% coconut milk. Chang and Peng (1996) reported 73-78 per cent rooting when tryptone (250 mg l^{-1}) or phloroglucinol (162mg l^{-1}) in combination with ancymidol (1.28 mg l^{-1}) was used. Khunachak *et al*. (1987) reported increased *in vitro* rooting in *Asparagus* species using ancymidol which has anti GA_3 activity, but in our case root formation resulted when ancymidol was used along with auxin (IBA). The plants with well developed root system were successfully hardened in potting mixture of cocopeat and 1% organic manure with 67.72% percent survival rate (Fig.1f).

Assessment of genetic fidelity: All the 10 RAPD markers and out of 10 ISSR markers 7 gave amplification. All the primers gave clear and distinct monomorphic bands and negligible polymorphism was detected during the marker analysis of micro-propagated and *in vitro* conserved clones. Banding pattern of micropropagated plants was similar to those of the mother plant (Fig. 2). The size of the DNA fragments produced by the tested primers ranged from 200 bp to 12000 bp. Thus no polymorphism between clones and mother plants supports that no somacloanal variation took

Table 2. Establishment of rhizome explants

Treatment (BAP+Kn)	BAP (mg l^{-1})	Kn (mg l^{-1})	Mean no. of explants inducing shoots	Mean no. of leafy shoots per explant
T_1	0.0	0.0	0.00	0.00
T_2	0.1	0.0	0.00	0.00
T_3	0.2	0.0	2.66	1.33
T_4	0.3	0.0	2.33	1.67
T_5	0.1	0.1	3.33	1.67
T_6	0.1	0.2	4.33	2.33
T_7	0.1	0.3	3.67	2.00
T_8	0.2	0.1	4.33	2.67
T_9	0.2	0.2	9.00	4.67
T_{10}	0.2	0.3	7.33	4.33
T_{11}	0.3	0.1	8.33	3.67
T_{12}	0.3	0.2	8.33	4.33
T_{13}	0.3	0.3	7.33	4.00
CD(p=0.05)			1.07	0.81

Table 3. Average number of shoots produced per rhizome explants culture after 5 weeks on MS medium

Treatment (mg l^{-1})	BAP (mg l^{-1})	Kn (mg l^{-1})	Multiplication rate (%)
T_1 (0.0 mg l^{-1} BAP + 0.0 mg l^{-1}lKn)	0.0	0.0	0.00
T_2 (0.1 mg l^{-1} BAP + 0.1 mg l^{-1}Kn)	0.1	0.1	1.20
T_3 (0.2 mg l^{-1}BAP + 0.1 mg l^{-1} Kn)	0.2	0.1	1.30
T_4 (0.3 mg l^{-1}BAP + 0.1 mg l^{-1} Kn)	0.3	0.1	1.40
T_5 (0.1 mg l^{-1}BAP + 0.2 mg l^{-1} Kn)	0.1	0.2	2.38
T_6 (0.2 mg l^{-1} BAP + 0.2 mg l^{-1} Kn)	0.2	0.2	3.50
T_7 (0.3 mg l^{-1} BAP + 0.2 mg l^{-1} Kn)	0.3	0.2	3.22
T_8 (0.1 mg l^{-1} BAP + 0.3 mg l^{-1} Kn)	0.1	0.3	2.65
T_9 (0.2 mg l^{-1}BAP + 0.3 mg l^{-1} Kn)	0.2	0.3	2.97
T_{10} (0.3 mg/l BAP + 0.3 mg l^{-1} Kn)	0.3	0.3	3.20
CD (p=0.05)			0.13

Fig. 1. *In vitro* plantlet regeneration from rhizome explants of *Asparagus adscendens* Roxb a.) Source of rhizome explants; b.) Rhizome explant cultured on regeneration medium; c.) *In vitro* Establishment of cultures; d.) *In vitro* shoot multiplication; e.) Rooting in *in vitro* established cultures; f.) Hardening of *in vitro* raised plantlets

Table 4. *In vitro* root regeneration on half strength MS medium supplemented with IBA and ancymidol

Medium composition	Percent rooting (%)	No. of roots	Root length (cm)
1/2MS	0.00	0.00	0.00
1/2MS+0.1 mg l^{-1}IBA	0.00	0.00	0.00
1/2MS+0.2 mg l^{-1}IBA	0.00	0.00	0.00
1/2MS+0.3 mg l^{-1}IBA	0.00	0.00	0.00
1/2MS+0.4 mg l^{-1}IBA	0.00	0.00	0.00
1/2MS+0.5 mg l^{-1}IBA	13.70	2.80	3.33
1/2MS+0.6mg/l IBA	16.16	3.16	3.20
1/2MS+0.7 mg l^{-1}IBA	21.70	3.13	3.16
1/2MS+0.8 mg l^{-1}IBA	26.20	3.13	3.43
1/2MS+0.9 mg l^{-1}IBA	35.60	3.20	3.66
1/2MS+1.0 mg l^{-1}IBA	51.96	3.50	3.76
1/2MS+1.5 mg l^{-1}IBA	47.26	3.43	3.66
1/2MS+2.0 mg l^{-1}IBA	44.60	3.40	3.66
1/2MS+1.0 mg l^{-1}IBA+0.1 mg l^{-1} Ancymidol	59.60	3.73	3.86
1/2MS+1 mg l^{-1}IBA+0.2 mg l^{-1} Ancymidol	63.03	3.63	4.00
1/2MS+1.0 mg l^{-1}IBA+0.3 mg l^{-1} Ancymidol	63.80	3.63	4.33
1/2MS+1. mg l^{-1}IBA+0.4 mg l^{-1} Ancymidol	61.80	3.60	4.06
1/2MS+1.0 mg l^{-1}IBA+0.5 mg l^{-1} Ancymidol	60.60	3.60	4.10
CD (p=0.05)	2.69	0.25	0.18

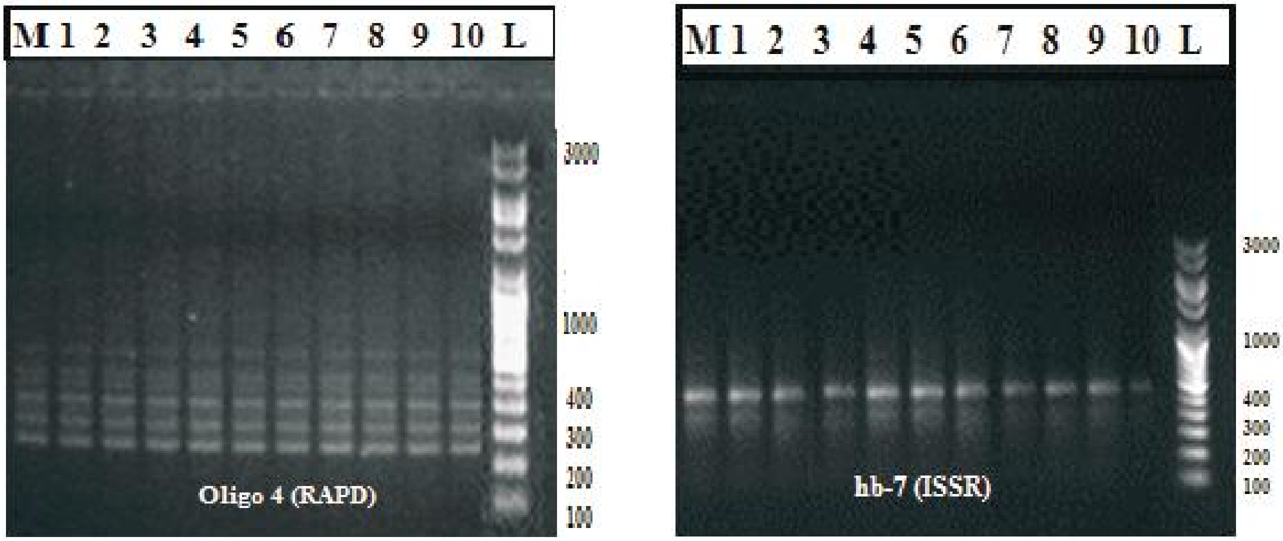

Fig. 2. RAPD and ISSR profiles generated by primers Lane M: the mother plant, Lanes 1 to 10: micro-propagated plants, Lane L: ladder

place in plants developed under *in vitro* conditions. Of various DNA based molecular markers RAPD and ISSR were used as they are very simple, fast, cost effective and highly reliable. The use of two markers, which amplify different regions of the genome, allows better chances for the identification of genetic variations in the clones (Martin *et al.,* 2004). No polymorphism was detected during the RAPD and ISSR analysis of *in vitro* raised clones. This work was in accordance with Rout and Das (2002) who obtained all monomorphic RAPD profiles among micro-propagated plants and with field grown mother plant in *Plumbago zeylanica* using 20 random decamer primers. A similar study was done by Nanda *et al.* (2003) in *Acacia mangium* to evaluate genetic stability through RAPD marker. No variation was detected among the micro-propagated plants by the use of RAPD markers.

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Abundance and Foraging Behaviour of Major Insect Pollinators on Seed Crop of Broccoli *(Brassica oleracea* L. var. *italica* Plenck)

Suman Devi and Ombir

CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: narwal_suman@yahoo.in

Abstract*:* *Apis mellifera* (7.34) was the most abundant visitor and highly significant over *Apis florea*, *Apis dorsata*, syrphid fly and *Apis cerana*. The foraging speed (time spent per flower) of different honey bee species on broccoli flowers was maximum in *A. florea (*38.54), which was highly significant over *A. dorsata, A. mellifera, A. cerana and* syrphid fly. Foraging rate (number of flowers visited minute^{-1}) of different honey bee species on broccoli flowers was maximum in *Syrphid fly (*17.61), which was highly significant over *A. cerana, A. mellifera, A. dorsata and A. florea*. There was direct and significant correlation of day hours and species of honey bees and syrphid fly.

Key Words: Abundance, Foraging rate, Foraging speed, Honey bees

Broccoli is cross pollinated and grown by seed and insect play major role in pollination. The flowers of broccoli, important sources for both pollen and nectar, are very attractive to honey bees. Among the total pollination activities, over 80% is performed by insects and bees contribute nearly 80% of the total insect pollination and therefore, they are considered the best pollinators. Bee pollination improves the yield and quality of crops, such as fruits, vegetable seeds, spices, oilseeds and forage crops (Dhakal, 2003; NARC, 2008). The number of flowers visited per minute by any type of bee species depends upon the number of factors including instinctive foraging behaviour, length of proboscis (Inouye, 1980) floral structure (Free, 1970) particularly the corolla depth (Gilbert, 1980) type and quantity of floral rewards (Rao, 1991) density of flowers on particular cultivar of the crop concerned and hours of the day. Foraging behavior play an important role on the production and productivity of the crops, which is use to compare pollination efficiency of different honeybee species. More foraging frequency indicated the more pollination efficiency (Singh *et al.,* 2006). There is very scanty information available for the role of insect pollinators and their efficiency in seed production of broccoli under agro-climatic conditions of Haryana. So, study was undertaken to record the abundance and forging behavior of major insect pollinators especially honey bees and syrphid fly on seed crop of broccoli.

MATERIAL AND METHODS

Abundance of major insect visitors/pollinators on broccoli flowers was recorded during the blooming period of the crop. The numbers of pollinators visiting per square meter area of crop/5 minutes were noted from five randomly selected areas. These observations were recorded from 0700 h to 1900 h at an interval of 2:00 hours. Observations were recorded for 7 days after the initiation of 10 days after flowering in the crop, at peak flowering and before the cessation of flowering in the crop. Foraging speed of bees was recorded in terms of time (seconds) spent by them on each flower (Free, 1993). A total of ten bees of each species were observed for recording time spent by them per flower at peak flowering period of the crop. The time spent to inject the proboscis and suck up the nectar or brushing/collecting pollens was considered as the time spent per flower, which was recorded with the help of a chonometer having an accuracy of 0.01 seconds. Ten observations were recorded for each bee species. Foraging rate of bees was recorded in terms of the number of flowers they visited per minute. A total of ten bees of each species were observed for recording the number of flowers visited per minute at peak activity time of particular species at peak flowering period of the crop. The numbers of flowers visited per minute were recorded including the flying time from one flower to another flower.

RESULTS AND DISCUSSION

The mean population of pollinators over different day hours ranged from 0.80 (syrphid fly) to 6.50 bees m^{-2} per 5 minutes (*A. mellifera*). The population of *A. dorsata* appeared in the morning hours 0700-0900 and significantly higher population was recorded. Population of *A. mellifera* was more active from 0900-1700 and it was significantly superior over other species including syrphid fly. Lowest population of syrphid fly (0.03 adult/5 minutes) was recorded and it was followed by *A. dorsata* and *A. cerana* and these were statistically at par with *A. florea*. Similar trend was recorded at 1100-1300 and maximium population of *A. mellifera* was recorded at this time also. It was followed by *A. florae* and it was significantly higher than other species. At 1300-1500, maximum population of *A. mellifera* was recorded at this time. It was followed by *A. florea* and significantly higher than other bees. Drastic reductions of the insect visitors were recorded at 1500-1700 and significantly higher population of *A. mellifera* was recorded at this time also. At 1700-1900 significantly higher population of *A. dorsata* was recorded. There was direct and significant correlation of day hours and species of honey bees and syrphid fly.

No population of *A. florea* and syrphid fly was observed during 0700-0900 hr, due to the low temperature in the 1st week of March. The mean population of bee species over different day hours ranged from 1.6 (*A. cerana*) to 9.3 bees m^{-2}/5 minutes (*A. florea*). The population of *A. dorsata* appeared in the morning hours 0700-0900 and significantly higher population was recorded. Population of *A. mellifera* was more active at 0900-1100 and it was significantly superior over other species including syrphid fly. Lowest population of syrphid fly (1.10 adults/5 minutes) was recorded and it was followed by *A. cerana*, *A. dorsata* and *A. florea.* Significantly higher population of *A. florea* was recorded from 1100-1700. Drastic reductions of the insect visitors were recorded at 1700-1900, significantly higher population of *A. mellifera* was recorded at this time.

No population of *A. florea* was observed during 0700-0900 h, due to the low temperature. The mean population of bee species over different day hours ranged from 0.70 (*A. cerana*) to 6.50 bees m^{-2}/5 minutes (*A. mellifera*). The population of *A. dorsata* appeared in the morning hours 0700-0900 and significantly higher population was recorded. Population of *A. mellifera* was more active at 0900-1100 and it was significantly superior over other speices including syrphid fly. Lowest population of syrphid fly was recorded and it was followed by *A. cerana*, *A. dorsata* and *A. florea*. Significantly higher population of *A. florea* was

Table 1. Diurnal abundance of major insect pollinators at initiation of the flowering of seed crop of broccoli variety GH-1 during Feb. - March, 2014

Species	Number of bees m^{-2}/5 minutes during different day hours						
	0700-0900	0900-1100	1100-1300	1300-1500	1500-1700	1700-1900	Mean
Apis mellifera	0.40 (1.20)	5.45 (2.54)	12.50 (3.67)	13.50 (3.80)	5.90 (2.63)	0.90 (1.36)	6.50 (2.53)
Apis dorsata	1.05 (1.43)	1.48 (1.57))	2.80 (1.93)	2.90 (1.97)	2.80 (1.93)	2.20 (1.96)	2.20 (1.80)
Apis cerana	0.00 (1.00)	1.48 (1.57)	2.06 (1.75)	2.80 (1.93)	1.70 (1.64)	0.20 (1.10)	1.40 (1.50)
Apis florea	0.00 (1.00)	1.50 (1.58)	11.4 (3.52)	11.8 (3.58)	2.90 (1.64)	0.0 (1.00)	4.60 (2.10)
Syrphid fly	0.00 (1.00)	0.03 (1.01)	2.30 (1.82)	2.70 (1.96)	0.05 (1.96)	0.0 (1.00)	0.80 (1.29)
Factors					CD (p=0.05)		
Species					0.01		
Day hours					0.01		
Species x day hours					0.03		

Each value represents mean of 5 observations at each sampling time
Figures in parentheses are $\sqrt{(x+1)}$ transformed values

Table 2. Diurnal abundance of major insect pollinators at peak of the flowering of seed crop of broccoli variety GH-1 during Feb. - March, 2014

Species	Number of bees m^{-2}/5 minutes during different day hours						
	0700-0900	0900-1100	1100-1300	1300-1500	1500-1700	1700-1900	Mean
Apis mellifera	0.98 (1.39)	7.40 (2.89)	18.10 (4.37)	16.20 (4.14)	8.30 (3.05)	3.50 (2.11)	9.10 (2.99)
Apis dorsata	2.10 (1.76)	2.90 (1.96)	2.10 (1.76)	2.30 (1.80)	2.10 (1.76)	1.90 (1.71)	2.20 (1.79)
Apis cerana	0.01 (1.00)	1.90 (1.69)	2.10 (1.77)	2.30 (1.80)	1.90 (1.69)	1.10 (1.44)	1.60 (1.57)
Apis florae	0.00 (1.00)	4.60 (2.37)	21.10 (4.70)	18.40 (4.40)	8.50 (3.07)	3.20 (2.05)	9.30 (2.93)
Syrphid fly	0.00 (1.00)	1.10 (1.44)	3.90 (2.20)	3.80 (2.18)	3.10 (2.03)	0.90 (1.37)	2.10 (1.70)
Factors					CD (p=0.05)		
Species					0.01		
Day hours					0.01		
Species x day hours					0.03		

Each value represents mean of 5 observations at each sampling time
Figures in parentheses are $\sqrt{(x+1)}$ transformed values

recorded from 1100-1700. Drastic reductions of the insect visitors were recorded at 1500-1700 and significantly higher population of *A. mellifera* was recorded. At 1700-1900 significantly higher population of *A. florea* was recorded.

No population of *A. florea* was observed during 0700-0900 hr, due to the low temperature. The mean population of bee species over different day hours ranged from 1.22 (*A. cerana*) to 7.34 bees/m^2/5 minutes (*A. mellifera*). The population of *A. dorsata* appeared in the morning hours 0700-0900 and significantly higher population was recorded. Population of *A. mellifera* was more active at 0900-1100 and it was significantly superior over other species including syrphid fly. Lowest population of syrphid fly was recorded and it was followed by *A. cerana*, *A. dorsata* and *A. florea.* Significantly higher population of *A. florea* was recorded from 1100-1500. Drastic reductions of the insect visitors were recorded at 1500-1700 and significantly higher population of *A. mellifera* was recorded. At 1700-1900 significantly higher population of *A. mellifera* was recorded. Similar finding was reported by Ricciardelli d' Albore (1984) indicated *A. mellifera* to be the best pollinators of thee *Brassica* crops in Perugia, Italy, constituting 88% of the insect population on *B. napus oleifera*, 92% on *B. rapa* and 67% on cauliflower (*B. oleracea* var. Botrytis).

The highest foraging rate (no. of flowers visited/minute) was of syrphid fly (18.71) followed by *A. cerana* (12.87), *A. mellifera*, *A. dorsata* and *A. florea*. Mean maximum foraging rate of syrphid fly, *A. cerana, A. mellifera, A. dorsata,* and *A. florea* was observed during 1500-1700, 1100-1300, 1300-1500, 1100-1300 and 0900-1100 hr of the day, respectively (Fig.1). Devkota and Thapa (2005) studied that two bee species (*A. cerana* and *A. mellifera*) differed significantly ($P<0.05$) on the number of flower visits $minute^{-1}$ on broccoli. *A. cerana* showed higher flower visiting

Table 3. Diurnal abundance of major insect pollinators at cessation of flowering of seed crop broccoli variety GH-1 during Feb. - March, 2014

Species	Number of bees m^{-2}/5 minutes during different day hours						
	0700-0900	0900-1100	1100-1300	1300-1500	1500-1700	1700-1900	Mean
Apis mellifera	0.97 (1.40)	6.90 (2.80)	12.20 (3.63)	11.80 (3.57)	4.90 (2.43)	2.10 (1.74)	6.50 (2.60)
Apis dorsata	1.90 (1.69)	2.10 (1.76)	1.90 (1.70)	2.20 (1.78)	2.07 (1.75)	1.90 (1.69)	2.00 (1.73)
Apis cerana	0.02 (1.01)	1.40 (1.54)	1.60 (1.60)	0.90 (1.37)	0.30 (1.14)	0.10 (1.03)	0.70 (1.28)
Apis florea	0.00 (1.00)	3.50 (2.12)	14.20 (3.90)	11.90 (3.59)	4.10 (2.24)	2.90 (1.98)	6.10 (2.47)
Syrphid fly	0.09 (1.04)	1.40 (1.54)	4.40 (2.31)	4.20 (2.28)	3.20 (2.05)	1.90 (1.71)	2.50 (1.82)
Factors					CD (p=0.05)		
Species					0.01		
Day hours					0.02		
Species X day hours					0.04		

Each value represents mean of 5 observations at each sampling time
Figures in parentheses are $\sqrt{(x+1)}$ transformed values

Table 4. Diurnal abundance (irrespective of flowering stage of crop) of major insect pollinators on blossoms of broccoli variety GH-1 during Feb. - March, 2014

Species	Number of bees m^{-2}/5 minutes during different day hours						
	0700-0900	0900-1100	1100-1300	1300-1500	1500-1700	1700-1900	Mean
Apis mellifera	0.80 (1.34)	6.58 (2.75)	14.20 (3.89)	13.80 (3.84)	6.37 (2.71)	2.17 (1.74)	7.34 (2.71)
Apis dorsata	1.68 (1.63)	2.16 (1.77)	2.27 (1.80)	2.47 (1.86)	2.32 (1.82)	2.01 (1.58)	2.15 (1.78)
Apis cerana	0.01 (1.01)	1.59 (1.60)	1.92 (1.71)	2.00 (1.71)	1.30 (1.50)	0.47 (1.20)	1.22 (1.45)
Apis florea	0.00 (1.00)	3.20 (2.03)	15.5 (4.05)	14.03 (3.86)	5.17 (2.43)	2.03 (1.68)	6.67 (2.51)
Syrphid fly	0.03 (1.01)	0.84 (1.34)	3.53 (2.12)	3.57 (2.13)	2.12 (1.71)	0.93 (1.36)	1.84 (1.61)
Factors					CD (p=0.05)		
Species					0.01		
Day hours					0.01		
Species x day hours					0.03		

Each value represents mean of 5 observations at each sampling time
Figures in parentheses are $\sqrt{(x+1)}$ transformed values

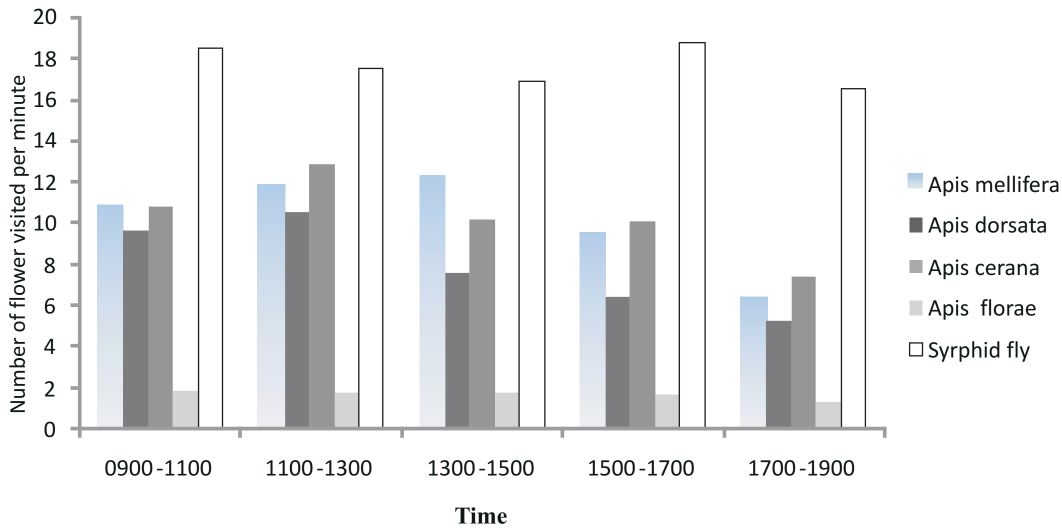

Fig. 1. Foraging rate of different honey bee species on broccoli flowers of variety GH- 1 at different hours

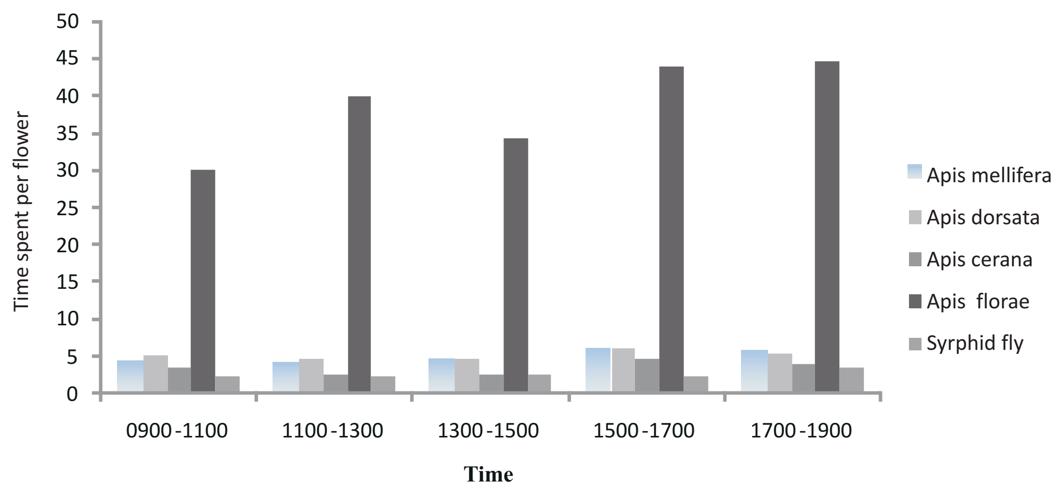

Fig. 2. Foraging speed of different honey bee species on broccoli flowers variety GH-1 at different hours of the day

efficiency as compared to *A. mellifera*. The average number of flower visited by *A. cerana* bee was 11.387 and 12.107 minute^{-1} as compared to 9.033 and 10.889 flower minute^{-1} by *A. mellifera* under caged and open conditions, respectively. The highest foraging speed was of *A. florea* (44.70) followed by *A. dorsata*, *A. mellifera*, *A. cerana* and syrphid fly (Fig.2). Mean maximum foraging speed of *A. florea, A. dorsata, A. mellifera, A. cerana* and syrphid fly was observed during 1700-1900, 1500-1700, 1500-1700, 1500-1700 and 1700-1900 hr of the day, respectively.

Foraging speed of *A. florea* during peak flowering irrespective of day hours was observed maximum (38.54) followed by *A. dorsata*, *A. mellifera*, and *A. cerana* and syrphid fly. Thakur *et al*. (2004) recorded that *A. mellifera* was the most frequent visitor of broccoli followed by *Helictus sp*. and *A. cerana*. Although *Bombus trifasciatus* was the most active spent minimum time per flower (1.95 seconds), its population was less compared to honey bees and *Helictus sp*. and hence ranked fourth. The syrphid fly, *Eristalis tenax* ranked last among the top 5 positions.

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Climate Change and its Impact on Apple Farming in High Hill Dry Temperate Zone of Himachal Pradesh-Farmers Perception and Responses

Hukam Chand, S. C. Verma, S. K. Bhardwaj, S. D. Sharma, Ravinder Sharma and P. K. Mahajan

Dr. Y.S Parmar, University of Horticulture and Forestry, Solan-173 230, India
E-mail: hukamchandevs@gmail.com

Abstract: The present study revealed that about 71.92% of farmers perceived a decrease in the sources of irrigation water and as per farmer perception the main reasons for decrease in irrigation water resources were less snowfall (50.96 %), increased temperature (16.35 %) and both (32.69 %). About 85.58% of the farmers noticed that increased incidence of insect-pest and diseases in the apple orchards were due to increased temperature (58.65 %) and change in precipitation (17.98 %) as well as both increased temperature and change in precipitation (24.72 %). Major factors affecting apple farming in the region includes change in snowfall pattern (71.15 %), increased temperature (63.46 %), pollination problems (61.54 %), change in rain fall pattern (57.69 %), less proportion of pollinizer varieties (52.88 %) and insect-pest and disease incidence (51.92).Thus, it can be concluded from the farmer perception that climatic condition in the region is becoming unfavorable for the apple cultivation.

Key Words**:** Apple, Climate change, Himachal Pradesh. Kinnaur

The impacts of climate change are seriously felt in Himalayan region because it belongs to the most vulnerable ecosystems and most of the population is dependent on the agriculture and horticulture for sustaining the livelihood. Mountains are early and important indicators of climate change which depict far-reaching consequences on our ecosystem, agriculture and livelihood of the farmers (Singh *et al.,* 2010). Himachal Pradesh is no longer remains unaffected from climate change and could be clearly depicted by changes like receding snowfall, increased temperature and shifting of temperate fruit belt upward which is adversely affecting productivity of apple (Awasthi *et al.,* 2001). This also resulted in increased incidence of insect-pest and diseases (Bhagat *et al.,* 2004). Apple is the major fruit crop of Himachal Pradesh commonly grown in the sub temperate to temperate hilly region of the state. Apple productivity declined up to 1500 m. above mean sea level to the tune of 40-50 per cent due to warmer climate resulting in lack of chilling requirement during winter and warmer summer in lower elevations resulting in to shifting of apple production to higher elevation, 2700 m amsl (Chadda *et al*., 2009). Kinnaur district of Himachal Pradesh is situated on both side of river Satluj from 31^{0}-05'-50” to 32^{0}-05'-15” north latitude and 77^{0}-00'-35” east longitude is situated between 2,100 m to 3,600 m above mean sea level. Total human population of district is 84,298 and the population density is estimated as 15 per km^{2} (Anonymous, 2011). The impacts of climate change on apple crop and its socio-economic impacts have not been studied so far in the region. So the present investigations was carried out in Kinnaur district of Himachal Pradesh during the year 2014-15 with the aim to understanding the impact of climate change and the resulting socio-economic responses.

MATERIAL AND METHODS

Seven Panchayats of Kinnaur District of Himachal Pradesh viz Kalpa, Dooni, Kothi, Roghi, Bathseri, Sangla and Rakchham representing altitudinal ranges between 2500-3000 m mean sea level (Table 1) and dominated by the apple cultivation has been selected purposely to examine the perceptions of farmers for climate change and apple cultivations. A pretested survey schedule was used for collection of detailed information climate change, its impact on apple productivity from the 104 respondents (apple growers) in seven selected panchayats of the district. Multistage random sampling was employed to collect

Table 1. Location of selected village panchayats in the Kinnaur district of Himachal Pradesh

Village Panchayat	Altitude (m amsl)	Latitude	Longitude
Dooni	2545	31°32.56”	78°15.36”
Roghi	2655	31°30.85”	78°13.87”
Kothi	2690	31°32.90”	78°15.98
Sangla	2718	31°26.04	78°19.26
Kalpa	2750	31°32.97	78°15.12
Bathseri	2755	31°24.46”	78°18.21”
Rakchham	2985	31°23.38”	78°21.19”

information on various aspects pertaining to climate change and its impact on apple production (Kish, 1995).

The data for present study was collected through pre tested schedule by personal interview method. The information was gathered on various climatic parameters like temperature, rainfall and snowfall and impact of these parameters on source of water, insect- pests, disease incidence, pollinators and apple productivity

RESULTS AND DISCUSSION

The natural springs (41.35%) and kulh water (21.15%) are the main sources of irrigation in the region, whereas, about 37.50 per cent of farmers responded that there were no sources of irrigation to their orchards (Fig. 1). 71.92 per cent farmers observed decrease in the sources of irrigation water during the last decade, whereas, rest did not perceive any change (Fig.2). About 50.96 per cent of farmers perceived that decreased snowfall is the main reason for the declining water sources where as increased temperature (16.35 %) as well as both decreased snowfall and increased temperature (32.69 %) were responsible for this (Fig. 3). This might be attributed as less snowfall may be responsible for the less water availability in the seasonal springs. An increased incidence of insect-pest and diseases in the apple orchard was reported by about 85.58 per cent of farmers (Fig. 4). Farmers' perceptions about the possible reasons for the increased incidence of major insect-pest and diseases revealed that increased temperature (58.65 %), change in precipitation (17.98 %) as well as both increased temperature and change in precipitation (24.72 %) were mainly responsible for increased incidence of major insect-pest and diseases in the apple orchards (Fig. 5). Sharma *et al*. (2004) has also reported that under high temperature and moisture stress conditions damage by shot hole borers, wooly apple aphid, San Jose Scale and blossom thrips were more prominent. 82.69 per cent farmers noticed decrease in

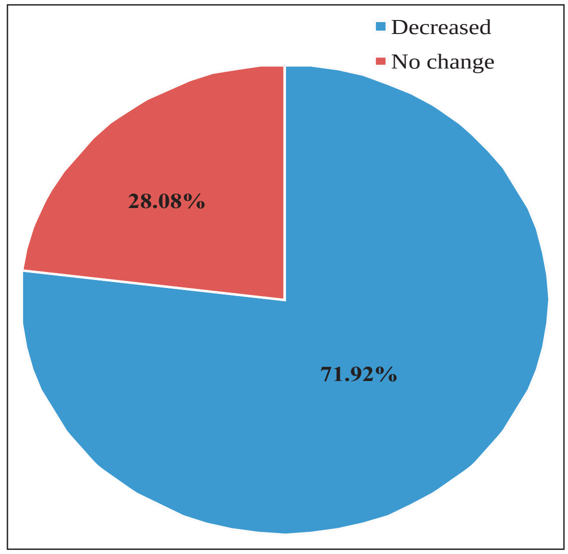

Fig. 2. Farmers perception about effect of climate change on irrigation water sources

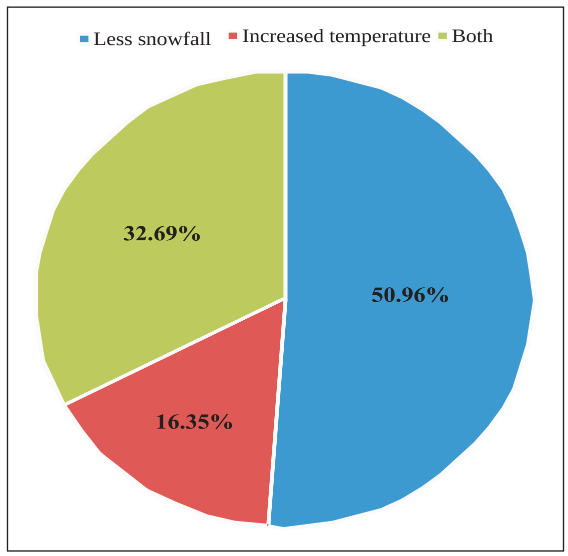

Fig. 3. Farmers perception about possible reasons for declining water sources

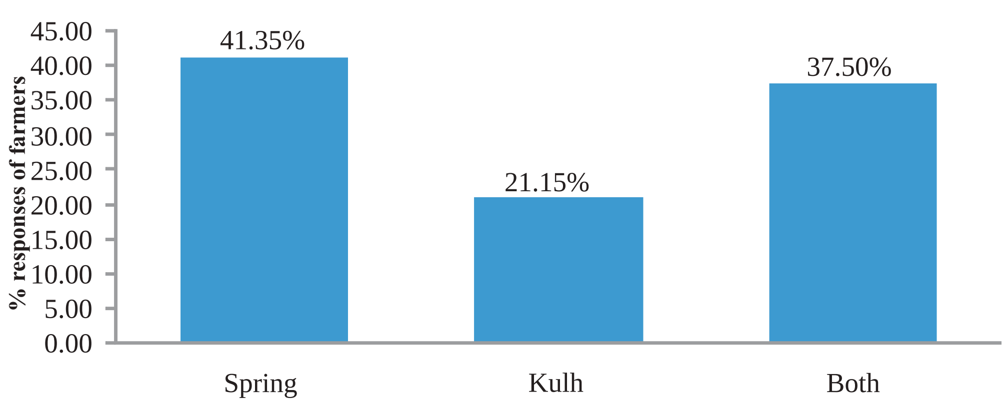

Fig. 1. Farmers perception about available sources of irrigation water to apple orchard

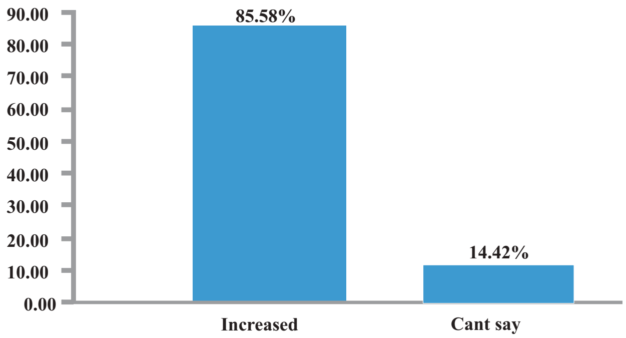

Fig. 4. Farmers perception about the incidence of insect-pest and diseases in the apple crops

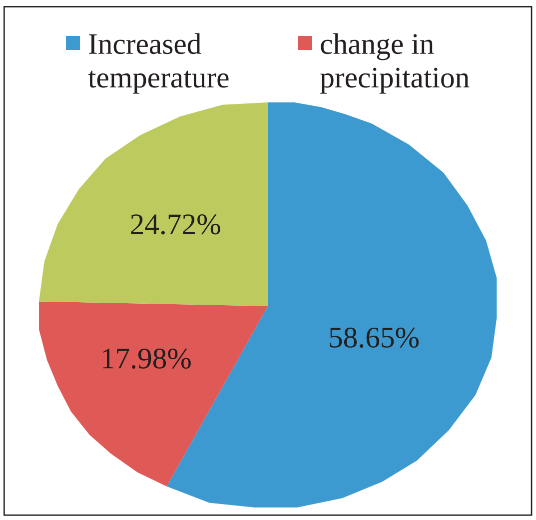

Fig. 5. Farmers perception about the possible reasons for increased incidence of insect-pests and diseases

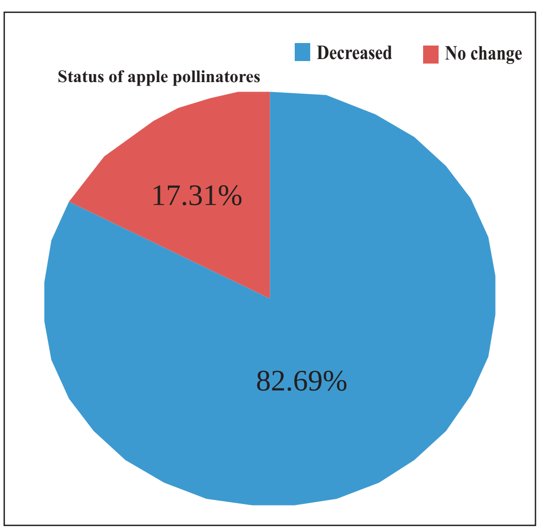

Fig. 6. Farmers perception about the status of pollinators for apple the crop

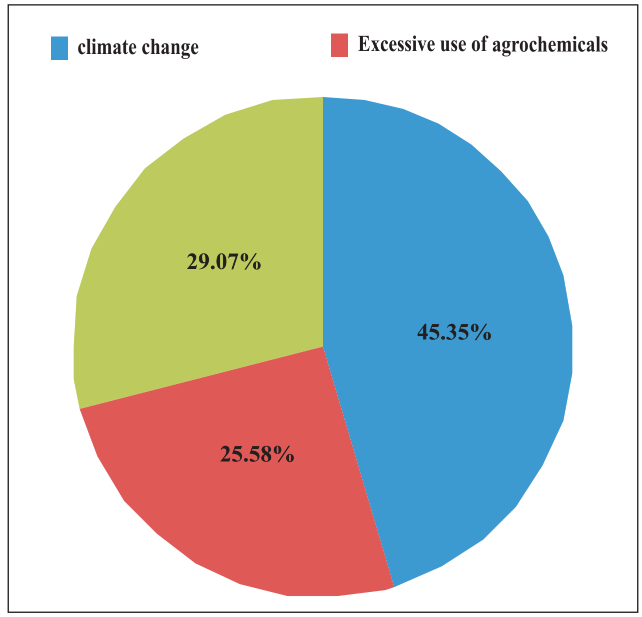

Fig. 7. Farmers perception about the possible reasons for decreased apple pollinators

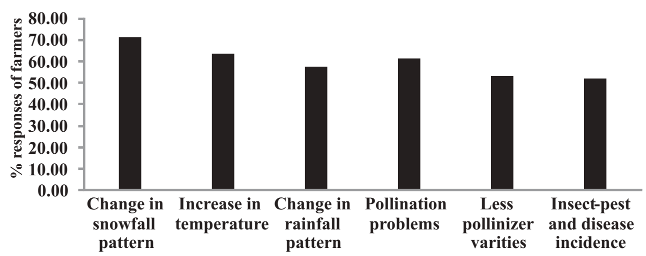

Fig. 8. Farmers perception about factors affecting the apple farming in Kinnaur district of Himachal Pradesh

insect pollinators' population during the last decade, whereas, only 17.31 per cent of farmers perceived no change (Fig. 6). 45.35 per cent farmers observed climate change is the major cause of decreasing pollinators' population since last decades, whereas, 29.07 per cent of the farmers responded that both climate change and excessive use of pesticides were the main reason for this, while 25.58 per cent of the respondent observed excessive use of pesticides responsible for declining pollinators' population (Fig. 7). Change in snowfall pattern (71.15 %), increased temperature (63.46 %), pollination problems (61.54 %), change in rain fall pattern (57.69 %), less proportion of pollinizer varieties (52.88 %) and insect-pest disease incidence (51.92 %) were the major factor affecting apple farming in the region (Fig. 8). Sharma *et al.* (2004) has also reported that fluctuating temperature during pollination and particularly rains accompanied by low temperature inhibits the transfer of pollen because of restricted bees' activity causes washing off of pollen. Thus, it can be concluded from the present investigations that climatic conditions in the region becoming unfavorable for apple farming, therefore in order to cope up apple cultivation with changing climate there is a need to standardize new technologies as well as package and practices for apple cultivation in the region.

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Effect of Various Mulching on Soil Properties and Fruit Quality Attributes of Eureka Lemon (*Citrus limon Burm*) in Kandi Area

Vijay Kumar, Vikas Sharma[1], A. K. Bhat[1], Neeraj Gupta and V. B. Singh

Rainfed Research Sub-station for Sub-tropical fruits, Raya-181 143, India
[1]Division of Soil Science & Agricultural Chemistry
S.K. University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India
E-mail vijaykumar.1144@yahoo.com

***Abstract*:** The various mulching materials like bajra straw, maize straw, grasses, brankad (*adhotada vassica*), farmyard manure, black polyethylene was compared with unmulched (control) for soil properties, available nutrients and yield quality attributes of Eureka lemon (*Citrus limon* Burm). Different organic and inorganic mulches did not have significant impact on soil pH, electric conductivity (EC) and fruit quality while it was ($p = 0.05$) significant on soil organic carbon and available N, P and K, in all treatments. Black polyethylene mulch recorded highest yield and fruit quality followed by farmyard manure and brankad (*adhotada vassica*). Farmyard manure and brankad improved the soil properties and quality attributes of the fruit. Organic mulch of brankad on recorded of better response than bajra and maize straw mulch in soil organic carbon and available nutrients. The yield was significantly higher in polyethylene mulch recorded highest yield (1848 kg ha^{-1}) followed by farmyard manure (1780 kg ha^{-1}) and brankad (1744 kg ha^{-1}) and was lowest in control (1700 kg ha^{-1}). Black polyethylene mulch than farmyard manure, brankad, bajra straw and maize straw recorded higher values of fruit weight, fruit size, reducing sugar, total sugar, ascorbic acid except in acidity per cent.

***Key Words*:** Mulching, Quality attributes, Rainfed condition, Soil properties

Eureka lemon (*Citrus limon Burm)* has become the important fruit crop of rainfed condition of arid, semi arid region of the country because of its precocity, thornlessness and heavy bearing nature. Citrus (*Citrus* sp.) tree generally require good amount of water compared to the other subtropical fruits because sap circulation never entirely ceases and transpiration take place throughout the year as it is evergreen. The Eureka lemon grows year-round and abundantly. In kandi areas, soils moisture and inherently poor fertility are the major constraints. The conservation of soil moisture by application of mulches becomes essential for portable cultivation under rainfed condition of semi arid ecosystem. In spite no assured irrigation in these regions, the moisture conservation technique is not in practice. Mulches not only conserve soil moisture but also impart manifold beneficial effect, like suppression of extreme fluctuation of soil temperature, reduce water loss through evaporation, resulting more stored soil moisture (Kumar *et al*., 2015), maintenance of soil fertility (Kumar, 2014 and Bakshi *et al*., 2015), improvement growth and yield (Kumar *et al.,* 2015). Various studies have indicated that in fruit crops like apple, sapota, and acid lime, mulching improves soil moisture status, growth, yield and quality of these fruits, besides reducing weed growth (Shirugure *et al.,* 2005, Singh *et al.,* 2008).

Continuous use of organic mulches are helpful in improving the physico-chemical properties of soil and available nutrients, which ultimately resulted into better growth and yield of plant (Singh *et al.,* 2008; Kumar *et al*., 2015). Mulching by plastic polyethylene has proved its effectiveness in conserving the soil moisture and increasing the growth, yield and quality in different citrus cultivars (Lal *et al*., 2003; Shirugure *et al.,* 2005). Considering the beneficial effect of mulching, this investigation was undertake to assess the effect of organic and inorganic mulches on soil properties, nutrients and quality attributes of Eureka lemon in rainfed condition of Jammu, India.

MATERIAL AND METHODS

This experiment was carried out at Rainfed Research Sub-Station for Sub-tropical fruits Raya, Jammu, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during 2009-10 and 2010-11. The experimental field is situated at an elevation of 332 m above mean sea level and lies between 32º39" North latitude and 74^{0}53" East longitude. The climate of experimental site is sub-tropical with hot and dry summer season, hot and humid rainy season and cold in the winter months. The maximum temperature rises up to 45ºC during summer and minimum temperature falls to 3.16ºC during winter. Rainfall of 1100 mm occurs annually but about 70 to 80 per cent from July to September and with a very high intensity. The rainfall distribution patterns are especially erratic in time and space leads to moisture stress condition during the major part of the year. Study was carried out on 2 years old plants of air layered Eureka lemon, which were planted in 2007 at a distances of 5m x 5m was treated with different types of mulches. The treatments were: bajra straw, maize straw, grasses, brankad, farmyard manure, black polyethylene and control (no mulch). The experiment was laid out in randomized block design with four replications. Ten centimetre thick mulches viz bajra straw, maize straw, grasses, brankad, farm yard manure all in quantity were imposed uniformly on the basin over a surface during April. For inorganic mulching 400 gauge black polyethylene was spread on plant basin covering the soil surface around the plant basin. In control no mulch was applied. Other cultural practices adopted were similar for all treatments.

The soil samples were analyzed for the properties and available nutrients. The soil reaction by pH metre, EC by EC metre, organic carbon in soil was by Walkley and Black's rapid titration methods. Available N was estimated as per the procedure of Subbiah and Asija (1956) and available P by Olsen *et al*. (1954). The fruits were harvested in the last week of August. The observation regarding fruit size (length and diameter) weight, total soluble solid (TSS) of fruits was estimated based on random four fruit samples. Total sugars, reducing sugars, ascorbic acid and acidity were estimated by adopting the standard procedure (Ranganna, 1986).

RESULTS AND DISCUSSION

Soil pH and EC: The highest soil pH and EC was observed in control (without mulch) and lowest in maize straw both the years (Table 1). Soil pH of the plant basin showed some reduction in their values, but the difference was non-significant. This might be due the soil pH decreased in addition of organic matter after decomposition of mulches; which releases organic acids and dissolve them from their soluble form. The soil EC of the tree basin showed some reduction in their values, but the difference among the treatments could not reached up to the level of significance. These findings are in close conformity with the results of (Kumar, 2014) and Bakshi *et al*. (2015).

Soil organic carbon: Soil organic carbon was significantly affected by different types of mulch (p = 0.05). The highest soil organic carbon was observed in farmyard manure followed by brankad (*Adhotada vassica*), maize straw, bajra straw, grasses and lowest in black polythene mulch of tree basin. Organic mulching can contribute to such a development by improving organic matter content in the soils and by affecting other soil characteristics (Ferrini *et al*., 2008). Farmyard manure is high nutrient status than other mulching treatment. Annual incorporation of the farmyard manure into the soil caused the highest content of soil organic carbon. Tree basin previously mulched with bajra straw, maize straw, grasses and branker still showed a higher

Table 1. Effect of mulching on soil properties and available nutrients in soil of Eureka lemon (2010-2011)

Treatment	pH		EC (dSm^{-1})		O.C ($g\ kg^{-1}$)		Avail N $kg\ ha^{-1}$		Avail P $kg\ ha^{-1}$		Avail K $kg\ ha^{-1}$	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Bajra straw	6.55	6.50	0.17	0.19	5.32	5.52	225.25	226.75	18.81	19.43	158.69	160.94
Maize straw	6.31	6.22	0.18	0.20	5.84	6.06	229.50	231.00	19.06	19.83	163.18	164.31
Grasses	6.61	6.40	0.17	0.20	5.12	5.32	222.00	224.25	18.46	19.12	155.33	156.45
Brankad	6.68	6.60	0.20	0.21	6.10	6.24	233.00	234.50	19.21	20.18	165.99	167.11
FYM	6.78	6.70	0.25	0.23	6.60	6.80	238.00	239.50	20.12	21.00	169.92	179.48
Black polyethylene	6.73	6.50	0.22	0.22	4.08	4.22	212.50	214.00	17.62	17.71	151.40	152.96
Control	7.03	7.07	0.24	0.25	4.22	4.44	214.50	215.50	18.06	18.21	152.52	154.52
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.	0.08	0.08	5.53	6.47	1.21	1.51	3.11	3.17

Table 2. Effect of mulching on fruit quality attributes of Eureka lemon (summer season-2010)

Treatment	Yield ha^{-1} (kg)	Fruit weight (gm)	Fruit diameter (cm)	Fruit length (cm)	TSS (%)	Reducing sugar (%)	Total sugar (%)	Ascorbic acid (mg/100 ml juice	Acidity (%)
Bajra straw	1560.00	50.51	4.49	4.62	6.50	5.65	2.16	46.20	6.11
Maize straw	1700.00	50.27	4.53	4.79	6.55	5.61	2.14	47.95	6.22
Grasses	1720.00	49.72	4.43	4.69	6.62	5.92	2.08	45.10	5.87
Brankad	1680.00	54.81	4.56	4.85	6.42	5.80	2.11	45.92	6.00
FYM	1744.00	55.80	4.50	4.74	6.57	5.43	2.22	46.47	6.15
Black polyethylene	1780.00	61.03	4.72	4.91	6.77	6.07	2.60	50.75	5.83
Control	1848.00	45.78	4.31	4.49	6.30	5.32	2.04	44.27	6.25
CD (p=0.05)	34.41	7.65	N.S.	N.S.	0.07	N.S.	N.S.	N.S.	N.S.

content of SOC than the unmulched tree basin. Although grass mulch quickly decomposes, the amount of soil organic matter (SOM) in the tree basin previously mulched with grass was higher compared with the unmulched tree basin. The results of these studies confirm that long organic farming positively influences the amount of SOM (Lagomarsino *et al*., 2009). It was observed that farmyard manure, brankad, maize straw, bajra straw and grasses decomposed after rainy season and added lot of humus to the soil. Covering the soil with different type of mulches can improved environmental condition for soil organism by preventing water and wind erosion, inhibiting drastic variation in humidity and temperature and by increasing organic matter as a source of nutrition. Thus it can provide a more stable environment for soil invertebrates (Jodaugiene *et al*., 2010).

Available nutrients (N, P and K): The highest soil available nitrogen, phosphorus and potassium was observed in farmyard manure followed by brankad, maize straw, bajra straw, grasses, control and lowest in black polythene mulch of tree basin. The higher available nitrogen content which might be due to higher potential of nitrate leaching in mulched soil could not be overlooked because nitrate accumulation peak was found at deeper layer of mulched soil compared to no-mulched soil. Soil organic N mineralization is related to the environment (Gao *et al*., 2009). Phosphorus concentration in farmyard manure is higher than its concentration in soil, therefore irrigation or raining season water can transfer phosphorus to soil layer. In other mulches, increasing mulch layer caused adjusting soil temperature and maintaining soil moisture that helped better phosphorus absorption condition in soil. The available potassium content which might be due to tree basin mulched with organic materials had significantly higher soil K concentrations than no mulched plots (Broschat, 2007). The organic acids produced during the decomposition of mulching materials complexes the metal cations Ca, Al and Fe, hereby helping in solubilization of native P and reduction in P sorption (Dahia and Malik, 2002). Nitrogen, phosphorus and potassium availability under mulch treatment increased in comparison with no mulched treatment (Kumar, 2014). Fertility status with respect to available N and P was dependent upon the amount of organic matter added in the soil where as status of K was mineral based. These findings are with the agreement of the results of Pande *et al*. (2005), Kamal *et al*. (2006) and Singh *et al*. (2008).

Yield: Influence of various mulches on fruit yield was found significant. The increase in yield was mainly attributed to increase in availability of soil organic matter and available nutrients in soils. The highest fruit yield was recorded with black polyethylene (1848 kg ha^{-1}) followed by farm yard manure, brankad and was least in without mulch. Yield with mulch by using maize straw, bajra straw and grasses were superior to control (no mulch). Similar results of increased yield due to mulch were reported in citrus and other crops (Neilsen *et al*. 2006; Singh *et al*., 2008; Kumar *et al*., 2015).

Fruit quality attributes: The fruit size (length and diameter), total soluble solids, reducing sugar, total sugar, ascorbic acid and the fruit acidity indicating no effecting of mulching was non significant among various treatment. The fruit weight (61.03 g) showed was observed in black polyethylene and lowest in control weight (45.78 g). The higher fruit weight was attributed to vigorous growth and developments of plants under black polythene mulches. Similar observations on higher fruits by mulching with black polythene have also been reported by Singh *et al*. (2008). The higher TSS (6.77 %) showed was observed in black polyethylene and lowest in control weight (4.49 %). Higher fruit TSS is related to weed free environment, higher moisture conservation and maximum nutrient uptake under black polythene mulch treatment. These results are in conformity with the findings of Singh *et al*. (2008) and Bakshi *et al*. (2015).

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Effect of Spacing and Fertilizers on Seed Quality of Okra [*Abelmoschus esculantus* (L.) Moench]

Vikash Kumar, S. K. Dhankhar, Chandanshive Aniket Vilas, Sunil Kumar and Neha Yadav

Department of Vegetable Science, CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: vikaskamboj7005@gmail.com

Abstract: Three spacing, three fertilizer levels and two varieties were used to observe the effect of spacing and fertilizer on seed quality of okra. The seed quality attributes were significantly affected by spacing, fertilizer and varieties. The maximum electrical conductivity, speed of germination, accelerated ageing test, field emergence, seedling establishment, tetrazolium test, seed density, dehydrogenase activity were achieved in variety Hisar Unnat at spacing of 30 x 15 cm with the fertilizer application of 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O ha^{-1}.

***Key Words*:** Accelerated ageing test, Seedling establishment, Standard germination, Tetrazolium test

Okra, *Abelmoschus esculantus* (L.) Moench, is one of the most important grown an area of 4.98 lack hectares with average production and productivity of 57.48 lakh tonnes and 11.75 t ha^{-1}, respectively. In Haryana, it occupies an area of 18,200 hectares with an average production and productivity of 1.54 lakh tonnes and 8.0 tonnes per hectare, respectively (Anonymous, 2014). Okra is grown in spring-summer (March-June) and rainy seasons (July-September) in tropical and subtropical regions of the country. Okra thrives best under hot and humid conditions. Hence, setting of fruits, seeds and their development is better in rainy season resulting in seed yield. However, in spring summer season, the prevailing temperature remains very high (>42°C) and low humidity (<50%) during spring summer season particularly in May-June leads to poor production of pollens, which affect the setting of seeds. So the seed yield is low in spring season crop than rainy season. However, incidence of yellow vein mosaic virus (50-90% depending on crop growth stage) and infestation of shoot and fruit borer are very high (>50%), which affect both seed yield and its quality drastically. So keeping this in view, the experiment was conducted to study the effect of spacing and fertilizers on seed yield and its quality.

The present study was carried out at CCS Haryana Agricultural University, Hisar during spring-summer season, 2013-14. Hisar is situated between 29°10´ N latitude and 15° 46´ E longitude at mean elevation of 215.2 meter above mean sea level, has a semi arid, sub-tropical climate, hot and dry winds during summer and dry severe cold in the winter are the common features of this region. The mean maximum and minimum temperature of 42° to 46°C is quite common during summer months (May-June). The rainfall is restricted mainly to the monsoon months from July to September, but sometime pre-monsoon showers occur in June also. The soil of the experimental field is derived from Indo-Gangentic alluvium, which is very deep and sandy loam in texture having pH varies from 7.8 to 8.9 since these soil are poor in organic carbon, available nitrogen, medium in phosphorus and rich in potash content.

The experiment with two varieties (Hisar Unnat and HBT-49-1), three spacing (30 x 5 cm, 30 x 10 cm and 30 x 15 cm) and three fertilizers levels (150 kg N + 60 kg P_2O_5, 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O and 225 kg N + 90 kg P_2O_5 + 60 kg K_2O) carried out in split-split block design with three replications. In each replication, there were 18 plots and each plot comprising of 3.6 m × 3 m size accommodating three rows having 2-3 seeds per hill were sown and later thinned to one plant per hill. Recommended package of practices for other operations were followed to raise a healthy crop (CCS Haryana Agricultural University package of practices 2013). The observations were recorded for seed quality on five competitive randomly selected plants. Seed quality parameter was measured according to the rules of International Seed Testing Association (ISTA, 1999). Accelerated aging test (%), electrical conductivity (dSm^{-1}), dehydrogenase activity were done as per standard method. The tetrazolium test (%) was performed after removal of seed coat were stained in 0.5% tetrazolium solution (2, 3, 5-triphenyl tetrazolium chloride) for 4 hrs. at 38°C and examined under magnifications. The number of seeds stained entirely red were considered as normal viable seeds and expressed in percentage.

Effect of spacing on seed quality: The spacing 30 x 15 cm and 30 x 10 cm were at par with each other in the term of speed of germination but significantly differ from spacing 30 x 5 centimeters. The seedling establishment was significantly more 30 x 15 cm as compared to 30 x 5 cm but spacing 30 x 10 cm did not vary from the 30 x 15 or 10 cm. The emergence was maximum in 30 x 15 cm at (75.94%) as compared to 30 x 10 and 30 x 5 cm but spacing 30 x 15 and 30 x 10 cm were at par with each other and significantly higher than 30 x 5 cm. The spacing of 30 x 15 cm produced significantly highest viable seed as compared to of 30 x 10 and 30 x 5 cm. Dehydrogenises activity was also showed the same trend. Electrical conductivity was significantly higher in spacing 30 x 15 cm as compare which were at par with each other. The seed density was also significantly higher in 30 x 15 cm as compare to spacing 30 x 10 cm and 30 x 5 cm. Rao *et al.* (2004) also reported that maximum seed density was observed in bold seeds harvested from lower nodes *i.e.*, 66.21 g (Kharif) and 69.30 g (summer). These results are also in conformity with the Sharma *et al.* (2012) and Dhankhar *et al*. (2012).

The **s**pacing of 30 x 15 cm produced significantly more viable seed as compared 30 x 10 cm and 30 x 5 cm. In case of accelerated ageing for 24 hrs, maximum was spacing 30 x 15 cm. But spacing 30 x 15 cm and 30 x 10 cm were at par with each other and significantly better than 30 x 5 cm. Accelerated ageing for 36 and 48 hrs was significantly higher in 30 x 15 cm as compare to spacing of 30 x 10 cm and 30 x 5 cm respectively. Accelerated ageing for 72 hrs was maximum in 30 x 15 cm. But spacing 30 x 15 cm and 30 x 10 cm were at par with each other and statistically higher than spacing 30 x 5 cm. The present results are similar to the findings of Sharma *et al.* (2012); Monirruzzaman and Quamruzzaman (2009).

Effect of fertilizers on seed quality: Application of fertilizer at the rate of 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O ha^{-1} resulted in higher speed of germination (27.16) as compared 225 kg N + 90 kg P_2O_5 + 60 kg K_2O (25.41) and 150 kg N + 60 kg P_2O_5 (22.09). The application of fertilizer with rate of 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O ha^{-1} resulted in significantly higher seedling establishment (69.55%) as compare to with rate of 225 kg N + 90 kg P_2O_5 + 60 kg K_2O and with rate of 150 kg N + 60 kg P_2O_5. The field emergence also showed same trend (75.35%) was maximum in 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O as compared to 225 kg N + 90 kg P_2O_5 + 60 kg K_2O and recommended dose of fertilizer. The highest values of tetrazolium test (84.77%) and

Table 1. Effect of spacing, fertilizers and varieties on seed quality parameters of okra

Treatments	Seed quality parameters				
Spacing	Speed of germination (%)	Seedling establishment (%)	Field emergence (%)	Tetrazolium test (%)	Seed density (g cc^{-1})
S1: 30 cm x 5	20.70	66.75	70.38	78.58	1.67
S2: 30 cm x 10	26.50	71.51	74.50	82.10	1.71
S3: 30 cm x 15	27.45	72.60	75.94	85.15	1.72
CD (p=0.05)	2.00	1.11	2.00	2.10	0.04
Fertilizer					
F1: 150 kg N + 60 kg P2O5 (RD)	22.09	64.73	70.78	79.12	1.66
F2: 187.5 kg N + 75 kg P2O5 + 60 kg K2O	27.16	69.55	75.35	84.77	1.73
F3: 225 kg N + 90 kg P2O5 + 60 kg K2O	25.41	67.56	74.67	81.94	1.71
CD (p=0.05)	2.23	0.99	1.61	2.39	0.06
Varieties					
V1: Hisar Unnat	26.50	69.25	76.79	83.95	1.72
V2: HBT-49-1	23.13	65.31	70.41	79.94	1.68
CD (p=0.05)	2.71	1.02	2.27	1.95	0.02

Table 2. Effect of spacing, fertilizers and varieties on seed quality parameters of okra

Treatments	Seed quality				
	Accelerated ageing for 24 hrs	Accelerated ageing for 36 hrs	Accelerated ageing for 48 hrs	Accelerated ageing for 72 hrs	Dehydrogenase activity (OD)
Spacing					
S_1: 30 cm x 5	76.30	67.30	53.34	40.54	1.64
S_2: 30 cm x 10	80.63	70.10	56.82	46.26	1.99
S_3: 30 cm x 15	81.50	71.50	59.90	48.22	2.11
CD (p=0.05)	1.50	1.10	2.80	4.85	0.07
Fertilizer					
F_1: 150 kg N + 60 kg P_2O_5 (RD)	77.30	63.50	46.85	33.43	1.66
F_2: 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O	81.35	74.20	60.12	48.11	2.06
F_3: 225 kg N + 90 kg P_2O_5 + 60 kg K_2O	79.31	68.80	52.93	44.42	2.04
CD (p=0.05)	1.20	2.1	1.19	4.20	0.18
Varieties					
V_1: Hisar Unnat	83.52	71.79	55.15	42.64	1.96
V_2: HBT-49-1	75.81	65.42	58.62	39.13	1.87
CD (p=0.05)	1.28	2.32	2.77	2.84	0.08

electrical conductivity (0.931 dSm^{-1}) was at 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O ha^{-1}, which was significantly higher than recommended and 225 kg N + 90 kg P_2O_5 + 60 kg K_2O ha^{-1}. The dehydrogenase activity (2.06 OD) and seed density (1.73 g cc^{-1}) of okra seeds also showed the same trend.

Application of fertilizer with rate of 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O ha^{-1} resulted in significantly higher accelerated ageing for 24, 36 and 48 hrs test value (81.35, 74.20 & 60.12, respectively) as compare to with rate of fertilizer application 225 kg N + 90 kg P_2O_5 + 60 kg K_2O (79.31, 68.80 & 52.93) and with rate of 150 kg N + 60 kg P_2O_5 (77.30, 63.50& 46.85, respectively).

The accelerated ageing for 24, 36 & 48 hrs test value was significantly higher with fertilizer application at the rate 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O ha^{-1} in comparison to 225 kg N + 90 kg P_2O_5 + 60 kg K_2O and 150 kg N + 60 kg P_2O_5 fertilizer application. The accelerated ageing for 72 hrs with fertilizer application of 187.5 kg N + 75 kg P_2O_5 + 60 kg K_2O ha^{-1} found higher (48.11) as compare to with fertilizer application of 225 kg N + 90 kg P_2O_5 + 60 kg K_2O (44.42) and 150 kg N + 60 kg P_2O_5 (33.43). The present result coincide with the finding of Sharma *et al.* (2012); Dhankhar *et al.* (2012).

Performance of varieties on seed quality parameters: The seed quality parameters like speed of germination (26.50), seedling establishment (69.25), field emergence (76.79), tetrazolium test is 5.02% were significantly higher in Hisar Unnat over HBT-49-1, seed density (1.72), accelerated ageing for 24, 36, 48, 72 hrs and value (83.52, 71.79, 55.15, 44.64) and dehydrogenises activity (1.96 OD) as compare to HBT-49-1 variety of okra. The results were in conformity with Iqbal *et al.* (2001).

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Effect of Protected Environment on Growth and Yield Performance of Bacterial Wilt Resistant Tomato (*Solanum lycopersicum* L .) Hybrids

Parveen Sharma, Akhilesh Singh, Pardeep Kumar, Neelam Bhardwaj and Shobha

Department of Vegetable Science & Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, India
E--mail: parveens012@gmail.com

Abstract: The study was conducted under modified naturally ventilated polyhouse conditions to evaluate the performance of sixteen hybrids of tomato to select promising hybrid combinations. Highly significant variation among the genotypes for all the characters (days to 50% flowering, days to first harvest, gross yield per plant, number of marketable fruits per plant, total number of fruits per plant, average fruit weight, plant height, intermodal length, marketable yield per plant) were observed. On the basis of mean performance, hybrid combinations 15-2(H/R) x Palam Pride, 15-2(H/R) x 16-B and BWR-5 x Palam Pride proved superior over environment for marketable yield and its component traits.

Key Words: Bacterial wilt, Hybrid, Protected environment, Tomato

Tomato is a warm season crop and requires a relatively long growing season and moderately high temperature (20-28^{0}C). It ensures that the optimum fruit setting is at night temperature and the optimum range is 10^{0}-12^{0}C) (Anonymous 2010). Recently, to overcome these environmental conditions and pesticide residue problem, protected cultivation of vegetables, particularly naturally ventilated polyhouse cultivation of tomato, cucumber and capsicum has been recommended. Protected cultivation of tomato offers distinct advantages of earliness, higher productivity and quality particularly pesticide free produce, besides higher returns to growers. The aim of protected cultivation is to achieve independence of climate and weather and to allow crop production in areas where the natural environment limits or prohibits plant growth.

Tomato plants are trained to two stem and tied up two string or wire by pruning out the lateral shoots and wrapping the stems around the string on wire hanging from an over head wire supported system. Polyhouse tomatoes are generally harvested with more colour than those from the field. Under protected environment the natural environment is modified to the suitable conditions for optimum plant growth which ultimately helps in the production of quality tomatoes suitable for exports and domestic consumption. It has been observed that polyhouse grown tomatoes have potential for better performance and produce higher fruit yield than open field conditions. Tomato can be grown successfully in the off-season in polyhouse for obtaining higher fruit yield. Occurrence of frost coupled with low temperature during the month of December and January cause death of tomato plant when grown in open field conditions, but under protected environment, the yield loss can be minimized. The following experiment was planned with the objective of evaluating bacterial wilt resistant hybrids of tomato in respect of yield and quality under protected conditions.

MATERIAL AND METHODS

The experiment was carried out at the experimental farm, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during 2012 and 2013 in randomized block design replicated thrice inside the modified naturally ventilated polyhouse of the size 25m x 10m. The experimental material used for the present study comprised of 15 diverse hybrids of tomato viz., (BWR-5(F/R) x CLN 1314G, BWR-5(F/R) x Palam Pride, BWR-5(F/R) x 16-B, CLN 1314G x Palam Pride, 1-2 x 16-B, 1-2 x BBWR-21-3-16, 12-1 x Palam Pride, 15-2(H/R) x Palam Pride, 15-2(H/R) x 16-B, 15-2(H/R) x Hawaii-7998, BL 333-1 x 16-B, Hawaii-7998 x Palam Pride, Hawaii-7998 x Palam Pink, BBWR-11-1 x BBWR-21-3-16, BBWR-21-3-16 x Palam Pride) developed at CSKHPKV, Palampur with one private sector hybrid (Avtar) as check.

Besides the application of vermicompost @ 5 t ha^{-1}, chemical fertilizers were applied as per adhoc recommendation of CSKHPKV for protected cultivation (50 kg each of N, P and K ha^{-1}) through straight fertilizers. Whole of the vermicompost and chemical fertilizers were applied in pits before transplanting. The fertigation was given twice a week by applying liquid fertilizer (19:19:19) @ 2.2 g m^{-2} of the effective area of polyhouse after third week of transplanting and was stopped 15 days before final harvest.

RESULTS AND DISCUSSION

Mean sum of square of all treatments were significant for all the characters in both environments. Mean sum of squares were found significant for all treatment because all genotypes are genetically different from each other and showed significant variation among each other (Table 1). Mean sum of squares of replication was not significant because among replication there is no significant difference within genotypes. Plant survival was 100 per cent in all of the genotypes in all the environments. No mortality was there, because all the parental lines used for hybrid combination were resistant to bacterial wilt.

Hybrid 15-2(H/R) x Palam Pride took significantly minimum days to 50 per cent flowering after transplanting followed by 15-2(H/R) x 16-B), BWR-5(F/R) x 16-B, BL 333-1 x 16-B and BBWR-21-3-16 x Palam Pride which were at par

Table 1. Mean performance of tomato hybrids in relation to different quantitative and quality traits in Environment I and II*

Genotypes	Days to 50 per cent flowering	Days to first harvest	Gross yield plant^{-1} (kg)	Number of marketable fruits plant^{-1}	Total no. of fruits plant^{-1}	Average fruit weight (g)	Plant height (cm)	Internodal length (cm)	Marketable yield plant^{-1} (kg)
BWR-5(F/R) x CLN 1314G	35.33	85.00	1.75	26.60	30.05	59.52	258.33	8.23	1.73
	(35.67)	(85.67)	(1.79)	(25.90)	(27.37)	(60.23)	(256.11)	(8.12)	(1.76)
BWR-5(F/R) x Palam Pride	34.67	81.00	2.15	35.44	38.18	64.98	288.33	7.77	2.07
	(33.67)	(79.00)	(2.12)	(35.62)	(36.70)	(64.59)	(288.26)	(7.69)	(2.10)
BWR-5(F/R) x 16-B	33.33	85.67	1.52	29.47	33.03	50.92	274.00	7.77	1.45
	(35.33)	(83.00)	(1.53)	(28.97)	(30.27)	(52.26)	(274.96)	(7.84)	(1.51)
CLN 1314G x Palam Pride	35.33	82.00	2.05	32.87	35.65	63.73	275.67	7.87	2.02
	(34.33)	(82.67)	(2.13)	(33.25)	(35.08)	(62.50)	(276.40)	(7.77)	(1.90)
1-2 x 16-B	35.00	81.67	2.02	33.92	37.18	64.20	278.00	7.83	1.99
	(34.00)	(80.67)	(2.09)	(33.72)	(35.27)	(62.82)	(279.21)	(7.75)	(1.95)
1-2 x BBWR-21-3-16	33.67	84.33	1.88	32.18	34.98	57.72	200.29	7.88	1.85
	(35.00)	(84.33)	(1.84)	(32.76)	(34.07)	(58.32)	201.62	(7.86)	(1.83)
12-1 x Palam Pride	37.67	86.00	1.74	27.93	30.92	61.21)	213.67	7.93	1.71
	(37.33)	(86.33)	(1.75)	(29.37)	(31.04)	(62.87)	216.77	(7.78)	(1.73)
15-2(H/R) x Palam Pride	30.67	76.67	2.29	40.06	43.91	60.41	309.00	7.36	2.26
	(31.33)	(77.67)	(2.25)	(38.85)	(40.54)	(60.63)	311.13	(7.63)	(2.23)
15-2(H/R) x 16-B	33.00	78.00	2.22	37.61	40.81	67.17	303.00	7.73	2.16
	(32.65)	(78.67)	(2.24)	(38.27)	(38.34)	(66.77)	302.91	(7.66)	(2.22)
15-2(H/R) x Hawaii-7998	36.00	85.67	1.69	28.20	31.70	61.74	268.48	8.35	1.66
	(36.33)	(80.67)	(2.09)	(28.83)	(29.89)	(61.72)	267.81	(8.18)	(1.84)
BL 333-1 x 16-B	33.33	86.00	1.85	26.80	29.67	59.05	229.00	7.97	1.83
	(35.33)	(83.00)	(1.81)	(27.10)	(28.46)	(67.91)	230.99	(7.86)	(1.80)
Hawaii-7998 x Palam Pride	36.00	84.67	1.78	28.07	30.94	57.00	236.00	8.14	1.69
	(35.67)	(84.00)	(1.70)	(28.64)	(30.33)	(55.98)	236.89	(7.86)	(1.69)
Hawaii-7998 x Palam Pink	37.00	81.00	1.88	29.84	33.53	59.15	215.67	8.37	1.84
	(34.33)	(87.00)	(2.04)	(29.53)	(31.36)	(57.90)	216.05	(8.26)	(1.89)
BBWR-11-1 x BBWR-21-3-16	35.67	87.33	1.81	32.67	34.90	62.61	258.00	8.07	1.77
	(34.67)	(86.33)	(1.76)	(32.70)	(33.94)	(61.47)	259.13	(8.14)	(1.74)
BBWR-21-3-16 x Palam Pride	33.33	87.00	1.70	26.33	29.86	59.52	255.84	8.67	1.69
	(37.33)	(86.67)	(1.65)	(26.65)	(28.68)	(59.15)	255.27	(8.52)	(1.65)
Avtar	36.33	89.67	1.72	26.60	31.77	59.43	200.29	7.36	1.45
	(35.97)	(88.00)	(1.68)	(26.43)	(27.50)	(59.10)	(201.62)	(7.63)	(1.51)
CD (p=0.05)	0.95	0.93	0.09	0.71	0.70	2.01	3.20	6.63	8.55
	(0.87)	(0.84)	(0.08)	(1.09)	(1.19)	(2.01)	(3.11)	(6.09)	(7.68)

Note: Plant survival = 100%; *Environment II in parentheses

Table 2. Pooled over mean performance of tomato hybrids in relation to different quantitative traits

Genotypes	Days to 50 per cent flowering	Days to first harvest	Gross yield plant^{-1} (kg)	Number of marketable fruits plant^{-1}	Total no. of fruits plant^{-1}	Average fruit weight (g)	Plant height (cm)	Internodal length (cm)	Marketable yield plant^{-1} (kg)
BWR-5(F/R) x CLN 1314G	35.50	85.33	1.77	26.25	28.71	59.88	257.22	8.18	1.75
BWR-5(F/R) x Palam Pride	34.17	80.00	2.13	35.53	37.44	64.79	288.30	7.73	2.09
BWR-5(F/R) x 16-B	34.33	84.33	1.53	29.22	31.65	51.59	274.48	7.80	1.48
CLN 1314G x Palam Pride	34.83	82.33	2.09	33.06	35.37	63.12	276.03	7.82	1.96
1-2 x 16-B	34.50	81.17	2.06	33.82	36.23	63.51	278.61	7.79	1.97
1-2 x BBWR-21-3-16	34.33	84.33	1.86	32.47	34.52	58.02	200.96	7.87	1.84
12-1 x Palam Pride	37.50	86.17	1.74	28.65	30.98	62.04	215.22	7.85	1.72
15-2(H/R) x Palam Pride	31.00	77.17	2.27	39.46	42.22	60.52	310.06	7.50	2.25
15-2(H/R) x 16-B	32.83	78.33	2.23	37.94	39.58	66.97	302.96	7.70	2.19
15-2(H/R) x Hawaii-7998	36.17	83.17	1.89	28.52	30.80	61.73	268.14	8.27	1.75
BL 333-1 x 16-B	34.33	84.50	1.83	26.95	29.07	63.48	230.00	7.91	1.82
Hawaii-7998 x Palam Pride	35.83	84.33	1.74	28.35	30.63	56.49	236.45	8.00	1.69
Hawaii-7998 x Palam Pink	35.67	84.00	1.96	29.69	32.44	58.53	215.86	8.32	1.87
BBWR-11-1 x BBWR-21-3-16	35.17	86.83	1.78	32.69	34.42	62.04	258.56	8.11	1.76
BBWR-21-3-16 x Palam Pride	35.33	86.83	1.68	26.49	29.27	59.34	255.55	8.60	1.67
							214.62	8.16	1.68
Avtar	36.00	88.83	1.70	26.51	29.64	59.26	200.96	7.49-8.59	1.48-2.25
CD (p=0.05)	1.91	2.18	0.06	1.69	0.67	3.90	2.31	5.76	7.52

Note: Plant survival = 100%

with each other (Table 1). However, in Environment II also 15-2(H/R) x Palam Pride took significantly less days to 50 per cent flowering followed by 15-2(H/R) x 16-B and BWR-5(F/R) x Palam Pride), which were at par with each other. Over environments data also revealed that hybrid 15-2(H/R) x Palam Pride took significantly less days to 50% flowering. Kaushik *et al.* (2011) and Mohamed *et al.* (2012) have also reported significant difference among the genotypes for Days to 50 per cent flowering.

In both as well as pooled over environments hybrid 15-2(H/R) x Palam Pride took minimum days to first harvest followed by 15-2(H/R) x 16-B and were at par with each other while maximum days were taken by the check hybrid Avtar. In the present study the hybrid combination 15-2(H/R) x 16-B was early as compared to the other entries. Thamburaj (2008) also observed genetic difference among genotypes for days to first harvest.

In Environment I, hybrid 15-2 (H/R) x Palam Pride produced significantly highest marketable yield per plant followed by 15-2(H/R) x 16-B, BWR-5(F/R) x Palam Pride and CLN 1314G x Palam Pride and were at par with each other. In case of Environment II 15-2 (H/R) x Palam Pride had significantly highest marketable yield followed by 15-2 (H/R) x 16-B and BWR-5(F/R) x Palam Pride and were also at par with each other. Over the environments, same results were obtained like Environment II, in which 15-2 (H/R) x Palam Pride showed significantly highest marketable yield. The higher yield in these cultivars might be due to the cumulative effects of higher flowers/inflorescence, higher fruit set and the cultivars which have inherent capacity to show resistance to bacterial wilt. Dar and Sharma (2011), Kaushik *et al.* (2011), Tasisa *et al.* (2011) and Dar *et al.* (2012) have also reported significant variation among genotypes for marketable fruit yield per plant. The marketable yield as well as gross yield plant^{-1} was almost similar because diseases as well as pest incidence were less under the protected condition.

In both the environments, hybrid 15-2 (H/R) x Palam Pride produced significantly maximum number of marketable fruits per plant followed by 15-2(H/R) x 16-B and 15-2(H/R) x 16-B, which were at par with each other (Table 1 and 2). Over environments, similar results were obtained in which hybrid 15-2 (H/R) x Palam Pride produced significantly maximum number of marketable fruits per plant. Maximum number of fruits plant^{-1} is due to indeterminate growth habit of the combination. Ara *et al.* (2009) have observed wide variation for total number of fruits per plant.

Significantly maximum average fruit weight was recorded in hybrid 15-2(H/R) x 16-B in Environment I followed by BWR-5(F/R) x Palam Pride, 1-2 x 16-B, CLN 1314G x Palam Pride, BBWR-11-1 x BBWR-21-3-16 and 15-2(H/R) x Hawaii-7998, which were at par with each other. In

Environment II, hybrid BL 333-1 x 16-B had significant maximum fruit weight followed by 15-2(H/R) x 16-B, BWR-5 (F/R) x Palam Pride, 12-1 x Palam Pride, 1-2 x 16-B and CLN 1314G x Palam Pride which were at par with each other. Over environments hybrid 15-2(H/R) x 16-B had significantly highest fruit weight followed by BWR-5(F/R) x Palam Pride, 1-2 x 16-B, BL 333-1 x 16-B and CLN 1314G x Palam Pride, which were at par with each other. Average fruit weight is the major component of quality in the greenhouse tomatoes and the normal average fruit weight of tomatoes is 80 to 120 g. In general, bacterial wilt resistant genotypes are less in fruit weight. Islam *et al.* (2012) also reported significant differences in genotypes for average fruit weight.

Hybrid 15-2(H/R) x Palam Pride had significantly minimum internodal length over as well as in both environments followed by 15 (H/R) x 16-B and BWR-5 (F/R) x Palam Pride. Variation in internodal length is due to the growth habit of the tomato plant. Maximum plant height was recorded in 15-2(H/R) x Palam Pride in all environments. Minimum plant height over environments was recorded for hybrid 1-2 x BBWR-21-3-16. The variation in the plant height among the hybrids might be due to their semi-determinate and indeterminate growth habit.

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Impact of Changing Rainfall Trend on Yield of Mango and Sweet Orange in Marathwada Region

P. R. Jaybhaye, S. D. Gawali, V. K. Mohite, P. B. Shinde and B. V. Asewar

Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani-431 402, India
E-mail: agmetprj@gmail.com

Abstract: The daily rainfall data 30 years (1981-2010) of seven districts of Marathwada region (Maharashtra) was used for analysis revealed that the district to district rainfall varied from 100.0 mm to 231.0 mm and regional annual trend of rainfall also increased (0.59 mm yr^{-1}) . The trend for rainy day was found decreasing (-0.87 R.D. yr^{-1}). Annual variation of rainfall (i.e. quantity) and rainy days (quality of rainfall) and trend was affected plantations, productivity and production of mango and citrus in the Marathwada region.

Key Words: Annual rainfall, Citrus species, Linear trend, Mango, Variability

Weather and climate are the most important input for the agriculture production. Agricultural enterprises under rainfed farming system are mainly dependent on monsoon rainfall and the vagaries of monsoon however, keep the profitability always at stake. Past historical data indicate that the variability of monsoon is almost regularly experienced in India (Karmakar *et al*., 2008; Sahu *et al*., 2010). It decreases remarkably from the East to West. Main stream of monsoon yielding rain in major part of India is from South West monsoon followed by North East monsoon, oscillating during the year.

The climate change and its impacts on agricultural sector is considered across the globe. Indian agriculture is facing challenges due to several factors such as increased competition for land, water and labour from non-agricultural sector and increasing climatic variability. The latter associated with global warming will result in considerable seasonal/annual fluctuations in fruit production. All Agricultural commodities even today are sensitive's to such variability. Drought, floods, tropical cyclones, heavy precipitation event, hot extremes and heat waves are known to have negative impact on agricultural production and farmer's livelihood. Hence, a study was conducted to record the impact of changing rainfall trend on yield of mango and sweet orange in Marathwada Region.

MATERIAL AND METHODS

The study is based on 30 year annual rainfall data for seven districts in Marathwada region. The data was collected from the different agromet observatories present at different centers which comes under Vasantrao Naik Marathwada Krishi Vidyapeeth, (VNMKV) Parbhani and Forecasting Agricultural Output Using Space Agrometeorology and Land Based Observation (FASAL) unit of Parbhani. The collected data of each district were summed up annually. The year was partitioned as per meteorological calendar, starting from 1st January of each year and ending on 31st December of the same year.

The data collected for each district of Marathwada region [Aurangabad division - (Aurangabad, Jalana and Beed) and Latur division (Parbhani, Hingoli, Nanded, Latur and Osmanabad)] were subjected to statistical analysis for recording the significance of observations.

RESULTS AND DISCUSSION

Rainfall Characterization: The data indicated that the lowest and highest annual mean rainfall was found in Aurangabad 613.1 mm (2008) and 1159.0 mm (2006), Parbhani 641.8 mm (2008) and 1463.0 mm (1988), Nanded 576.1 mm (1998) and 1193.6 mm (1960), Osmanabad 546.8 mm (1994) and 918.6 mm (2000), Jalna 645.8 mm (2001) and 1002.2 mm (1994), Latur 505.8 mm (2001) and 1195.1 mm (1990), Beed 560.2 mm (1982) and 1180.1 mm (1988). Whereas, the normal rainfall for the each district were worked out (Table 1) and it shows that the highest normal rainfall was received in Parbhani district (925.8 mm) and lowest rainfall in

Table 1. District wise mean annual rainfall (mm) of Marathwada region (Database 1981-2010)

Year	Aurangabad	Parbhani	Nanded	Osmanabad	Jalna	Latur	Beed	Marathwada
Mean	806.8	925.8	912.1	732.0	825.0	831.6	785.2	831.2
SD	144.7	231.0	200.5	105.4	100.0	179.3	157.5	89.20
CV	17.9	25.0	22.0	14.4	12.1	21.6	20.1	10.73

Osmanabad (732.0 mm).

Intra annual variation of annual mean rainfall was observed 10.73 per cent with annual mean rainfall for (normal) Marathwada region (831.2 mm). Intra district annual mean rainfall i.e. normal's for each district were observed in Aurangabad (806.8 mm), Beed (785.5 mm), Jalna (825.0 mm), Latur (831.6 mm), Nanded (912.1 mm), Osmanabad (732.0 mm) and Parbhani (925.8 mm). While, lowest normal rainfall was observed in Osmanabad (732.0 mm) and highest in Parbhani (925.8 mm). It means that intra district variation of normal rainfall is high and most affecting factor on rainfed as well as dryland agriculture. While, the variation in the year to year annual mean rainfall was ranged between 12.1 per cent (Jalna) to 25.0 per cent (Parbhani) with the annual degree of variation in quantum of rainfall are 100.0 mm (Parbhani) to 231.0 mm (Jalna). The variation more than 100 mm rainfall plays a vital role in reproductive growth and development of crop and finally it reflected into yield of fruit crops.

Rainfall trend: The study revealed that increasing trend (0.59 mm yr^{-1}) of annual rainfall in the Marathwada region was observed and similar trend was seen within the some districts of Marathwada region (Fig.1 and 2). The decreasing trend within the district was observed in Aurangabad (-1.3 mm yr^{-1}), Parbhani (-0.2 yr^{-1}), Latur (-1.6 mm yr^{-1}), Beed (-1.2 mm yr^{-1}) and increasing trend was observed in Nanded (+2.4 mm yr^{-1}), Osmanabad (+2.8 mm yr^{-1}), Jalna (+3.4 mm yr^{-1}). The monsoon rainfall has increased in most of the districts of Madhya Maharashtra and for only three districts of Kokan region, while for the two districts each of Marathwada and Vidarbha rainfall has decreased significantly. Annually monsoon rainfall was significantly decreased (-3.23 mm yr^{-1}) in Latur district only.

However, the changing rainfall trends ranged between -1.6 to + 3.4 (Fig. 2). Though, the trend is seen statistically significant but it may be non-significant for agriculture. The data on rainy days showed that the number of rainy days (i.e. distribution of rainfall) was not uniform year over the years. While, the trend of rainydays showed decreasing pattern (Fig. 3). The decreasing rainy days and no change in rainfall or increasing rainfall means increasing heavy rainfall events it is very disastrous to agricultural community. Specially, the rainfall (unseasonal rainfall) during bahar treatment causes negative effect and it distructs the bahar treatment, which enhances the vegetative growth rather than the reproductive growth (i.e. flower bud or fruit bud initiation, blooming, etc.).

More variation in production (i.e. yield) than the productivity may be due to increasing or decreasing area under cultivation as well as rainfall quantity and its distribution (quality). While, the year to year variation in productivity was observed because of short term weather calamities *viz.,* unseasonal rainfall during productive growth stages (i.e. bahar stage). Productivity was found lower when rainfall was received less and more when rainfall received more (Fig. 2). However, some variations may be because of uneven distribution of rainfall and other uncongenial weather elements. On the similar line evidences were recorded and it was noted that overcast conditions and mild rains in some post of Central and South Gujarat in the last two years affected the mango crop adversely (Anonymous, 2010). Erratic rainfall has been hurting the production of mango up to 50 per cent in Navsari (Gujarat) (Anonymous, 2012). However, sometimes weather calamities showed severe impact on fruit plantation. The damage to fruit plantation due to cold was so severe then many farmers uprooted their well established mango trees in Punjab, Haryana, Himachal Pradesh and Bihar (Parsai, 2004).

The productivity of the mango and sweet orange not only depends on the annual mean weather condition but also depends on seasonal and weekly weather condition. It is

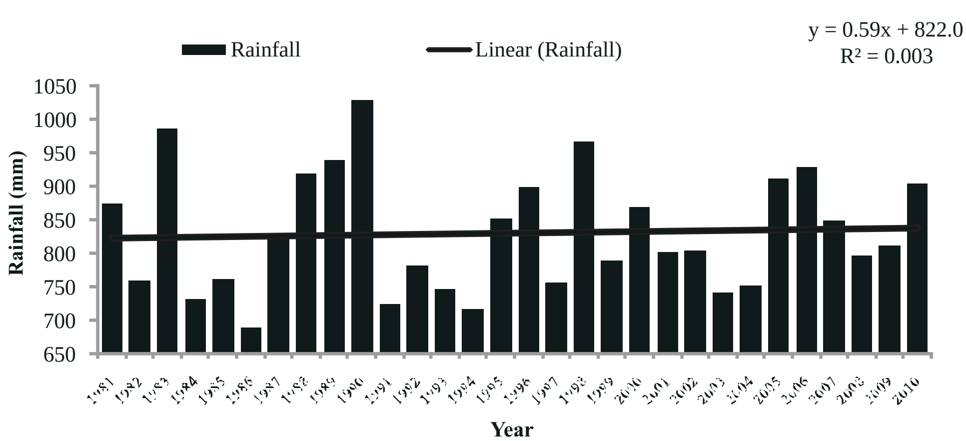

Fig. 1. Annual mean rainfall and rainfall trend of Marathwada region

Table 2. Rainfall and Rainy days observed during the crop growth period and area, production and productivity of mango and sweet orange crop in Marathwada region during 1995-2010

Marathwada								
	Mango			Sweet Orange			Weather Parameters	
Year	Area ('000'ha.)	Production ('000'MT)	Productivity (Production ha^{-1})	Area ('00'ha.)	Production ('000'MT)	Productivity (Production t ha^{-1})	Rainfall (cm)	Rainy days
1994-95	3.20	13.46	4.50	7.34	4.60	8.70	71.73	47
1995-96	3.31	15.85	5.00	12.71	5.38	8.60	85.23	52
1996-97	3.89	20.29	5.10	14.99	6.22	8.40	89.88	50
1997-98	3.63	17.53	5.20	15.45	6.65	8.30	75.84	46
1998-99	3.64	19.39	5.30	17.83	6.00	10.10	96.64	53
1999-00	3.69	19.82	5.10	15.38	6.09	9.20	78.96	48
2000-01	3.77	19.79	5.20	17.67	6.43	8.80	87.10	47
2001-02	3.83	16.04	4.50	18.20	5.16	9.00	80.23	44
2002-03	3.92	17.50	4.80	20.30	5.26	8.70	80.46	44
2003-04	4.12	18.98	5.00	19.14	5.39	8.60	74.15	48
2004-05	4.74	23.43	5.10	19.70	7.23	9.30	75.28	44
2005-06	6.37	29.66	4.60	20.65	8.17	9.30	91.31	52
2006-07	6.95	34.79	4.80	22.31	8.89	9.50	93.01	47
2007-08	7.91	37.26	5.20	24.22	9.16	9.50	85.04	48
2008-09	7.14	32.52	5.30	24.28	8.22	10.00	79.79	42
2009-10	7.62	34.50	5.60	28.14	9.04	9.70	81.34	47
Mean	4.86	23.17	5.02	18.64	6.74	9.11	82.87	47
SD	1.69	7.82	0.31	4.99	1.52	0.56	6.84	4.80
CV(%)	34.80	33.74	6.14	26.77	22.50	6.10	8.13	4.22

Table 3. Year wise initiation and withdrawal of monsoon, deficiency in rainfall during the year in percentage

Year	Date of monsoon Initiation	Date of monsoon withdrawal	Deficit R.F. (%)
2005	18 – 19 June	7 Oct.	--
2006	28 May – 1 June	9 Oct.	--
2007	15 – 18 June	8 Oct.	(-12%)
2008	7 – 9 June	12-13 Oct.	--
2009	7 – 23 June	12 Oct.	(- 29%)
2010	10 – 15 June	26 Oct.	--

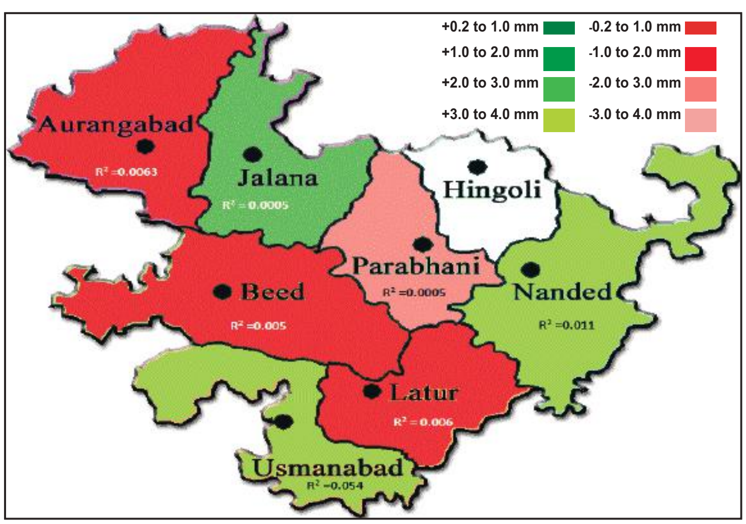

Fig.2. District wise annual mean rainfall trend of Marathwada region (1981-20101)

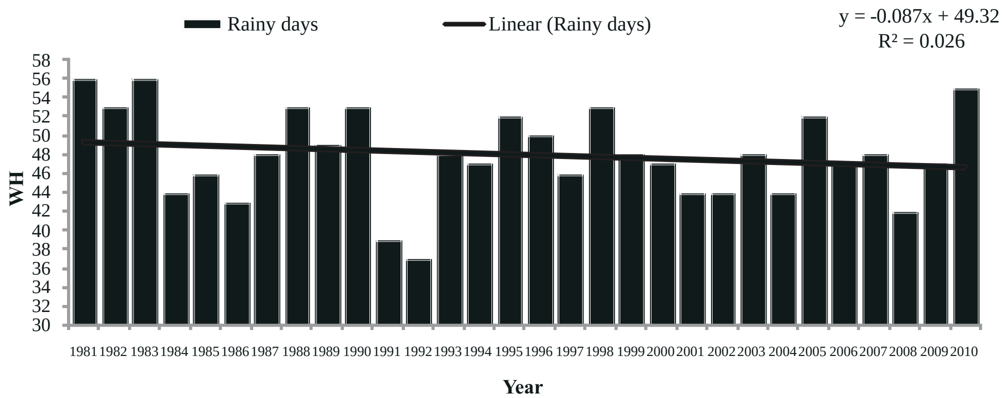

Fig. 3. Annual mean rainy days and trend of Marathwada region

understood that the most important weather parameter affected productivity of mango and sweet orange was due to rainfall in terms of quantum and distribution (Table 2 and 3). It is clearly understood from uneven deficit rainfall was received in Marathwada (-23, -27, -12 and -29) during the 2003, 2004, 2007 and 2009, respectively. It is also in accordance with monsoon initiation and withdrawal dates during the drought year and crucial year (Table 3).

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Effect of Bunch Management Practices on Yield and Quality in Nendran Banana

Sheeba Rebecca Isaac and Linitha Nair

Farming Systems Research Station, Sadanandapuram, Kottarakkara, Kollam-691 531, India
Kerala Agricultural University, Thrissur-680 656, India
E-mail: sheebarebecca@yahoo.co.in

Abstract: The field experiment to evaluate the effect of bunch management practices, potassium sulphate spray and covering of the bunches after bract removal, on the yield and quality in Nendran banana revealed significant variations with the concentrations used and covering practice adopted. Highest yields (9.73 kg plant^{-1}and 21.41 tha^{-1}) were recorded with 3 % spray of potassium sulphate. Yield attributing characters recorded positive correlations with bunch yields. Quality assessment in terms of total soluble sugars also recorded maximum value of 24.6 % with the 3 % spray. However, spraying on bunches without covering did not have any stimulating effect at higher concentrations and the lowest concentration of 1.5 % spray proved to the best. Benefit cost ratios were maximum at 3% spray with covering (2.44) followed by 1.5% spray without covering (2.29).

Key Words: Banana, Covering, Potassium sulphate, Quality, Yield

Banana is one of the most remunerative fruit crop in Kerala and among the different groups, Nendran banana is the most popular. The crop is reported to be a heavy feeder of nutrients (Gogoi *et al*., 2004) and nutrient management practices assume significant importance in the production technology of banana. Inadequate nutrients or non-availability just prior to the shooting stage, that normally occurs five months after planting, under the current package of practices recommendation, leads to poor filling and development of the bunches and fingers. It is interpreted that at this growth stage large quantities of photosynthates begin to move from the source to the sink, the developing fruit bunches (Kumar and Kumar, 2007). Any limitation in the supply of nutrients will affect bunch size and quality negatively. However, application of fertilizers basally at finger development stage is not advisable, as the uptake would be slow and low (Buragohain and Shanmugavelu, 1986). Ganeshamurthy *et al.* (2011) have reported that among the major nutrients, potassium has significant role in improving not only the yield but also the quality and hence is often referred to as the *quality element* for crop production. In banana, bunch is the most drastically affected part with potassium deficiency and hence adequate supply of the nutrient is crucial in its cultivation. Integrated nutrient management practices are widely adopted, but the increasing awareness on the role of potassium in improving yields has encouraged the application of potassium at later stages and on bunches. This requires a scientific recommendation and hence a field trial was initiated to assess the potential impact of potassium foliar spray and bunch covering in Nendran banana so as to standardize a recommendation for higher yields and returns.

MATERIALS AND METHODS

The field experiment was conducted in the research station farm at Sadanandapuram under Kerala Agricultural University during March-December 2013. The initial soil analysis revealed values for the chemical parameters as follows: pH- 5.1, electrical conductivity - 0.03 mmhoscm^{-1}, organic carbon - 1.5 %, available P - 50.4 kg ha^{-1} and available K- 275.0 kg ha^{-1}. Nendran banana suckers were planted at 2 m x 2m spacing and crop was managed with the NPK recommended dose of 190:115:300g NPK plant^{-1} (KAU, 2011). The treatments of potassium sulphate spray and bunch covering were imposed after bunch emergence and removal of bracts. The ten treatments were replicated in five plants as 1.5% potassium sulphate spray without bunch covering, 2% potassium sulphate spray without bunch covering, 2.5% potassium sulphate spray without bunch covering, 3% potassium sulphate spray without bunch covering, no spray, 1.5% potassium sulphate spray with bunch covering, 2% potassium sulphate spray with bunch covering, 2.5% potassium sulphate spray with bunch covering, 3 % potassium sulphate spray with bunch covering and bunch covering alone. Potassium sulphate sprays were done twice, first after opening of the last hand and removal of bracts (denavelling), and second, 15 days after the first spray. Bunch covering was done with gunny bags after spray and retained until harvest. Observations on plant height, number of leaves, bunch yield and finger characters were recorded at harvest. The fruits were kept for ripening to record the changes in appearance on storage and to assess the fruit peel- pulp weight ratios and total soluble sugar contents. The latter was done using hand refractometer and the results were expressed in percentage. Economic gains/ losses with potassium sulphate sprays and covering were also computed.

RESULTS AND DISCUSSION

The data recorded at harvest on the plant height and pseudostem girth of the plants revealed non-significant variations while the number of leaves varied significantly. Higher values were recorded in the plants with 1.5 per cent spray without bunch covering, followed by 3.0 and 1.5 per cent spraying with covering. The number of fingers per hand and number of hands per bunch showed significant variations but all these variations cannot be attributed to potassium sulphate sprays as the sprays were given only after bract removal. The number of hands and fingers would have been differentiated by this time. However, the enlargement and growth of the fingers were affected by the sprays and concentrations.

Yield: Yield in banana is a function of bunch weight and number of plants per hectare. Hence, any nutrient management study should aim at producing maximum bunch weight, so that, the productivity could be enhanced reasonably. In the present study, application of potassium sulphate exerted positive influence on bunch yield. The highest yield was obtained with 3 per cent spray with covering (9.73 kg) and was significantly superior to all other treatments (Table 2). This was followed by 1.5 per cent spray given without bunch covering (8.77 kg). Per hectare yields were significantly highest in T9 (21.41tha^{-1}) and least in T8 (15.40 tha^{-1})

The yield attributing characters, finger length, girth and weight (Table 2) also recorded higher values for the treatments T9 and T1. Maximum fruit weight (224.7g) was in the 3% spray + covering and this was 25 per cent more than the control in which no chemical spray was given. Ripened fruit weights also showed similar trends. It is interpreted that

Table 1. Growth and bunch characters of Nendran banana at harvest

Treatments K_2SO_4	Plant height (m)	No. of leaves at harvest	Pseudostem girth (cm)	No. of hands bunch^{-1}	No. of fingers hand^{-1}
T1 - 1.5%	3.17	7.3	38.50	4.67	8.33
T2 - 2.0 %	2.93	6.3	38.53	4.33	7.90
T3 - 2.5 %	2.97	6.3	37.83	4.67	8.40
T4 - 3.0 %	3.10	6.7	40.27	3.33	8.08
T5 - no spray (control)	2.90	6.7	38.13	4.67	8.82
T6 - 1.5% + covering	3.24	7.0	43.97	4.33	7.48
T7 - 2.0% + covering	3.02	6.0	39.20	4.33	8.15
T8 - 2.5% + covering	3.40	6.3	38.07	4.33	7.80
T9 - 3.0% + covering	3.23	7.0	38.27	4.67	9.80
T10 - covering alone	3.00	6.3	37.87	4.33	8.08
CD (p=0.05)	-	-	-	NS	1.12

Table 2. Effect of K_2SO_4 spraying and bunch covering on banana yield and fruit quality

Treatments K_2SO_4	Bunch weight (kg plant^{-1})	Bunch yield (t ha^{-1})	Finger length (cm)	Finger girth (cm)	Fruit weight (g)	Ripened fruit weight (g)	Peel: pulp ratio	TSS %
T1 - 1.5%	8.77	19.29	23.700	13.71	193.5	172.16	2.00	21.50
T2 - 2.0 %	7.57	16.65	24.37	13.60	191.6	173.50	2.17	19.90
T3 - 2.5 %	7.13	15.69	21.4	12.72	180.8	164.66	2.87	21.00
T4 - 3.0 %	8.07	17.75	21.33	15.30	186.0	167.16	2.73	20.33
T5 - no spray (control)	7.67	16.87	20.19	13.69	179.7	162.63	2.67	19.40
T6 - 1.5% + covering	7.17	15.77	20.9	13.50	181.8	165.50	2.47	21.97
T7 - 2.0% + covering	7.90	17.38	20.95	13.99	186.7	169.83	2.43	20.87
T8 - 2.5% + covering	7.00	15.40	20.76	13.31	177.8	162.00	1.90	18.60
T9 - 3.0% + covering	9.73	21.41	24.99	14.60	224.7	204.83	1.87	24.67
T10 - covering alone	7.62	16.76	20.14	12.65	179.3	160.96	2.27	20.40
CD (p=0.05)	1.21	2.65	3.27	NS	13.201	13.47	0.368	2.32

potassium being the key element in promoting translocation, would have encouraged filling and bulking of the fingers. Inclusion of sulphur would have favourably influenced photosynthesis and fruit yields. Peel to pulp ratios were comparatively higher for potassium sulphate spray treatments without bunch covering at 2.5 and 3 per cent concentrations. Kumar and Kumar (2008) have recommended integration of sulphate of potash in nutrition of banana for higher bunch weights.

The bunch yields in the non -treated plants were significantly lower than 3 per cent spray, but comparatively higher than 2.5 per cent sprays despite lower values for finger girth, length and weights. Perusal of the data revealed that the number of hands bunch^{-1} and fingers hand^{-1} recorded were higher in the selected plants and this would have contributed to the higher yields in these treatments. The beneficial effect normally stated for covering bunches after bract removal was not observed in the present study. Correlations of the yield attributes to the bunch yields over all treatments indicate positive values of 0.88 in fruit weight, 0.66 in fruit length and 0.57 in fruit girth.

Quality: The days to edible ripening varied significantly with the treatments (Table.3) and were fewer in sprayed fruits (2.0 to 3.7 days), while the non sprayed fruits took 4 to 4.7 days for ripening. In the non covered bunches, potassium sulphate sprays induced darkening of the peel earlier, black discoloration and softening of tissues were more in the 3 per cent sprayed fruits proving that shelf life was better at lower concentrations. Nevertheless, in the covered bunches, least damage was observed on the 3 and 2.5 per cent sprayed fruits. Total soluble sugar (TSS) contents recorded also illustrate the quality enhancement possible with 3 per cent spray along with covering practice in banana. Kumar and Kumar (2008) had earlier reported that foliar SOP sprays were effective in enhancing quality parameters such as TSS, reducing, non-reducing and total sugars and acidity. Varied effects of bagging bunches have been documented (Kutinyu *et al*., 2014) in which, although no significant effect on fruit parameters including yield was recorded, the fruit defects were considerably reduced with the bagging.

Economic analysis: The economics of banana cultivation with potassium sulphate spraying and bunch covering were computed based on input cost, labour charges and market prices of banana and are presented in Fig.1. The additional

Table 3. Physical changes of fruits observed on storage after five days

Treatments	Days to edible ripening stage	Changes observed		% damage
		Fruits	Peel	
T1 - 1.5%	2.3	Very soft	Slight black colouration	15
T2 - 2.0 %	3.3	Slightly soft	Slight black colour	12
T3 - 2.5 %	4.0	Soft	No black spots	5
T4 - 3.0 %	3.0	Very soft	Fully black colour	75
T5 - no spray (control)	4.7	Slightly soft	Slight discolouration	25
T6 - 1.5% + covering	3.3	Slightly soft	Slight discolouration	5
T7 - 2.0% + covering	3.7	Soft	Black spots	30
T8 - 2.5% + covering	3.3	Intact	No discolouration	Nil
T9 - 3.0% + covering	2.0	Intact	No discolouration	Nil
T10 - covering alone	4.0	Soft	Black spots	50
CD (p=0.05)	0.80	-	-	-

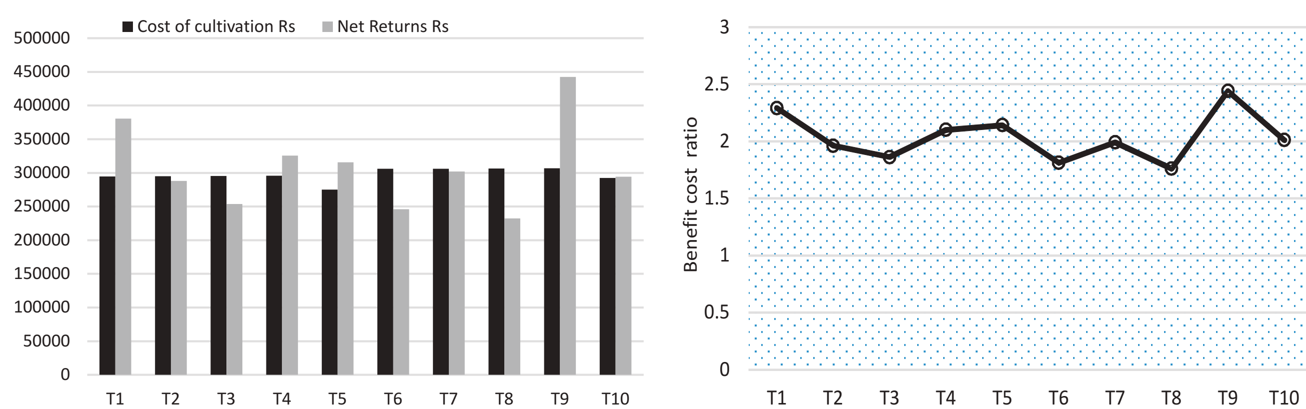

Fig.1. Economics of Nendran banana cultivation with K_2SO_4 sprays and covering

costs incurred for the spraying and/covering were 10.4 % (spray + covering) to 7 % (spray alone) of the total costs and were compensated by the increased yields when done at 3 per cent concentration. The benefit cost ratios were 2.44 and 2.29 in the 3 and 1.5 per cent sprays, respectively. The non-monetary benefits include increased TSS values and earlier ripening in the sprayed bunches.

The study has brought to light the significance of potassium sulphate spray on bunches at 3 per cent concentration combined with covering of the bunches with gunny bags. Economic analysis revealed that the spray and covering though warranted additional input cost and labour, economic gains was 14 per cent more, which would definitely be of great importance to the banana cultivators. The results clearly indicated the benefit of potassium sulphate in increasing the bunch size with better quality fruits, and hence it is recommended to integrate potassium sulphate application at 3 per cent concentration twice, at fifteen days interval and covered with gunny bags after spray until harvest in the nutrient package for Nendran banana.

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Sprouting Behaviour of Different Sizes and Cultivars of Potato Under Room Temperature Storage

Archana Brar and M. K. Rana

Department of Vegetable Science, CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: brararchanaarch@gmail.com

Abstract: The storability and sprouting behavior of three grades (small, medium and large tubers) from four Indian potato cultivars was studied under ambient conditions. Kufri Badshah showed the best control over sprouting, whereas, 100% sprouting was observed in Kufri Bahar with all possible combinations during storage. The minimum sprouting was observed in Kufri Pushkar. The sprouting was noticed more in larger tubers than medium or small tubers.

Key Words: Potato cultivars, Room temperature storage, Sizes, Sprouting behaviour

Potato (*Solanum tuberosum* L.), a member of Solanaceae family is the only non-cereal food crop to commend such a high position in the world since being nutritious food it can solve the problem of mal- and under-nutrition. The potato tubers after harvest remain dormant for sometimes and the duration of dormancy varies with the variety. Some varieties may have better keeping quality due to their morphological features and longer dormancy period than the other varieties. Cool and wet weather is known to extend the dormancy period (delay sprouting), while dry and warm weather conditions shorten it. Potatoes from crop grown under short day conditions have shorter dormancy than those grown under long day conditions and higher storage temperature hastens dormancy release. A total of 90 percent of potato production in India is from the Indo-Gangetic plains, where the crop is harvested from January to March before the onset of long hot summer. Storage under ambient conditions in Indian plains can result in enormous losses due to attack by micro-organisms. The perishable nature of potatoes coupled with increased production and insufficient cold storage facilities often result in post harvest glut and consequent crash of prices due to distress sale. In India, a large number of high yielding and disease resistant potato varieties have been developed for plains where potato harvest is followed by rising temperature in hot and dry summer. Due to inadequate and expensive refrigerated storage facility, more than half of the produce is stored at room temperature for varying periods. At room temperature, there are losses due to rottage, sprouting and shrinkage of tubers. Extent of weight loss during storage is dependent on genotype (Kang *et al.*, 2001; Patel *et al.*, 2006). Keeping in view the above facts, this experiment was conducted to evaluate the effect of tuber size on sprouting behaviour of potato varieties and to assess the quality changes in different graded potato tubers during storage.

MATERIAL AND METHODS

The present investigation was carried out to evaluate the effect of tuber size on keeping quality of potato varieties and sprouting behavior of different grades potato tubers at CCS Haryana Agricultural University, Hisar during spring-summer season. Hisar is situated at a latitude of 29°10' N, longitude of 75°46' E and height of 112 meters above mean sea level and enjoys semi-arid and subtropical climate with hot and dry summer and severe cold in winter months. The three grades of potato tubers, *i,e,*, small (> 25-50 g), medium (>50-75 g) and large (>75 g) size of variety Kufri Badshah, Kufri Bahar, Kufri Pukhraj and Kufri Pushkar were packed in gunny bags in all the possible combinations under room temperature conditions. The data related to sprouting behavior were statistically analyzed by using complete randomized design (factorial). The tubers showing sprouting were weighed at an interval of 10 days and percentage of sprouting of tubers was calculated on number and on weight basis separately.

Based on tubers showing emergence of sprouts externally, the date of sprouting of tubers was recorded. The tubers showing sprouting were weighed at an interval of 10 days and percentage of sprouting of tubers was calculated on number and on weight basis separately. The sprouting loss on weight basis was observed at the interval of 10 days in tubers stored at room temperature. The sprouting loss was calculated on the basis of weight loss, numbers and sprout weight.

RESULTS AND DISCUSSION

The sprouting loss was significantly influenced due to the effect of variety, size and their combination on 90th day of storage. Sprouting started on 60th day of storage in all the treatment combinations. It is evident from the table that the sprouting loss increased considerably as the storage period increased. The rate of sprouting loss was highest between 60th and 70th day, moderate between 70th and 80th day and lowest between 80th and 90th day. The highest loss was recorded on 90th day followed by 80th day of storage.

Sprouting loss on weight basis: All the varieties with respect to sprouting loss differed significantly from each other. Kufri Bahar showed the significantly maximum cumulative sprouting loss followed by Kufri Pukhraj while Kufri Pushkar showed the minimum cumulative sprouting loss followed by Kufri Badshah. The size of potato tubers differed significantly with respect to sprouting loss on weight basis. The small sized tubers had the significantly lowest sprouting loss followed by medium sized tubers and in large sized tubers as shown in Table 1.

The interaction between variety and size was found significant for all the treatment combinations. The significantly minimum weight loss due to sprouting was recorded with small sized tubers of Kufri Pushkar followed by Kufri Badshah, whereas, the maximum weight loss due to sprouting was recorded with large sized tubers of Kufri Bahar followed by Kufri Pukhraj on 60th, 70th, 80th and 90th day of experimentation, respectively.

Sprouting loss on number basis: The percent sprouting loss on number basis differed significantly with variety, size and their interaction. The extent of cumulative percent loss due to sprouting increased up to the end of storage, however, the extent of sprouting loss was more from 60 to 70 and 80 to

Table 1. Effect of varieties and tuber size on sprouting (%) on weight basis of potato during storage under ambient conditions

Treatments	Storage period (days)			
	60	70	80	90
Kufri Badshah				
Small	20.1 (26.80)	32.0 (36.25)	40.7 (39.62)	44.2 (42.09)
Medium	30.0 (33.20)	42.0 (40.38)	50.0 (45.73)	57.4 (49.25)
Large	39.0 (39.10)	58.9 (48.43)	65.0 (54.01)	71.7 (57.84)
Mean	29.7 (30.02)	44.3 (41.69)	51.9 (46.45)	57.8 (49.73)
Kufri Bahar				
Small	55.3 (48.37)	75.0 (61.19)	100.0 (89.39)	100.0 (89.39)
Medium	67.1 (55.42)	78.4 (63.61)	100.0 (89.39)	100.0 (89.39)
Large	87.7 (70.23)	100.0 (89.39)	100.0 (89.39)	100.0 (89.39)
Mean	70.0 (58.01)	84.5 (71.40)	100.0 (89.39)	100.0 (89.39)
Kufri Pukhraj				
Small	47.3 (44.21)	62.0 (50.40)	69.0 (54.99)	76.0 (59.65)
Medium	60.0 (49.52)	68.0 (54.50)	76.0 (59.87)	80.6 (63.81)
Large	67.6 (56.02)	77.0 (60.11)	82.0 (65.12)	88.6 (70.22)
Mean	58.3 (49.92)	69.0 (55.00)	75.7 (59.99)	81.7 (64.56)
Kufri Pushkar				
Small	8.0 (15.54)	12.6 (20.75)	20.3 (26.76)	25.3 (30.18)
Medium	21.0 (26.24)	31.5 (34.89)	44.0 (41.88)	52.3 (46.30)
Large	38.5 (37.27)	43.0 (42.34)	56.5 (48.72)	65.0 (53.71)
Mean	22.5 (26.35)	29.0 (32.66)	40.3 (39.12)	47.5 (43.40)
Mean of Size				
Small	43.5 (33.73)	45.4 (42.15)	57.5 (59.22)	61.4 (55.33)
Medium	59.4 (41.09)	55.0 (48.34)	67.5 (54.75)	72.6 (62.19)
Large	77.6 (50.65)	69.7 (60.10)	75.9 (64.31)	81.3 (67.79)
CD (p=0.05)				
Variety	0.75	1.17	0.78	0.75
Size	0.65	1.01	0.67	0.64
Variety x Size	1.30	2.03	1.35	1.29

Values in parentheses are angular transformed values

90 days of storage period as shown in Table 2. The data pertaining to sprouting loss on number basis differed significantly with the variety. The percent cumulative sprout loss on number basis was noted significantly highest in Kufri Bahar followed by Kufri Pukhraj and significantly minimum in Kufri Pushkar followed by Kufri Badshah on first, second, third and fourth observation taken on 60th, 70th, 80th and 90th day of storage, respectively.

The sprouting loss on number basis among the tuber sizes differed significantly, which was significantly lower in smaller tubers than medium and larger tubers. The minimum cumulative sprouting loss was observed in small sized tubers followed by medium sized tuber and the highest cumulative percent sprouting loss was noticed in large sized tubers on 60th, 70th, 80th and 90th day of storage, respectively. The interaction between variety and size was statistically significant for sprouting loss on number basis. The large sized tubers of Kufri Bahar contributed the significantly maximum cumulative sprout loss followed by medium sized tubers of same variety, whereas, small sized tubers of Kufri Badshah contributed the significantly minimum cumulative sprout loss followed by small sized tubers of Kufri Pushkar on 60th, 70th, 80th and 90th day of storage, respectively.

The differences in size of the tubers were found to be significant. Large sized tubers had the maximum sprouting rate as well as increasing number of sprouts with increasing size of potato tubers. Higher rate of sprouting in large-sized

Table 2. Effect of varieties and tuber size on sprouting (%) on number basis and sprout weight at 90th day of potato tubers during storage under ambient conditions

Treatments	Storage period (days)				
	60	70	80	90	At 90th day
Kufri Badshah					
Small	6.9 (14.90)	12.2 (20.46)	19.3 (26.04)	40.5 (40.37)	2.15
Medium	21.2 (27.40)	32.3 (34.60)	48.7 (44.21)	55.7 (48.23)	5.38
Large	56.6 (48.04)	77.9 (62.20)	97.2 (80.34)	100.0 (89.40)	9.32
Mean	28.2 (30.11)	40.8 (39.08)	55.1 (50.20)	65.3 (59.33)	5.62
Kufri Bahar					
Small	65.5 (53.99)	83.9 (66.32)	100.0 (89.39)	100.0 (89.39)	13.60
Medium	74.1 (59.41)	86.3 (68.25)	100.0 (89.39)	100.0 (89.39)	17.55
Large	90.0 (71.59)	100.0 (89.40)	100.0 (89.39)	100.0 (89.39)	20.00
Mean	76.7 (61.67)	90.1 (74.65)	100.0 (89.39)	100.0 (89.39)	17.05
Kufri Pukhraj					
Small	48.3 (44.01)	61.8 (51.80)	67.8 (55.15)	85.5 (67.60)	10.67
Medium	57.3 (49.17)	70.4 (57.04)	81.5 (64.50)	90.9 (72.37)	12.00
Large	73.5 (59.90)	84.9 (66.76)	90.6 (72.08)	94.7 (77.84)	14.65
Mean	59.7 (51.02)	72.4 (58.53)	80.0 (63.91)	90.4 (72.60)	12.44
Kufri Pushkar					
Small	19.3 (26.05)	31.9 (34.62)	40.3 (39.35)	44.8 (42.24)	1.26
Medium	24.0 (29.31)	39.0 (38.64)	53.4 (46.93)	58.4 (49.81)	4.32
Large	37.4 (37.70)	55.1 (47.91)	74.7 (59.76)	79.9 (62.48)	7.55
Mean	26.9 (31.02)	42.0 (40.40)	56.1 (48.68)	61.0 (51.51)	4.38
Mean of Size					
Small	35.0 (34.74)	47.4 (43.30)	56.8 (52.48)	67.7 (59.90)	6.92
Medium	44.2 (41.32)	57.0 (49.63)	70.9 (61.26)	76.2 (64.95)	9.81
Large	64.4 (54.30)	79.5 (66.53)	90.6 (75.39)	93.7 (79.78)	12.88
CD (p=0.05)					
Variety	0.83	0.34	0.36	0.63	0.11
Size	0.72	0.29	0.31	0.55	0.09
Variety x Size	1.44	0.58	0.62	1.09	0.19

Values in parentheses are angular transformed values tubers might be attributed to decreased duration of dormancy due to their greater age as they formed earlier than the small sized tubers and smaller tubers were formed later than the larger tubers and therefore had longer dormancy period. The increasing number of sprouts with increasing size of potato tubers could be attributed to more number of eyes on larger tubers with large surface area. Similar types of observation have been reported by Das *et al*. (2000). The results are also in close conformity with the findings of Tabori *et al*. (1999) who have also reported earlier and higher sprouting with more number of sprouts in larger tubers than smaller ones. The interaction between varieties and size of potato tubers was found significant.

Sprouting loss on sprout weight (%): The sprout weight was significantly affected by the variety, size and their combination (Table 2). The data pertaining to sprout weight differed significantly with the variety. The sprout weight was noted significantly highest in Kufri Bahar followed by Kufri Pukhraj and significantly minimum in Kufri Pushkar followed by Kufri Badshah on 90th day of storage.The sprout weight differed significantly, which was significantly lower in smaller tubers than medium and larger tubers. The minimum sprout weight was observed in small sized tubers followed by medium sized tuber and the highest sprout weight was noticed in large sized tubers on 90th day of storage.

The interaction between variety and size was statistically significant for sprout weight at the end of storage. The large sized tubers of Kufri Bahar contributed the significantly maximum sprout weight followed by medium sized tubers of same variety, whereas, small sized tubers of Kufri Pushkar contributed the significantly minimum sprout weight followed by small sized tubers of Kufri Badshah at the end of the storage. Sprouting loss on weight and number basis of different grade tubers was affected significantly by potato varieties. This is in accordance with the findings of Vecchio *et al*. (2000) and Sharma *et al*. (2012).

The investigation results show that sprouting of tubers increased continuously with the increase in storage length. Kufri Bahar had a shortest dormancy period than the other three varieties, thus, the percent sprouting loss was highest in Kufri Bahar under ambient conditions. Sprouting of tubers resulted in higher storage loss, especially at room temperature. Sprout itself adds to storage loss as it results in reduced fresh weight of tubers, thus, higher sprout growth resulted in higher storage loss in Kufri Bahar, making it less suitable for on-farm storage under ambient conditions. The results confirm the earlier findings of Paul and Ezekiel (2003). Das *et al*. (2004) have also reported significant differences in the number of sprouts tuber^{-1} among different potato varieties during storage of tubers at ambient conditions of eastern Indian plains.

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Efficiency of Potato Seed Production by Multiple Harvesting

Vineeta Pandey and Vandana A. Kumar
Department of Seed Science and Technology, CCS, Haryana Agricultural University, Hisar-125 004, India
E-mail: pandeyvini3@gmail.com

Abstract: Investigation was carried out in potato cultivar Kufri Himalini to increase the efficiency of seed by two harvests from in-vitro grown plant. In-vitro plantlets hardened for 10 & 30 days (10-P and 30-P) were planted in summer 2010 and harvested twice (H1 at 3 months and H2 for 4 months) viz. a- viz. control (C at 4 months). The tubers in H1+H2 of 10-P and 30-P were 217% &184% higher, respectively, than their respective controls. Weight of H1+H2 of 10-P and 30-P were also 105% & 140% higher than their respective controls. The performance of 30-P was proven to be better than 10-P because weight and number of tubers was higher in 30-P-H1 +H2 as compared to10-P-H1+H2. Harvested tubers were graded in 6 groups based on weight and tubers in which G2, G3 and G4 (5 to 35g) contributed 69% in 10-P and 58% in 30-P. By two harvests (H1+H2) from in-vitro plantlets in both treatments more number of suitable seed grade could be obtained.

Key Words: Grading, In-vitro plantlets, Multiple harvest, Number, Weight

In recent years, micro-propagation has been alternative to conventional propagation of potatoes using the tissue culture technique of micro-propagation, it is possible not only to reduce the number of field exposures but also to increase the rate of multiplication several times. Micro-tubers plantlets and mini-tubers are the initial source for production of quality potato seed. These propagules are multiplied and increased until sufficient quantity becomes available for commercial use (Naik and Khurana, 2003). Planting of disease-free seed is a prerequisite for a productive crop. Rapid multiplication of these disease-free clones using micro-propagation coupled with conventional multiplication methods has now become an integral part of seed production in many countries (Donnelly *et al.*, 2003). Plantlets are very small plants produced under completely sterile conditions (called *in-vitro* conditions) but transplants can be produced by planting *in-vitro* plantlets under non-sterile condition (called *in-vivo* conditions) or conditions between *in-vitro* and *in-vivo*(Struik and Wiersema, 1999). The practice of using *in-vitro* plantlets has been successfully applied for large scale production of seed potato mini-tubers. *In-vitro* micro-plants for seed production had been adopted by Kumar *et al.* (2007), Hassanpanah *et al.* (2008) and Lommen and Putten (2008). Efficiency improvement of mini-tubers in field is done by multiple harvesting instead of destructive harvesting. Keeping the above facts in view, the objective of present work is to increase the efficiency of seed production by increasing the number of harvested tubers.

MATERIAL AND METHODS

The experimental site Hill campus, Ranichauri, Tehri Garhwal is located 10 kms away from Chamba (Rishikesh - Gangotri Road) at an altitude of about 2100 meters above mean sea level, lying between 30^{0}15' N latitude and 78^{0}30' E longitude under mid hill zone of Uttarakhand, India. Experiment was conduct on variety Kufri Himalini during March 2010.

In-vitro plantlets of uniform length (16.25cm) were hardened in polyhouse for different time periods i.e.10 days and 30 days. The increase in height of plantlets recorded at every 10 day interval. Final height attained in 10 days hardened (10-P) and 30 days hardened (30-P) plantlets was 8.25cm and 14 cm, respectively. All the 10 and 30 day old hardened plantlets were transplanted in 3 replications each. There were 4 ridges per replication and 10 plants per ridge. To carry out present investigation potato plantlets of uniform length were taken from culture room for hardening. In-vitro developed plantlets were hardened in polyhouse on 19th March and 9th April 2010 under controlled environment. All the precautions for regular watering and weeding were under taken carefully till plantlets were ready for transplanting. On 19th April 2010, micro plantlets were transplanted, maintaining 60 cm row to row distance and 20 cm plant to plant distance. All the recommended agronomic practices were followed during experiment. Proper shade to the plantlets by small leafy twigs was provided for 10 days. When the plantlets were established properly, the shade was removed. Tubers were harvested twice at monthly intervals i.e. July and August. During 1st harvest, apical tubers whether small or big were plucked. During the 2nd harvest all tubers were plucked. Observations were recorded on same plants for two harvests. Grading of tubers was done on the basis of tuber weight after the harvest, and 6 grades are specified as G1<5.00, G2-5.00-14.99, G3-15.00-24.99, G4- 25.00-34.99, G5- 35.00-49.99 and G6 >50.

The *in-vitro* plantlets hardened in polyhouse were transplanted in field. Tubers were harvested after 90 and 120 days of transplanting in case of P-H1 and P-H2, respectively, *viz. a-viz.* control (P-C) after 120 days. After each harvest tubers were graded into 6 grades (G1through G6) on the basis of individual tuber weight

RESULTS AND DISCUSSION

The number of tubers (60 plants) In 10 day old harden plantlets varied from 297to 750 with significant difference higher in P-H1+P-H2 as compared to control. In 30 day old harden plantlets varied from 551 to 1266with significantly difference higher in P-H1+P-H2 as compared to control. When comparing the data in 10 and 30 day hardened plantlets, it was found that P-H1+P-H2 of 30 day was significantly higher than P-H1+P-H2 of 10 day which was 1266 and 750, respectively. Obviously, there was 184% increase in number of tubers in case of two harvests (P-H1+P-H2) of 30 day and 217% in case of two harvests of 10 day.

It clearly indicated that days of hardening of plantlets significantly affected the number of tubers. Performance of 30-P obviously was always better than 10-P. Samant (2010) reported that 8 tubers were harvested per plant during three harvest in potato cultivar Kufri Himalini, whereas, in the present experiment the efficiency of production further increased to 21 tubers per plant (30-P) and 13 tubers per plant (10-P) in only two harvests.

Table 1. Number of tubers of different harvests collected from 10 and 30 day hardened plantlets

Treatments*	Number of tubers (60 plants per treatment)	
	10 day	30 day
P-H1	297	551
P-H2	453	715
P-H1+P-H2	750	1266
P-C	346	689
CD (p=0.05)	1.66	3.94

*P-H1=Plantlets of Ist harvest, P-H2=Plantlets of 2nd harvest, P-H1+P-H2= Plantlets of Ist & 2nd harvest, P-C=Control

Table 2. Weight of tubers of different harvests collected from 10 and 30 day hardened plantlets

Treatments*	Total weight of tubers (kg)	
	10 day	30 day
P-H1	6.917	5.732
P-H2	9.327	24.155
P-H1+P-H2	16.244	29.887
P-C	15.447	21.419
CD(p=0.05)	0.003	0.003

*Treatment details as in Table 1

Weight of tubers in two harvests (P-H1+P-H2) of 30 day and 10 day was 29.887kg and 16.244kg respectively, which were significantly higher than their respective controls i.e. 30-P-C (21.419kg) and 10-P-C (15.447kg).Comparison of weight of tubers in combined harvest(PH1+ PH2) and control indicated that there was 140% increase in case of two harvests of 30 day and 105% in case of two harvests of 10day. This was clearly due to the physiological effect of lack of apical dominance which had increased the branching in stolons in two harvests. Apical dominance was minimized by plucking the tubers developing on terminal portion of stolons as a result of which more tubers were obtained during next harvest of the same plant. The performance of 30 day was proven to be better than 10 day because weight of tubers (24.155kg) in 30-P-H2 was higher than that of 10-P-H2 (9.327kg) and similarly weight in combined harvests i.e. P-H1 P-H2 (29.887kg) was better in 30 day than that of P-H1+P-H2 (16.244kg). As 60 plants were taken in present experiment, the weight of tubers per plant was calculated to be 498g in case of 30-P-H1+ 30-P-H2 and 270g in case of 10-P-H1+ 10-P-H2 as compared to 356g and 257g in their respective controls where only single harvest at the end of crop season was done. Average weight of tubers in case of two harvests in present study was found to be better than that of three harvests reported by Samant (2010) where average tuber weight per plant was 177g.

Gradation as per number of tubers: The number of tubers obtained in all the grades of 30-P-H1+30-P-H2 was always significantly higher as compared to that of 30-P-C. G2 particularly contributed 33% in 30-P-H1+30-P-H2 (33%) and was also higher than that of 30-P-C (30%). Maximum number of tubers i.e. 234 and 189 was recorded in G2 in both the harvests H1 and H2, respectively, and it contributed 42% and 27% respectively. The number of tubers obtained in G1 through G4 grades of 10-P-H1+10-P-H2 was always significantly higher as compared to that of 10-P-C. The G2 grade contributed 48% and 26%, respectively in case of P-H1 and P-H2 harvests, whereas, it was 39% in the sum of two harvests P-H1 + P-H2. On the contrary, the G2 in P-C contributed to only 20%.

Comparison of data further indicated that the contribution of G2,G3 and G4 in 30-P was 58% and that in 10-P was 69%, in comparison to their respective controls i.e. 57% in 30-P and 47% in 10-P. These grades were highly suitable for seed purpose. Mini-tubers are small seed potato tubers produced thoughout the year and are principally used for the production of pre basic or basic seeds by direct field planting(Lommen, 1999, Ritter *et al.,* 2001) and the size of mini-tubers ranged from 5-25mm (Struik and Wiersema, 2007).

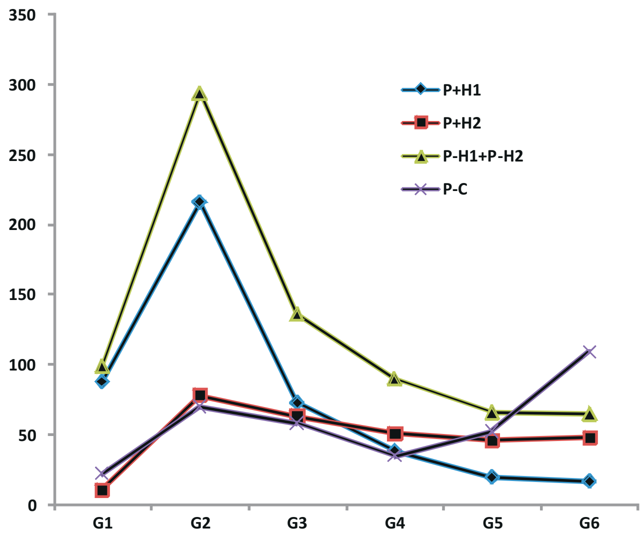

Fig.1. Gradation as per of number of tubers in 30-P

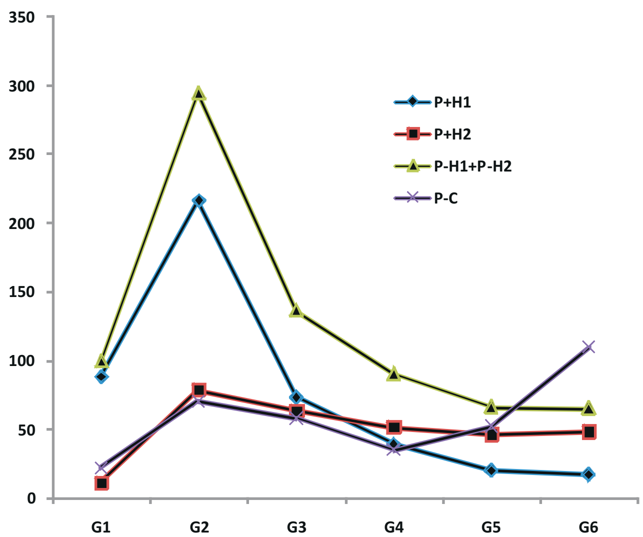

Fig. 2. Gradation as per of number of tubers in 10-P

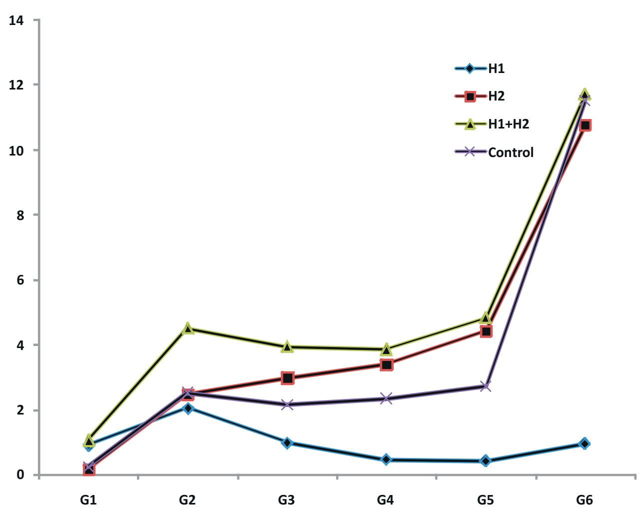

Fig. 3. Grade wise distribution of weight of tubers harvested from 30-P

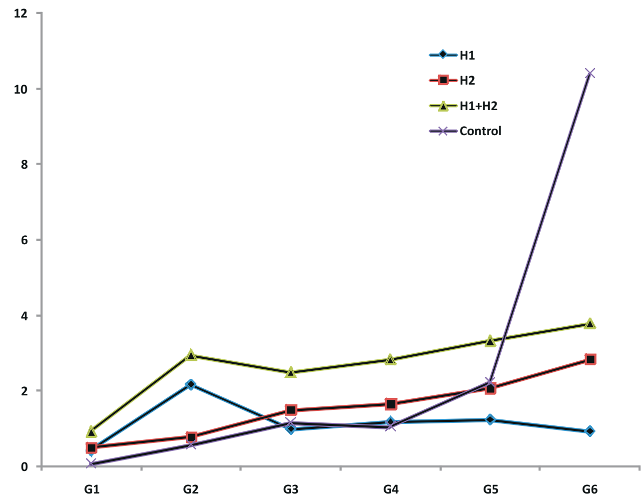

Fig. 4. Grade wise distribution of weight of tubers harvested from 10-P

Gradation as per weight of tubers: The weight of tubers obtained in all the grades of 30-P-H1+30-P-H2 was always higher as compared to that of 30-P-C.

The weight of tubers obtained in G1 through G5 grades of 10-P-H1+10-P-H2 was always significantly higher as compared to that of 10-P-C. The G6 grade which was extra larger in size contributed to 67% in case of 10-P-C whereas, in 10-P-H2 it was 31% because relatively smaller tubers more suitable for seed were obtained due to two harvests. Similarly in 30-P contribution of G6 in P-C (54%) was higher and less suitable than that of P-H2 (45%).

Diameter of tubers: Diameter in all grades of H2 was smaller than respective values of control indicating that the size of tuber in H2 harvest was smaller than control because additional H1 harvest had already been obtained from those plants. In fact big size of tubers obtained in control was not desirable.

Number of eyes: The data revealed that grade wise number of eyes increased gradually. Average number of eyes ranged between 1.6 to 4.9 in H1, 1.8 to 4.7 in H2 and 2 to 4.7 in control in both 10-P and 30-P harvests. However, the values for average number of eyes recorded in H1-G1 in both 30-P and 10-P was a bit higher than rest of the groups. Similar observation that very small tubers such as micro-tubers or mini-tubers already bear a surprisingly high number of potentially active eyes' was also pointed out by Struik and Wiersema (2001). It was likely that the higher number of eyes during very early growth phase could have been due to the fact that in-vitro grown plantlets were used. However, further studies on the initial development of eyes would be required to comment on such observation.

By using *in-vitro* method, large scale production of plantlets is possible that can directly be used in field as a substitute to tuber seed. If more than one harvest are possible in *in-vitro* plants, more production of seed tuber can be obtained, unlike to the conventional potato production method in which tubers are used as seed and only single harvest is practiced. To increase the efficiency of seed production by increasing the number of harvested tubers.

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Effect of Different Herbicides on Growth, Yield and Quality Parameters of Kinnow

Bhanukar Manoj, S. S. Sindhu, Preeti and Prince
Department of Horticulture, CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: bhanumanu0326@gmail.com

Abstract: The experiment was conducted to find out the effect of herbicide application on growth, yield and quality parameters in kinnow. Plant growth parameters viz. plant spread, girth and height of Kinnow plant had been significantly influenced by different weed control treatments. Maximum increase was observed with manual weeding at monthly interval. In herbicidal treatments, atrazine 2 kg + glyphosate 1% was recorded most effective for maximum increase in vegetative growth. All the herbicides significantly influenced the total soluble solids, acidity, ascorbic acid and juice content. In herbicidal treatments, highest TSS, ascorbic acid and juice content and minimum acidity were recorded with combination of atrazine 2 kg + glyphosate 1%. Manual weeding was most effective in increasing fruit length, breadth, weight and number of fruits increment, while, in herbicidal treatments, atrazine 2 kg + glyphosate 1% was found best for all above characters.

Key Words: Growth, Herbicides, Kinnow, Quality, Yield

Citrus is a commercially important fruit crop of India with a production of 8.89 million tonnes from an area of 0.72 million hectares during year of 2013-14 (Mistry *et al.,* 2014). There are many factors which exert pressure on the production of citrus plants, and weeds have competitive role to lessen the production of Kinnow. Weeds in the orchards compete with trees for nutrients, water and light resulting in stressed plant and poor fruit quality and yield. Buker (2005) is of the view that weeds density can affect the vegetative growth, fruit yield and critical periods. Weeds slow down the growth of young trees and increase their susceptibility to insect and disease damage. Weeds therefore reduce the crop production and contribute in future problems through constant increase in weed seed banks. Chemical control of weeds in citrus was reported to affect various physical and chemical properties and quality of fruits (Mohanty *et al*., 2002). Glyphosate has been the most widely used herbicide for post emergence weed control in citrus (Barbora *et al*., 2002; Singh and Singh, 2004). The length of critical period increases with increase in the weeds density. The present study was undertaken to assess the effect of herbicides on growth, yield and quality parameters in kinnow orchard.

The present investigation was carried out on Kinnow trees at experimental orchard of the department of Horticulture, CCS HAU, Hisar during the year 2013. The experiment was laid out in randomized block design with nine treatments (Table 1) and three replications. Plant girth was measured with the help of digital vernier caliper from the base of the trunk. Plant spread was determined by measuring distance between points to which most of the branches of the tree had grown in the east-west and north-south direction. The height of the tree was calculated up to the maximum point of height, ignoring only the off type shoots. The leaf water potential was estimated by pressure chamber apparatus. The TSS of the representative fruit juice was determined by using hand refractometer. The titratable acidity and ascorbic acid was estimated as per the method given by AOAC (1990)

The average weight was calculated by selecting 10 fruits at random. Fruit length and breadth of these randomly selected fruits was measured with the help of digital vernier calipers. The number of fruits per tree was calculated by visually dividing the canopy of the tree into two equal halves and then counting the number of fruits on both halves and total number of fruits is obtained by adding the number of fruits of two halves. The total fruit yield per tree was calculated by multiplying total number of fruits per tree with the average fruit weight.

There was significant increase in plant spread however non-significant increase in girth and height of the plants in different treatments (Table 1). The maximum per cent increase in plant spread was recorded in manual weeding at monthly interval and was significantly better than atrazine, but at par with other treatment. Among herbicidal treatments, maximum was in atrazine 2 kg + glyphosate 1% but at par with other treatments with respect to NE spread but was better than atrazine. This might be due to control of weeds during whole experimentation period and increase in soil properties and nutrient status. In control, the uninterrupted growth of weeds throughout the growing season is responsible for least growth.

Fruit length, breadth, weight, number of fruits and yield: The fruit length, breadth, weight, number of fruits and yield were significantly affected by various weed control treatments and maximum values (7.11, 7.24, 177.41, 228.54 and 40.55, respectively) were recorded with manual weeding at monthly interval, whereas among herbicidal treatments, maximum values (6.96, 7.21, 176.11, 225.24 and 39.66, respectively) were observed with atrazine 2 kg + glyphosate 1% but minimum in control (Table 2).

This might be due to more availability of nutrients, less crop weed competition and slightly increase in moisture per cent of soil in weed control treatments, while in control treatments due to competition of weeds in main crops reduced the general nutrient status of the soil, which ultimately affect the yield attributes except weight of the fruits.

TSS, acidity, ascorbic acid and juice content: The TSS, acidity, ascorbic acid and juice content were significantly influenced by various weedicide treatments (Table 3). The maximum TSS (8.50) and minimum acidity (0.78) was recorded with manual weeding at monthly interval followed by atrazine 2 kg + glyphosate 1% (8.37 and 0.79), whereas, minimum TSS (7.80) and maximum acidity (0.91) was recorded in control. The highest ascorbic acid and juice content (42.37 and 52.27) was observed in manual weeding at monthly interval treatment followed by atrazine 2 kg + glyphosate 1% (41.23 and 51.78) and lowest (33.87 and 42.13) was recorded in control.

The improvement in fruit quality with various herbicidal treatments may be due to reduced weed growth as compared to control. The nutrients and the moisture availability in sufficient quantity also help in improving the quality of fruits as compared to untreated plot. Similar findings have also been reported by Bal *et al.* (2003), Bal and Kumar (2005), Maji *et al.* (2008) and Das *et al.* (2010).The leaf water potential was not influenced by various weed control treatments significantly. The minimum leaf water potential (12.75) was recorded with manual weeding at monthly interval treatment and maximum (13.62) was observed in control. Weed control treatments did not affect the soil moisture per cent hence leaf water potential were unchanged during the time frame. Leaf water potential has the direct

Table 1. Effect of herbicides on per cent increase in plant spread, height and girth

Treatments	Spread		Height	Girth
	East- West	North - South		
Atrazine 2 kg	8.04	7.34	7.40	5.28
Glyphosate 1%	8.34	7.80	7.56	5.60
Paraquat 0.6%	8.20	7.66	7.45	5.45
Atrazine 1 kg + glyphosate 1%	8.52	8.11	7.68	6.13
Atrazine 1 kg + paraquat 0.6%	8.45	7.94	7.62	5.85
Atrazine 2 kg + glyphosate 1%	9.04	8.39	7.82	6.35
Atrazine 2 kg + paraquat 0.6%	8.67	8.23	7.71	5.82
Manual weeding at monthly interval	9.17	8.45	7.93	6.61
Control (Unweeded check)	7.21	6.46	7.21	5.03
CD (p=0.05)	1.05	1.01	NS	NS

Table 2. Effect of herbicides on fruit length, breadth, weight, number of fruits and yield

Treatments	Length (cm)	Breadth (cm)	Weight (g)	Number of fruits	Yield (kg plant^{-1})
Atrazine 2 kg	6.48	6.74	179.12	187.68	33.61
Glyphosate 1%	6.71	6.95	173.94	201.33	35.02
Paraquat 0.6%	6.60	6.82	176.58	192.95	34.08
Atrazine 1 kg + glyphosate 1%	6.80	7.13	171.92	213.58	36.72
Atrazine 1 kg + paraquat 0.6%	6.76	7.04	170.81	206.79	35.32
Atrazine 2 kg + glyphosate 1%	6.96	7.21	176.11	225.24	39.67
Atrazine 2 kg + paraquat 0.6%	6.92	7.17	169.71	223.38	37.91
Manual weeding at monthly interval	7.11	7.24	177.41	228.54	40.55
Control (Unweeded check)	6.40	6.58	180.05	178.56	32.15
CD (p=0.05)	0.15	0.14	4.19	12.21	2.56

Table 3. Effect of herbicides on TSS, acidity, ascorbic acid and juice content

Treatments	TSS (^{0}B)	Acidity (%)	Ascorbic acid (mg/100g)	Juice content (%)
Atrazine 2 kg	7.90	0.89	35.74	43.26
Glyphosate 1%	8.00	0.87	38.29	46.77
Paraquat 0.6%	7.90	0.88	37.00	44.40
Atrazine 1 kg + glyphosate 1%	8.30	0.84	39.57	49.52
Atrazine 1 kg + paraquat 0.6%	8.07	0.86	38.82	47.86
Atrazine 2 kg + glyphosate 1%	8.37	0.79	41.23	51.78
Atrazine 2 kg + paraquat 0.6%	8.33	0.81	40.76	50.77
Manual weeding at monthly interval	8.50	0.78	42.37	52.27
Control (Unweeded check)	7.80	0.91	33.87	42.13
CD (p=0.05)	0.19	0.03	1.16	1.41

correlation with soil moisture content (Urdaneta *et al*., 2003).

CONCLUSION

The highest TSS, ascorbic acid and juice content and minimum acidity were recorded with combination of atrazine 2 kg + glyphosate 1%. Manual weeding was most effective in increasing fruit length, breadth, weight and number of fruits increment, while atrazine 2 kg + glyphosate 1% was also found best for crop yield.

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Influence of Pretreatments and Different Drying Methods on Lycopene Content of Dried Tomato

Omar Bin Hameed, Hafiza Ahsan, Mudasir Bhat, Nazia Nissar, Naeema Jan and Monica Reshi

Division of Post-Harvest Technology
Sher-e- Kashmir University of Agricultural sciences and Technology, Srinagar-190 011, India
E-mail: omargojwari@gmail.com

Abstract: The study was carried out to investigate the effect of different chemical pretreatments (2% ethyl oleate + 1% potassium carbonate, 1% ascorbic acid+1% citric acid and 2% sodium metabisulfite, 1% calcium chloride + 0.25% sodium chloride and 1% sodium chloride at different drying methods (sun drying, solar tunnel drying and cabinet drying at 45°C, 55°C and 65°C) on lycopene retention of dried tomato slices. The effects of drying methods and pretreatments and their interactions were found statistically significant ($p<0.05$). Maximum lycopene content was found in cabinet dried tomatoes at 55°C, 65°C and lowest in sun dried tomatoes. Especially ethyl oleate + potassium carbonate and ascorbic acid + citric acid increased the lycopene content of dry tomatoes at high temperature drying applications.

Key Words: Cabinet, Drying, Lycopene, Pretreatments, Slices, Tomato

Tomato (*Lycopersicon esculantum* L.*)* is one of the most widely consumed fresh vegetables in the world. Tomatoes are rich source of lycopene (60-90 mg kg^{-1}), polyphenols (10-50 mg kg^{-1}) and small quantities of vitamin E (5-20 mg kg^{-1}) and also a nutritionally recognized vegetable for their vitamin C content, with an average tomato supplying about 40% of the adult United States Recommended Daily Allowances (RDA) of 60 mg (Charanjeet *et al.,* 2004).

The preservation of fruits and vegetables by dehydration offers a unique challenge. Due to the structural configuration of these products, the removal of moisture must be accomplished in a manner that will be least detrimental to the product quality. Tomato (*Lycopersicum esculantum* L.) has a limited shelf life at ambient conditions and is highly perishable. It creates glut during production season and becomes scanty during off-season. Over the past few years, consumers have increasingly demanded food products providing both good sensorial quality and specific nutritional properties. Thus, there exists a need to develop suitable technology for processing and preservation of this valuable product in a way that will not only check losses but also generate additional revenue for the country.

Tomato as other fruits and vegetables can be dried using various methods and the quality of dehydrated tomato depends on many parameters such as tomato variety, total soluble solid content of the fresh product, size of the tomato segments and air temperature. Processing of tomatoes using sun drying with cut pieces, drying of whole tomatoes, spray drying and convection drying using solar or mechanical systems has been used for many years (Baloch *et al.,* 1997). Traditional sun-drying is a slow process compared with other drying methods and quality losses may result from high moisture content, colour degradation by browning, microbial growth (Lewicki *et al.,* 2002).

Presently, there are few published studies comparing the single or mixed effects of calcium chloride and sodium metabisulfite dipping treatments on quality parameters of cabinet-dried tomatoes. Hence, the objective of this study was to evaluate the effects of different pre-treatments and drying methods on the lycopene content.

Two varieties of fresh tomato (Shalimar I and Punjab Chuhra) were selected for the present study. Fruits were sorted and washed with water to remove dirt and soil and finally they were cut into slices of 15mm thickness. Following pretreatment methods were applied to tomatoes before drying:

T_1: Whole tomatoes were dipped in 2% ethyl oleate + 4% potassium carbonate solution for one minute and the 1% ascorbic acid +1% citric acid dipping solution was applied to sliced tomato samples for 2 minutes.

T_2: Whole tomatoes were dipped in 2% ethyl oleate + 4% potassium carbonate solution for one minute and then 2% sodium metabisulfite dipping solution was applied to sliced tomato slices for 2 minutes.

T_3: Tomato slices were treated with 1% calcium chloride + 0.25% sodium chloride solution for 2 minutes.

T_4: Tomato slices were treated with 1% sodium chloride solution for 2 minutes.

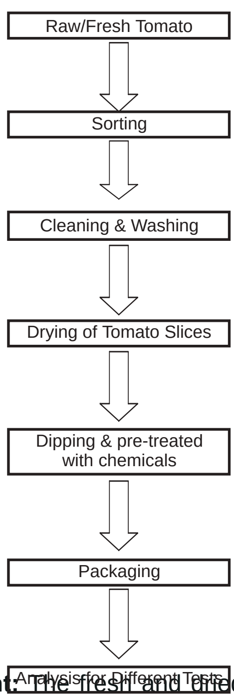
T_0 Control: Non- pretreated samples were used as control samples.

The pretreated samples were dried by following drying methods namely:

Sun drying (SD): Perforated sample trays were used in sun drying experiments. During the sun drying of tomato slices, the air temperature and relative humidity were determined by using thermometer and hygrometer. The air temperature and relative humidity was recorded as 26-32°C and 33- 44%, respectively. Open sun drying experiments were done between 10:00 and 05:00.

Solar tunnel drying (ST): Solar tunnel drier was constructed using high density polyethene (HDPE). Sample was placed on trays specially designed for the solar tunnel drier. During solar tunnel drying, the air temperature and relative humidity was recorded as 30-37°C and 39-45%, reseptively using thermometer and hygrometer respectively.

Cabinet drying (C): Cabinet drying was carried out in cabinet drier which was designed and constructed in Ludhiana, India with model no NSW -154. Three different drying temperatures, 45°C (D_1), 55°C (D_2) and 65°C (D_3) were used to dry the product.



Process flow chart of tomato dehydration process

Lycopene content: The fresh and dried tomato (5-10gm) was extracted repeatedly with acetone in a pestle and mortar until the residue is colourless. Acetone extract was transferred to a separating funnel containing 10-15 ml of petroleum ether and mix gently and the carotenoid pigments were transferred into the petroleum ether by diluting the acetone (lower phase) with water or water containing 5% Na_2SO_4. The lower phase was then transferred to another separating funnel and the petroleum ether extract containing the carotenoid pigments to an amber coloured bottle. The extraction of the acetone was repeated similarly with petroleum ether until it turns colourless and acetone phase was discarded. Small quantity of anhydrous Na_2SO_4 was added to petroleum ether extract and then transferred to a 50 ml volumetric flask and diluted to mark with petroleum ether. Calculations were made by the formula

$$\text{Lycopene mg per 100g} = \frac{3.1206 \times \text{OD of sample} \times \text{volume made up} \times \text{dilution} \times 100}{1 \times \text{weight of sample} \times 1000}$$

As it can be observed from the Figure 1, 2 and 3, the lycopene content increased upon drying. Effects of drying methods and pretreatments on the lycopene values were found statistically significant ($P<0.05$). Among both the varieties, the highest lycopene content of 95.76 was observed in variety II in T_1 pretreated sample dried in cabinet (55°C) and Lowest of 60.41 in T_0 pretreated sample dried in sun (variety I). Ethyl oleate, potassium carbonate and ascorbic acid and citric acid treated samples had significant protective effect on lycopene degradation and it was more effective than any other treatment applied.

Many researchers stated about advantages of cabinet drying method and reported that products that were cabinet dried and appropriately packed, technically can be stored for a long time (Saldamli and Saldamli, 2004; Marques and Freire, 2005; Sablani *et al.*, 2007). On the other hand, lycopene content varied from 60.41-68.86 mg/100gm for variety I and for variety II it varied between 65.50-68.75 mg/100gm for sun dried tomato slices (Fig.1). Similar results were determined by Roldan-Gutierrez and Luque de Castro (2007). The lowest retention of lycopene in sun dried samples could be explained that during sun drying the sample was exposed to air temperature for longer time which resulted in degradation of lycopene. Among the sun dried samples the highest lycopene content was found in T_2 pre-treated samples. Results were in compliance to findings of Davoodi *et al.* (2007).

As compared to sun dried samples, the retention of lycopene in solar tunnel dried samples and cabinet dried samples was higher and it varied between 85.21-86.11 mg/100gm and 83.25-89.09 mg/100gm and 88.36-95.03 mg/100gm and 88.03-95.76 mg/100gm for variety I and

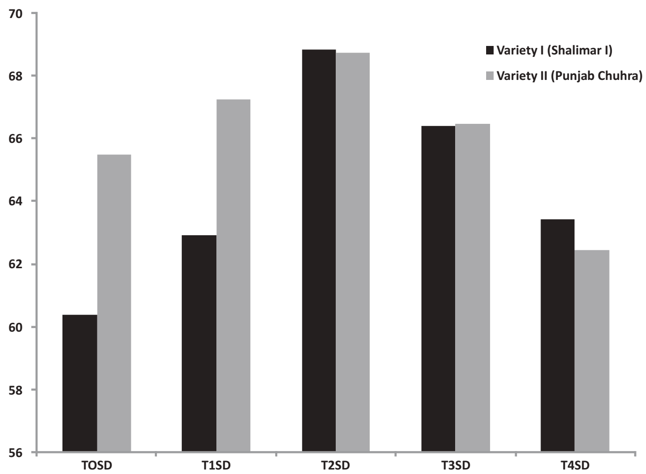


Fig. 1. Influence of drying methods and pretreatments on lycopene content mg/100gm (sun dried)

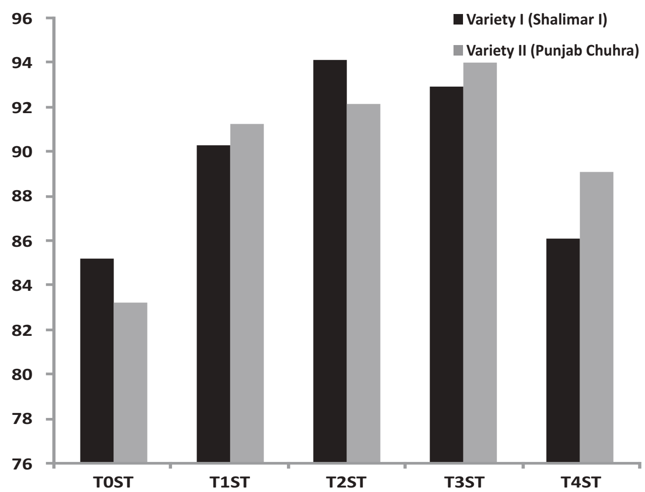


Fig. 2. Influence of drying methods and pretreatments on lycopene content mg/100gm (solar tunnel dried)

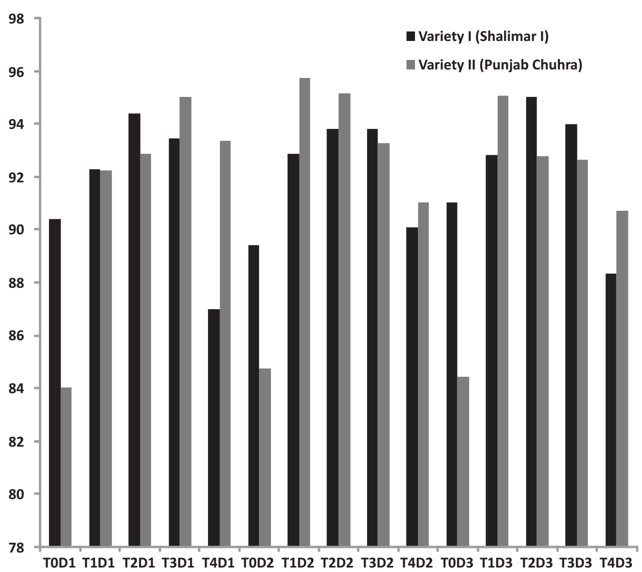


Fig. 3. Influence of drying methods and pretreatments on lycopene content mg/100gm (cabinet dried)

variety II respectively (Fig 2 and 3). The values of the lycopene content obtained after hot air drying were relatively higher than the 82.90 mg/100g reported by (Takeoka *et at.,* 2001). Results indicate that hot air drying increased lycopene retention in tomato slices, subjected to drying, but the rate of degradation was significantly different and pre-treatments influenced the rate of reduction during dehydration process. More Lycopene degradation was observed in control samples for all the experiments, however, sodium metabisulphite had significant protective effect on lycopene degradation. Results regarding the effect of sodium metabisulphite were qualitatively similar to those reported by Sharma and Maguer (1996) and Baloch *et al.* (1987).

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Scope and Opportunities of Medicinal and Aromatic Plants and Spices in Jute Seed Based Cropping System

M. S. Behera, D. K. Kundu, S. Satpathy, A. K. Jha, Amarpreet Singh and R. K. Nayak

ICAR-Central Research Institute for Jute and Allied Fibres, Barrackpore-700 120, India
E-mail: behera_ms@rediffmail.com

Abstract: Crop diversification by integrating medicinal and aromatic plants (MAPs) and spices in jute (seed) based cropping system incorporating autumn rice in rotation was evaluated at the Central Research Institute for Jute and Allied Fibres, Barrackpore. After harvest of jute (seed crop), MAPs and spices viz., ashwagandha (transplanted), senna, stevia, isabgol, fennel, Ajwain, dill seed, nagella, coriander, fenugreek, peppermint with one traditional crop as tomato was raised followed by autumn rice. The highest jute equivalent yield was recorded in stevia (230.68 q ha^{-1}). Among the spices ajwain recorded the highest jute equivalent yield (83.75 q ha^{-1}) followed by nagella (79.33 q $ha^{-1)}$ and fennel (79.15 q ha^{-1}). Tomato recorded 77.67 q ha^{-1} in case of traditional crop. Considering the system as whole, the BC Ratio was highest with ajwain (2.72) followed by stevia with 230.68 q ha^{-1} and BC ratio of 2.43. Among the aromatic plants, peppermint the yield is recorded as 61.75 q ha^{-1} of oil with BC ratio of 2.26. Among the spices ajwain, crop such as and peppermint can be grown in jute seed-rice cropping sequence for higher income to farmers. Among the spices ajwain, MAP crop such as stevia and peppermint can be grown in jute seed-rice cropping sequence for higher income to farmers.

***Key Words*:** Ajwain, Jute equivalent yield, Stevia

There is annual demand of 10000 tonnes of jute seeds for Bangladesh and India and seed is generally not produced in jute fibre producing area and is grown in states like Maharashtra, Andhra Pradesh, Karnataka, etc. Jute seed is harvested from a patch of un-harvested fibre crop in jute growing area. But changes like growing jute seed as a sole crop and shifting of jute seed production to non-jute growing area occurred through intervention of various stakeholders and adoption of government policies for strengthening seed sector of the country. Total domestic requirement of jute is around 5000 tons and considering the export market, jute seed requirement goes up to 9-10 thousand tons (Bera *et al.,* 2010). Regeneration ratio of jute seed is as high as 1:80.with high replacement rate in comparison to other self pollinated crops.

While developing high yielding varieties of jute, consideration was never given to seed potentialities. However analysis of seed production data from Central Seed Research Station for Jute and Allied Fibres at Bud Bud, Kolkata for 3 years indicated that new generation jute varieties have higher capacity of seed production. Earlier this system of seed production used to yield very meagre quantity of seed, seed yield used to vary between 1.8-3.0 g $plant^{-1}$ and quality was not always satisfactory. So an attempt has been made for crop diversification to make jute farming profitable by integrating medicinal and aromatic plants and spices in jute (seed) based cropping system incorporating autumn rice in rotation as rice is the staple food in the region.

MAPs and seeds spices are in general short duration crops that fit into other cropping system, intercroppings and cover cropping for efficient utilization of land and other resource to sequester the carbon. They have tolerance to adverse conditions like water, salinity, alkalinity, nutrients and temperature and have better tolerance/ resistance to insects, pests and diseases (Sinha *et al*., 2009; Mahapatra *et al*., 2012). These are high value crops and their cultivation will conserve the biodiversity and will increase the farm income.

The present experiment was conducted at ICAR-Central Research Institute for Jute and Allied Fibres during 2013-14 to study the production potential of growing spices and medicinal crops in jute seed based cropping system. The experimental site is located at 88° 26` E longitude and 22° 35` N latitude 9m above mean sea level. The experiment was laid out in split plot design with three replications and two fertility levels (recommended dose of fertilizer and RDF + 5t FYM) . The experimental soil was sandy loam in texture with pH 6.8, high in organic carbon 0.66%, medium in available nitrogen (290 kg ha^{-1}) , high in available P2O5 (36 kg ha^{-1}) and potash (234 kg ha-1). In order to assess the most profitable jute (seed)-spices and MAPs-autumn rice sequence, eleven spices and medicinal crops viz ashwagandha (transplanted) (*Withania sominfera*), senna (*Cassia lentiva)*, stevia (*Stevia rebaudiana)*, isabgol (*Plantago ovate)*, fennel (*Foeniculum vulgare)*, ajwain (*Trachyspermum Ammi)*, dill seed (*Anethum graveolens)*, nagella (*Nigella sativa)*, coriander (*Coriandrum sativum)*, fenugreek (*Trigonella foenum-graecum)*, peppermint (*Mentha piperita)* were evaluated along with

Table 1. Yield and system economics of MAPs and Spices in jute (seed)-MAPs and Spices-Autumn rice cropping sequence

Treatments	Jute seed yield (q ha^{-1})	JEY (q ha^{-1})	MAPs and spices yield (q ha^{-1})	JEY (q ha-1)	Rice yield q ha^{-1})	Jute equivalent yield (q ha^{-1})	Total JEY (q ha^{-1})	Net (Rs. ha^{-1})	B:C ratio
Cropping systems									
Jute-fennel-autumn rice	8.26	24.10	9.60	32.56	41.66	22.49	79.15	122379	2.34
Jute-isabgol-autumn rice	8.13	23.71	4.38	18.33	39.80	21.49	63.53	86615	2.02
Jute-ashwagandha-autumn rice	8.43	24.59	5.92	15.40	41.21	22.25	62.24	98607	2.42
Jute-nagella-autumn rice	8.25	24.05	5.8	32.93	41.40	22.35	79.33	123433	2.36
Jute-senna-autumn rice	7.63	22.26	6.44	22.18	40.92	22.09	66.53	110807	2.16
Jute-dill seed-autumn rice	7.70	22.61	7.02	26.91	40.21	21.71	71.23	107224	2.26
Jute-stevia-autumn rice	8.58	25.03	25.96	183.97	40.15	21.68	230.68	366525	2.43
Jute-ajwain-autumn rice	8.46	24.68	7.75	36.64	41.54	22.43	83.75	142991	2.72
Jute-coriander-autumn rice	8.26	24.69	8.95	15.52	40.35	21.78	61.99	94918	2.31
Jute-fenugreek-autumn rice	8.13	23.71	8.2	15.79	39.70	21.43	60.93	92673	2.29
Jute-pipper mint-autumn rice	7.60	22.16	0.78	17.67	40.60	21.92	61.75	92953	2.26
Jute-tomato-autumn rice	8.78	25.61	160	30.64	39.67	21.42	77.67	103258	1.97
CD (p=0.05)	1.49	4.34	0.41	1.41	0.001	0.143	4.23	1450.49	0.002
Fertility Levels									
Recommended dose	8.00	23.37	19.21	31.36	36.34	17.21	78.83	127287	2.21
Recommended dose of fertilizer with 5t FYM	8.40	24.5	22.68	43.11	44.85	26.64	88.45	128641	2.37
CD (p=0.05)	0.06	0.18	1.608	3.12	3.433	3.33	3.62	2048.99	0.02
Interaction (C x F)									
CD (p=0.05)	0.22	0.62	5.55	10.81	11.91	11.54	12.55	7097.91	0.077
CV (%)	1.63	1.54	1.61	3.16	0.017	0.562	4.22	0.946	0.150

tomato (*Solanum lycopersicum)* as prevailing traditional crop. Jute was raised for seed and after harvesting of crop, sowing of medicinal and spices crops along with conventional crops tomato was taken up followed by autumn rice. The jute equivalent yield of fibre cum seed was calculated based on prevailed market price.

Jute equivalent yield: The jute-stevia-autumn rice cropping sequence recorded the maximum jute equivalent yield (230.68 q ha^{-1}), which is significantly higher and 197% more than the traditional cropping systems i.e, jute-tomato-autumn rice (77.67 q ha^{-1}), taken as control. The jute equivalent yield ranged from 60.93 q ha^{-1} to 230.68 q ha^{-1} in different cropping systems under study (Table 1). In Jute-Medicinal plants-autumn rice cropping system, the highest jute equivalent yield was recorded in stevia (230.68 q ha^{-1}) followed by senna (66.53 q ha^{-1}) and isabgol (63.52 q ha^{-1}). Among the spices ajwain recorded the highest jute equivalent yield (83.75 q ha^{-1}) followed by nagella (*Nigella sativa)* (79.33 q ha^{-1}) and fennel (79.15 q ha^{-1}). However pipper mint registered 21.92 q ha^{-1} yield in case of jute-aromatic plants-autumn rice cropping system. The jute equivalent yield was significantly higher in all the three spices, medicinal and aromatic plants such as ajwain, stevia and pipper mint based cropping system compared to traditional crop sequence.

Application of recommended dose of fertilizer with 5t FYM (F_2) recorded maximum jute equivalent yield of 88.45 q ha^{-1}, which is 12.2% higher than F_1 (RDF).

Net return: Considering the system as a whole, the jute-stevia-autumn rice cropping sequence recorded the maximum net return (Rs. 3, 66,525 ha^{-1}), which was 254% significantly higher than the traditional cropping system i.e, jute-tomato-autumn rice (Rs. 1,03,258 ha^{-1}), taken as control. The net return ranged from Rs. 86,615 ha^{-1} to Rs. 3,66,525 ha^{-1} (Table 1). In jute-medicinal plants-autumn rice cropping system, the highest net return was recorded in stevia (Rs. 3,66,525 ha^{-1}) followed by senna (Rs. 1,10,807 ha$^{-1)}$ and ashwagandha (Rs.98,607 ha^{-1}). In jute-spices-autumn rice cropping system, ajwain recorded the highest net return (Rs. 1,42,991, ha^{-1}) followed by nagella (Rs. 1,23,433 ha^{-1}) and fennel (Rs. 122379 ha^{-1}). However, net return of Rs. 92953 ha^{-1} was recorded in jute-pippermint-autumn rice cropping sequence. Application of recommended dose of fertilizer with 5t FYM registered higher net return (Rs. 1,28,641 ha^{-1}), which is 1.05 % higher than recomemdede dose.

Benefit-cost ratio: The jute-ajwain-autumn rice cropping sequence recorded the maximum benefit-cost ratio (2.72), which is 38 % more than the control (1.97). The benefit-cost ratio ranged from 1.97 to 2.72 in different cropping systems under study (Table 1). In jute-medicinal plants-autumn rice cropping system, the highest benefit-cost ratio was recorded in stevia (2.43) followed by ashwagandha (2.42) and isabgol (2.02). Among the spices, ajwain recorded the highest benefit-cost ratio (2.72) followed by nagella (2.36) and fennel (2.34). However, pipper mint registered benefit-cost ratio of 2.26 in case of aromatic plants. Maximum benefit-cost ratio (2.37) was obtained when recommended dose of fertilizer with 5t FYM was applied to the crops. The benefit-cost ratio was significantly higher (7.2%) than RDF.

Considering the system as a whole, jute-stevia-autumn rice cropping system recorded the maximum jute equivalent yield of 230.68 q ha^{-1} with BC ratio of 2.43. In case of aromatic plants, pippermint recorded the jute equivalent yield of 61.75 q ha^{-1} with BC ratio of 2.26.Similarly, Jute-ajwain-autumn rice cropping system registered jute equivalent yield of 83.75 q ha^{-1} with BC ratio of 2.72 in case of spices. Among the spices, ajwain and in case of MAP, stevia and pippermint can be grown in jute seed-rice cropping sequence for higher income.

It is concluded that spices like ajwain, medicinal crop such as stevia and aromatic crop such as peppermint can be grown profitably in jute seed-MAPs and seed spices-autumn rice cropping sequence for higher income and making the jute growing farmers self sufficient in case of jute seeds.

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Influence of Planting Time and Spacing on Growth Parameters of Tuberose (*Polianthes tuberosa* L.)

Prince, G. S. Rana, D. S. Dahiya, Preeti and Manoj Bhanukar
Department of Horticulture, CCS Haryana Agriculture University, Hisar-125 004, India
E-mail: prince.hau@gmail.com

Abstract: The present study was carried out with four planting time (last week of March, second week of April, last week of April and second week of May) and three spacing (20 × 10 cm, 20 × 20 cm, 20 × 30 cm.) effect on tuberose growth. The last week of April planting at 20 × 10 cm spacing showed better results in terms of initiation of sprouting of bulbs, complete sprouting of bubs, whereas, at 20 x 30 cm spacing, the results in terms of plant height and number of leaves per plant of tuberose were better.

***Key Words*:** Growth, Planting time, Spacing, Tuberose

Polianthes tuberosa is a member of family Asparagaceae and is native of Mexico. It can be cultivated both in tropical and sub tropical condition. The tuberose flowers are used in preparation of garlands, floral ornaments, bouquets, etc. The long floral spikes are excellent material for table decoration. Many factors, like climatic conditions, fertility level of soil, size of bulbs, spacing and planting time, affect the yield and quality of flowers. The planting time and spacing is very important in tuberose production but due to varied agro-climatic conditions prevailing in India, tuberose is planted at different times in different parts of the country. It is planted in February and March in the plains and in April and May in the hills.

Spacing between plants is particularly important for the cultivation of tuberose to maximize flower quality and quantity characteristics. Khalaj *et al.* (2007) reported that length and diameter of plant shoot increases with higher plant spacing and, a spacing of 25 x25 cm produces the highest quality and quantity of flower and bulbs. The spacing of 30cm x 25cm recorded the maximum value of growth characters, flowering characters and corm yield characters in gladiolus (Vikrant *et al.,* 2007). It has been observed that early spike emergence and flowering occurred in tuberose at wider (30 x 30 cm) planting distances than narrow one (Mane *et al.,* 2006). Malam *et al.* (2010) observed that, the widest spacing (45 cm x 45 cm) registered the highest values for plant height, number of leaves clump^{-1} spike length, spike diameter, diameter of open flower, rachis length, number of spikes clump^{-1}, number of florets per spike, number of bulbs clump^{-1} and number of bulblets clump^{-1}. There is limited information on the effects of integrated use of planting time and spacing on growth parameters and quality of flower in tuberose. Hence, there is a need to work out the time of planting and spacing for tuberose in changing climatic conditions of Haryana. Therefore, the study was carried out with the objective to study the influence of planting time and spacing on growth parameters of tuberose.

MATERIALS AND METHODS

The investigation entitled on influence of planting time and spacing on growth parameters of tuberose (*Polianthes tuberosa* L.) was carried out at CCS Haryana Agricultural University, Hisar during 2013-14. Land was prepared and soil was brought to a fine tilth by repeated ploughing. Beds were prepared by maintaining plot bed size 1.20 × 1.20 m for planting of bulbs. Total number of beds prepared was thirty six. Before planting of bulbs, FYM was applied at the rate of 20 t ha^{-1} and mixed well into the soil. Standard dose of fertilizer were applied during the course of study. Fertilizers were applied at the ratio of 200 kg each of nitrogen, phosphorus and potassium ha^{-1} and incorporated into the soil. Half N and full dose of P_2O_5 and K_2O were applied as basal dose and the remaining half dose of N was applied after 40 days of planting in each plot. Prajwal variety of tuberose was selected for the study. The planting was done at fortnightly intervals starting in last week of March, second week of April, last week of April and second week of May in the year 2013. Bulbs were planted at three different spacing (20 × 10 cm, 20 × 20 cm, 20 × 30 cm). Planting depth was 5 cm in all treatments. The bulbs selected for planting had uniform diameter i.e. between 2.5-3.5 cm. First irrigation was given just after planting while subsequent irrigation was applied at the interval of 8 days. The data collected from ten plants were selected randomly and tagged in each treatment of three replications.

RESULTS AND DISCUSSION

The initiation of sprouting significantly influenced due to the planting time and spacing. The pair wise interactions between the treatments were also found significant (Table 1). The minimum number of days (9.21) initiation of sprouting was recorded in second week of May sown crop followed by last week of April planting, whereas, maximum (16.30) in last week of March. The reason for early sprouting in late sown condition might be due to increase atmospheric temperature, which played crucial role in growth of the plant, that eventually promoting sprouting. These results are in close conformity with earlier findings of Sheoran *et al.* (2014), Asif *et al.* (2001) and Ahmad *et al.* (2011) in tuberose. Maximum number of days (13.02) taken for initiation of sprouting was at 20 × 10 cm spacing and minimum (11.79) was recorded at 20 × 30 cm spacing. Number of days taken for initial sprouting in tuberose also significantly reduced with increasing levels of spacing over 20 × 10 cm and 20 × 20 cm. Shortening of initial sprouting period at wider spacing might be due to the fact that wider spaced plants had less competition for nutrients, water and light without any shading effect that resulted in early sprouting of bulbs. These results are in close conformity with Mane *et al.* (2006). The plants grown at S_3 in combination with T_4 took minimum days (8.66) for initiation of sprouting followed by S_2T_4 (9.20), while maximum days for initiation of sprouting (16.86) were observed with S_1T_1 combination.

The days taken for completion of sprouting also varied significantly due to different times of planting, spacing and interaction between the treatments (Table 1). The bulbs planted in last week of March took maximum number of days (19.90) to complete sprouting, whereas, planted in second week of May took minimum number of days (11.90) for completion of sprouting followed by last week of April planting. These results are in accordance with the findings of Sheoran *et al.* (2014) and Kumar *et al.* (2010) in tuberose. The combined effect of planting time and spacing also reduced the days taken for complete sprouting of bulbs significantly.

The time of planting significantly influenced the plant height 90 days after planting (Table 2). The planting done in last week of April produced plants with the maximum height (49.41 cm) at 90 days after planting followed by second week of April planting and minimum plant height (40.41 cm) was recorded in second week of May planting. This might be attributed to the fact, that during this period the day and night temperature was very favourable for the vegetative growth resulting in higher plant height at 90 days after planting. Short plant height was recorded in second week of May planting due to fluctuation in temperature prevailing at that time. Similar results were also obtained by Kulkarni and Reddy (2008) in chrysanthemum and Ghosh and Pal (2008) in marigold (*Tagetes erecta).* The plant height decreased significantly with the increasing levels of spacing. Maximum plant height (45.40 cm) was at 20 × 10 cm spacing followed by 20 x 20 cm, while short plant height was (43.17 cm) in 20 × 30 cm. The decrease in plant height with wider spacing can also be due to competition for light under inadequate spacing. These results are in agreement with the findings of Sheoran *et al.* (2014), Beniwal *et al.* (2005) and Mane *et al*. (2006) in tuberose. The interaction between different planting time and spacing showed significant increase in the plant height. Maximum plant height (51.46 cm) was in T_3 S_1 while minimum plant height (39.43 cm) was observed in T_4 S_3. Planting time and spacing in combination showed significant change in the plant height. Similar results were also obtained by Ghosh and Pal (2008) in marigold (*Tagetes erecta) and* Sheoran *et al.* (2014) in tuberose.

Leaves per plant: The planting done in last week of April resulted maximum number of leaves per plant (20.73) at 90 days after planting followed by second week of April planting (T_2), while minimum number of leaves per plant (19.54) was observed in second week of May planting (Table 2). This might be attributed to higher temperature and longer days prevailing during that period. According to earlier findings similar results were obtained by Asif *et al.* (2001) in tuberose

Table 1. Effect of planting time and spacing on days taken for initiation and complete of sprouting of bulbs in tuberose cv. Prajwal

Time of planting	Initiation of sprouting of bulbs				Complete sprouting of bulbs			
	Spacing			Mean	Spacing			Mean
	S_1 (20 x 10 cm)	S_2 (20 x 20 cm)	S_3 (20 x 30 cm)		S_1 (20 x 10 cm)	S_2 (20 x 20 cm)	S_3 (20 x 30 cm)	
T_1 (last week of March)	16.86	16.13	15.90	16.30	20.50	19.76	19.43	19.90
T_2 (second week of April)	14.30	13.76	12.90	13.65	17.90	17.40	16.36	17.22
T_3 (last week of April)	11.16	10.20	9.70	10.35	14.36	13.56	12.06	13.33
T_4 (second week of May)	9.76	9.20	8.66	9.21	12.36	12.20	11.13	11.90
Mean	13.02	12.32	11.79		16.28	15.73	14.75	
CD (p=0.05)	T = 0.16	S = 0.13	T x S = 0.27		T = 0.30	S = 0.26	T x S = 0.52	

Table 2. Effect of planting time and spacing on plant height and number of leaves at 90 days after planting in tuberose cv. Prajwal

Time of planting	Plant height (cm)				Number of leaves			
	Spacing			Mean	Spacing			Mean
	S_1 (20 x 10 cm)	S_2 (20 x 20 cm)	S_3 (20 x 30 cm)		S_1 (20 x 10 cm)	S_2 (20 x 20 cm)	S_3 (20 x 30 cm)	
T_1 (last week of March)	42.90	41.70	41.30	41.96	19.23	19.60	20.23	19.68
T_2 (second week of April)	45.70	45.33	44.70	45.24	19.36	19.76	20.43	19.85
T_3 (last week of April)	51.46	49.50	47.26	49.41	19.93	20.36	21.90	20.73
T_4 (second week of May)	41.56	40.23	39.43	40.41	19.10	19.50	20.03	19.54
Mean	45.40	44.19	43.17		19.40	19.80	20.65	
CD (p=0.05)	T = 0.37	S = 0.32	T x S = 0.64		T = 0.18	S = 0.16	T x S = 0.32	

and Kulkarni and Reddy (2008) in chrysanthemum. The numbers of leaves plant^{-1} were increased significantly with increased level of spacing. Maximum numbers of leaves plant^{-1} (20.65) was observed in 20 x 30 cm spacing followed by 20 x 20 cm, whereas, minimum (19.40) was in 20 x10 cm. The influence of different spacing on number of leaves per plant was to be obvious as spacing affected the competition between the plants for food, water and light. The interaction between different planting time and spacing was significant and exhibited on increase in number of leaves per plant at 90 days after planting. Maximum number of leaves (21.90) was in last week of April planting with wider spacing 20 x 30 cm, whereas minimum number of leaves per plant (19.10) was observed in second week of May planting with closer spacing 20 x 10 cm. This might be attributed to the fact, that during this period the day and night temperature along with the wider spacing was very favorable for the better uptake of nutrients and water from the soil resulting in maximum vegetative growth. These results are in close conformity with Asif *et al.* (2001) and Khalaj *et al.* (2012) in tuberose.

CONCLUSION

Results showed that planting of bulbs in last week of April increased the number of sprouting of bulb, plant height and number of leaves per plant. Overall performance of the plant in terms of growth, flowering and flower quality was better when the bulbs planted in last week of April at a spacing of 20 x 30 cm under agro-ecological condition of Haryana.

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Domestic and Export Potential of Organic Coconut in Coimbatore, Tamil Nadu, India

S. Menaka, K. Mani and R. Sangeetha

Department of Agricultural Economics, Center for Agricultural and Rural Development Studies
Tamil Nadu Agricultural University, Coimbatore-641 003, India
E-mail:ms.menaka@gmail.com

***Abstract*:** A study on domestic and export potential of organic coconut was conducted in Coimbatore district of Tamil Nadu. The details were collected from 30 organic and 30 inorganic coconut farmers. Result of the study revealed that gross income per hectare from organic and inorganic coconut farmers were Rs. 223093 and Rs. 161250, respectively. The net income per hectare of organic coconut and inorganic farms were Rs. 178170.8 and Rs. 130627, respectively. Nominal protection coefficient for united state was 0.1, 0.096 for Singapore and 0.090 for Malaysia. *Farmers ranked that the p*rice fixing mechanism for organic was the major constraint and it was followed by non availability of agricultural labor, long distance of markets, no premium price for the produce, material as second, third and fourth constraints, respectively.

***Key Words*:** Cost and returns, Domestic and export potential, Organic coconut

At present there is growing awareness and recognition of benefits of organic produces among the consumers in Coimbatore district. Government of India has implemented the National Programme for Organic Production (NPOP), which involves the accreditation programme for certification bodies, standards for organic production, promotion of organic farming, etc. Australia accounts for 12 million hectares of total area under organic farming across the world. India ranks 10th among cultivable land under organic certification and produced around 1.34 million tonnes of certified organic products which included sugarcane, cotton, coconut, basmati rice, pulses, tea, spices, coffee, oil seeds, and fruits. Organic farming is being promoted and is gaining acceptance all over the world, especially in Southeast Asia, as part of the latest efforts to encourage agriculture systems that are both socially and ecologically sustainable (Sharma and Singh, 2004). Over the last 15 years, the market for certified organic agricultural products has grown from a very low base to reach 1.5 to 2.5 per cent of total food sales in North America and the European Union (EU), and up to 5 per cent in Denmark and Switzerland. Singh (2010) reported that in India rice, wheat, pulses and vegetables were the prominent crops being grown under organic farming using organic manures like farmyard manure and vermin compost. . The objectives of the study are to assess the economics of organic coconut in Coimbatore district, to find out the export potential and to document the constraints faced by organic coconut farmers.

The cost of cultivation was estimated by using the methodology as used by commission on agriculture cost and price, Government of India. To find out the export potential, Nominal Protection Coefficient (NPC) was used. Thondamuthur, Madukkkari, Pollachi North, and Pollachi south areas of Coimbatore districts were selected for the study. For finding the domestic potential, 30 coconut farmers who got certification from the TNOCD (Tamil Nadu Organic Seed Certification Department) were selected randomly. To have a comparative study 30 inorganic coconut farmers were selected randomly. To study the export potential of coconut relevant particulars like, quantities of Organic Produce Exported from Tamil Nadu, countries to which coconut are exported, and constraints in organic produce export, were collected from the exporter using the interview schedule.

Nominal protection coefficient: NPC = Pd/Pw = Pw (1+t)/Pw, where Pd is domestic price of a product, Pw is world price of a product, t is tariff rate. If NPC <1, it implies that protected that is we can export our organic produce to the foreign countries. if NPC >1, dis-protected, it's not profitable to export our produce.

Garrett's Scoring Technique (for constrains): The respondents were asked to rank the problems in production, processing and marketing. In the Garrett's ranking technique these ranks were converted into pe rcent position by using the formula

$$\text{Percentage position} = \frac{100\,(R_{ij} - 0.5)}{N_j}$$

Where, R_{ij} = Rank given for i th factor by j th individual

N_j = Number of factors ranked by j th individual

Cost of cultivation of organic and inorganic coconut: In case of organic coconut the cost of hired human labour accounted for 2.04% of the total cost of cultivation, were as for the inorganic coconut it accounted for 6.33%. Similarly the

Table 1. Income of organic and inorganic coconut

Particulars	Organic coconut amount (Rs) ha $^{-1}$	Inorganic coconut amount (Rs) ha $^{-1}$
Hired human labour	5245 (2.04)	10200 (6.33)
Bullock labour	340 (0.13)	125 (0.08)
Hired farm machinery	507 (0.20)	555 (0.34)
Seedling	1562 (0.61)	1,200 (0.74)
Depreciation	1500 (0.58)	7240 (4.49)
Irrigation	2575 (1.00)	150 (0.09)
Organic manures	25000 (9.71)	1450 (0.90)
Electricity charges	450 (0.17)	3500 (2.17)
Interest on working capital	1729 (0.67)	1729 (1.07)
Other expenses (land revenue and other taxes)	1014 (0.39)	1014 (0.63)
Cost A_1 (1to 10)	39922 (15.50)	24463 (15.17)
Interest on value of owned capital asset	1500 (0.58)	1513 (0.94)
Cost 'B1' (11+12)	41422 (16.08)	25976 (16.11)
Rental value of owned land	2000 (0.78)	3000 (1.86)
Cost 'B2' (13+14)	43422 (16.86)	28976 (17.97)
Imputed value of family labour	1500 (0.58)	1647 (1.02)
Cost C_1 (13+16)	42922 (16.67)	28976 (17.35)
Cost C_2 (16+ 17)	44922 (17.44)	30623 (18.99)
Gross income	2,23,093 / ha	161250
Net income	Gross income – Cost C_2 = 178170.8/ha	Gross income – Cost C_2 = 130627/ha
Farm business income	Gross income – Cost A = 183171 /ha	Gross income – Cost A = 136787 /ha
Family labour income	Gross income – Cost B_2 =1,79,671 / ha	Gross income – Cost B_2 =132274 / ha

cost of organic manures accounted for 9.71% of the total cost of cultivation, whereas, the cost for inorganic manures accounted only 0.90 % of total cost. The costs B1, B2,C1 and C2 are higher for the inorganic coconut cultivation than organic coconut cultivation. The gross income from organic and inorganic coconut is Rs.223093 and Rs. 161250, respectively (Table 1). Net income from the organic coconut is Rs. 178170.8ha^{-1}, the farm business income is Rs. 183171 ha^{-1} and the family labour income is Rs. 179671 ha^{-1}, respectively. Net income from the inorganic coconut is Rs. 130627 ha^{-1}, the farm business income is Rs. 136787 ha^{-1} and the family labour income is Rs. 132274 ha^{-1}, respectively. The Nominal protection value for united state, Malaysia, Singapore, United Kingdom, Dubai, and Thailand were 0.1, 0.090, 0.096, 0.089, 0.086, and 0.084, respectively (Table 2). Hence we can gain from exporting our organic coconut to these six countries.

Table 2. Nominal protection coefficient

Countries	Domestic price / tender coconut (Rs)	World price / tender coconut (Rs)	NPC
United state	25	250	0.1
Malaysia	25	275	0.090
Singapore	25	260	0.096
United kingdom	25	280	0.089
Dubai	25	290	0.086
Thailand	25	295	0.084

Table 3. Constrains faced by organic coconut farmers

Constrains	Average score	Rank
Non availability of productive labour to agricultural work	74.4	2
Poor quality in drip irrigation materials and non suitability in spacing of knobs	8.26	5
Distance of markets	49.6	3
less cost for the produce	33.06	4
Price fixing mechanism for organic produce is not good	82.66	1

Farmers ranked that the price fixing mechanism for organic produce as first constraint, followed by non availability of productive agricultural labor, distance of markets, less cost for the produce, material and non suitability in spacing of knobs as second, third, fourth and fifth constraints, respectively.

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An Agri-Silvi-Horticultural System to Optimize Production, Quality and Cash Returns in Indo-Gangatic Alluvial Plains of Haryana

V. Dalal, K. K. Bhardwaj, Rajesh Kathwal and N. Kaushik
CCS Haryana Agricultural University, Hisar - 125 004, India
E-mail: v.dalal1979@gmail.com

Abstract: The study was carried out to check the effect of agri-silvi-horticultural system on yield and quality parameters of wheat crop under already established silvi-horticultural system with *Dalbergia sissoo* and *Prosopis cineraria* as timber component were taken as forest tree species and *Psidium guajava* and *Embilica officinalis* as fruit trees at 6 × 6 m spacing. Wheat (var. WH-711) was sown in the interspaces. The numbers of tillers, plant height, dry weight per meter row length, yield of grains per hectare of sole crop were significantly higher than agri-silvi-horticulture systems. Guava+Khejri system exhibited highest wheat yield. All quality parameters *viz*. protein content, sedimentation value and gluten content in wheat were significantly lower in crops grown as sole crop than the crops grown as intercrops with woody trees in different combinations. The protein content (11.60 and 11.33%) in sole wheat crop was significantly lower than agri-silvi-horticultural systems. The net return and benefit: cost ratio per hectare was recorded higher when wheat was intercropped with guava+shisham followed by guava+khejri combination than sole cropping.

Key Words: Agri-silvi-horticultural system, Economics, Growth, Light interception, Wheat, Yield

Haryana with geographical area of 4.42 million hectare is predominantly an agrarian state having 80% of its area under intensive and mechanical agriculture but the state is not be bestowed with a bountiful of natural forests. The forest occupies only 1587 km^2, which comes out to be about 3.85% of its geographical area. In view of the prevailing socioeconomic and agro-climatic conditions favourable for agriculture in the state, it is not possible to divert the fertile agriculture land to forests. The only option to increase the area under tree cover is to integrate the tree species with agricultural crops on farm lands. Productivity in horti-silvicultural system is comparatively higher than the productivity of sole agriculture and seems to be a potential viable land use system for maximization and sustainable productivity on farmers' field (Chauhan *et al.,* 2007). The soil quality and its production capacity can be restored and improved by adopting agro-forestry system like agri-silvi-horticulture system, which provides a way to sustain agricultural productions (Thakur and Kumar, 2006). Under dry land, horticultural fruit trees like guava and *ber* integrated with short duration arable crops like pulses, vegetables and groundnut proved to be the most profitable oriented among different agro-forestry systems (Giri Rao, 2009). A combination of *Prosopis cineraria* and *Ziziphus mauritiana* grown in agri-silvi-horticulture system had very little effect on wheat yield as an agricultural crop, thus, this system may be replicated and proposed for greater benefits in terms of fodder, fruit and food production in the arid environment (Singh *et al.,* 2012). With due cognizance of the above facts, the present experiment was planned to study the effect of agri-silvi-horticulture system comprising guava, *Aonla*, *Shisham* and *Khejri* in arid-ecosystem on growth, yield and economics of wheat.

MATERIAL AND METHODS

The present study was conducted at Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Bawal located in the low rainfall zone of the southern Haryana (28.1° N, 76.5° E and 266 m above mean sea level). The soil is loamy sand in texture, low in organic carbon and alkaline in reaction. The experiment was conducted at already established ten years old combinations of fruit and tree species namely shisham *(Dalbergia sissoo)* + aonla *(Embilica officinalis),* shisham (*D. sissoo)* + guava (*Psidium guajava),* khejri (*Prosopis cineraria)* + aonla (*E. officinalis)* and khejri (*P. cineraria)* + guava (*P. guajava) planted* at a spacing of 6m x 6m and wheat crop (WH-711) was grown as inter crop. Before sowing of winter crop, half dose of nitrogen (5 kg) and full dose of phosphorus (6 kg) and potash (4 kg) @ 100:60:40 kg NPK ha^{-1} were applied and mixed thoroughly into the soil. The remaining nitrogen was top dressed after first irrigation. For growth studies of wheat, number of plants per meter row length was counted after one week of germination; plant height was recorded at 30, 60, 90 and 120 days after sowing (DAS), number of tillers was recorded in running meter row length before harvesting, dry weight (g) was taken after harvesting of crop (per meter row length) from three locations in each plot till constant weight was attained and maturity dates were recorded for all treatments to work out the number of days taken to maturity. For yield attributes of wheat**,** number of ear head per meter row length was recorded at harvest from the places where the markers were inserted for counting plant population, number of grain per ear head was recorded out of ten ear heads in each plot at maturity stage before the harvesting, a complete sample of grains was taken from the final produce of each plot for recording the weight of 1000 grains in gram and after threshing the grain and straw yield from each plot were separately weighted in kg and was converted into the quintal per hectare. The quality component like protein and sedimentation values were determined in percentage using Micro-Kjeldahl's method (AACC, 1995) and gluten test on dry weight basis**.** The cost of cultivation and gross income of various treatments were calculated on the bases of approved market rates for inputs and outputs. To find out the net return, the cost was subtracted from the gross income of the received treatments. The experiment was conducted in randomized block design with three replications. The data were analyzed statistically as per method given by Panse and Sukhatme (1989).

RESULTS AND DISCUSSION

Growth studies of crops: There was no significant effect of woody trees on the germination of wheat crop during both the season of 2011-12 and 2012-13 as compared to sole crop (Table 1). However, germination in sole crop was slightly higher than the crop sown in agri-silvi-horticultural system. It might be due to moisture availability in agri-silvi-horticultural system, which is an important factor for the germination of seeds. The reason of moisture availability in agri-silvi-horticultural system was tree canopy, which reduced evaporation loss of soil surface (Datta and Singh, 2007). It was observed that the different combinations of agri-silvi-horticultural systems were at par with each other considering their effect on number of tillers per meter row length in wheat crop during both the years of study (Table 1). However, the number of tillers in sole crop was significantly higher than the tillers in crops grown with trees. The number of tillers in wheat during 2011-12 and 2012-13 were 76.70 and 77.80, respectively. There was 4.85 and 8.37% reduction in number of tillers per meter row length in wheat in guava + khejri based combination. However, the maximum reduction of 8.23 and 9.47% in wheat was observed in aonla + shisham combination during 2011-12 and 2012-13, respectively.

The plant height in agri-silvi-horticulture system was significantly higher than in sole crop at 30 days after sowing (DAS) in both the years of observation (Table 1). However, at 60 DAS, the plant height in sole wheat crop was

Table 1. Effects of agri-silvi-horticulture system on growth parameters of wheat during different years

Treatment	Plant germination (number of plants m^{-1})		No. of tillers m^{-1}		Plant height (cm)							
					30 days		60 days		90 days		120 days	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Sole crop	50.17	51.01	76.70	77.80	16.83	17.00	51.26	50.67	77.30	76.30	88.80	88.67
Aonla+shisham	45.95	44.03	70.38	70.43	23.06	24.20	48.90	49.32	71.46	70.00	84.18	84.67
Aonla+khejri	46.80	45.98	71.65	70.45	21.86	21.72	48.10	49.01	67.00	68.30	85.60	85.83
Guava+shisham	48.38	46.04	72.14	71.01	24.20	23.90	49.80	50.03	71.36	71.00	84.20	84.87
Guava+khejri	47.15	46.59	72.98	71.29	20.53	21.67	49.03	50.07	72.76	71.50	86.47	86.37
CD (p=0.05)	N.S.	N.S.	3.10	3.27	2.14	2.32	N.S.	N.S.	5.38	5.50.	2.31	1.98

mrl: Meter row lenght

at par with the crops under agri-silvi-horticulture system. However, at 90 and 120 DAS, the plant height in sole crop was significantly lower than the agri-silvi-horticulture system. The plant height in sole crop was significantly lower than the crop under agro-forestry system 30 days after sowing but at 60, 90 and 120 days after sowing, the plant height was significantly more in sole crop than the crop grown under agri-silvi-horticulture system. Within the agri-silvi-horticulture system, the plant height was significantly more in shisham based agri-silvi-horticulture system than the khejri based agro-forestry system. The data on dry matter accumulation per meter row length presented in Table 2 revealed that in sole wheat crop, the dry matter content (357.33 g and 385.33g) was significantly higher than all combinations of agri-silvi-horticulture system in 2011-12 and 2012-13, respectively. Among agri-silvi-horticulture system, significantly higher dry matter accumulation of wheat was recorded in guava based agro-forestry system than aonla based agro-forestry system.

The number of tillers, plant height, and dry weight per meter row length of sole crops were significantly higher than agri-silvi-horticulture systems (Table 1 and 2). This might be due to the reduced light intensity under agri-silvi-horticultural system. The maximum days taken to maturity in wheat (140.00) were recorded in aonla + shisham combination followed by guava + shisham (139.33) and minimum in guava + Khejri combination (137.50) followed by aonla + Khejri (138.50), however, the values were at par under agri-silvi-horticulture system. There was delayed maturity of crops sown under agri-silvi-horticultural system than sole crops due to negative interaction of trees on crops for light, moisture and change in microclimate under the trees. The longer duration for maturity under canopy may be due to continuous shade, which had adverse effects on reproductive growth. Delaying physiological maturity under low light, low temperature and higher humidity increased the seed filling duration (Rani *et al*., 2011; Hadi *et al*., 2006 and Nasurullahzadeh *et al*., 2007).

Yield and yield attributes: The number of ear head (71.01) was significantly higher in sole wheat crop than wheat crop sown with different combinations of horti silviculture system ranging between 65.10 and 67.23 (Table 4). However, the number of ear head was at par among different combinations of silvi-horticulture system during 2011-12 but in 2012-13, the number of ear head in sole wheat crop (70.59) was at par with wheat crop sown in guava based combinations. The number of grains per ear head was significantly higher in sole wheat crop than wheat crop grown under different combination of agri-horti-silviculture system during both the years of observations.

The test weight of wheat during the year 2011-12 and 2012-13 (32.46 and 33.78 g, respectively) was significantly higher in sole crop than all combinations of agri-silvi-horticulture system. The test weight of wheat sown with guava based silvicultural system was significantly higher than wheat sown with aonla based system (24.91and 25.85 g), whereas, the least test weight (24.91 and 25.85 g) of wheat crop grown under aonla + shisham based combination was recorded during both the years of observation.

The grain yield (40.67 and 40.80 q ha^{-1}) of sole wheat crop was significantly higher than all combinations of agri-silvi-horticulture system where the grain yield ranged between 23.43 and 30.18 q ha^{-1} in 2011-12 and 25.26 and 31.30 q ha^{-1} in 2012-13. Among agri-silvi-horticultural combinations, the guava based system supported significantly higher grain yield than aonla based combination during both the years of observation. Similar trend was observed in straw yield of wheat, where the straw yield of 47.90 and 51.07 q ha^{-1} in control (sole wheat) was significantly higher than all other treatments of agri-silvi-horticulture system.

Guava + Khejri based combination was recorded higher values for yield and yield attributes as compared to rest of the combinations. It might due to relatively lesser reduction of light under khejri canopy as compared to other combinations (Table 3). Higher crop yield under khejri tree canopy due to improved soil fertility have been reported earlier by several workers (Yadav *et al*., 2005; Singh *et al*.,

Table 2. Effects of agri-silvi-horticulture system on dry weight and maturity of wheat during different years

Treatment	Dry weight (g)		Days to maturity	
	2011-12	2012-13	2011-12	2012-13
Sole crop	357.33	358.00	132.66	131.67
Aonla+shisham	205.58	208.00	140.00	139.33
Aonla+khejri	219.52	223.00	138.50	137.00
Guava+shisham	255.81	257.48	139.33	138.02
Guava+khejri	264.85	263.03	137.50	136.57
CD (p=0.05)	14.94	15.79	2.92	2.90

Table 3. Light intensity (lux) in wheat crop under agri-silvi-horticulture system during 2011-12 and 2012-13 with average ISR (%)

Treatments	December 2011						December 2012						Avg. ISR(%)
	8 a.m.	10a.m.	12 noon	2 p.m.	4 p.m.	ISR (%)	8 a.m.	10 a.m.	12 noon	2 p.m.	4 p.m.	ISR (%)	
Sole crop	107.50	435.67	674.00	601.33	299.00		106.00	428.83	670.00	597.33	296.50		
Aonla+shisham	39.33	85.67	146.67	103.33	48.33	19.99	39.00	83.67	142.50	97.17	43.67	19.35	19.67
Aonla+khejri	51.50	103.83	157.83	111.33	52.50	22.53	47.67	101.17	154.00	107.50	50.00	21.93	22.23
Guava+shisham	44.17	93.00	158.67	150.83	47.67	23.35	41.17	88.83	155.67	147.17	44.33	22.74	23.05
Guava+khejri	66.83	106.17	165.67	178.67	50.67	26.82	64.50	106.17	163.67	176.67	48.67	26.67	26.75
CD (p=0.05)	22.75	44.88	93.69	56.65	20.07		23.25	44.16	94.46	56.87	20.00		
	January 2012						January 2013						
Sole crop	110.83	346.33	745.33	592.83	217.83		108.33	342.67	741.50	596.50	214.33		
Aonla+shisham	55.83	84.83	264.00	216.33	87.33	35.18	48.00	78.50	253.33	210.83	83.67	33.66	34.42
Aonla+khejri	60.00	135.17	269.00	233.50	103.50	39.80	52.83	130.33	265.17	230.33	100.83	38.91	39.36
Guava+shisham	56.50	114.33	316.00	214.33	91.50	39.37	48.50	111.00	305.17	208.17	78.17	37.49	38.43
Guava+khejri	57.33	129.67	323.50	271.50	109.67	44.29	52.67	126.17	317.83	265.00	99.67	43.00	43.65
CD (p=0.05)	7.92	35.05	72.94	36.03	37.04		5.61	36.52	77.83	30.51	37.25		
	February 2012						February 2013						
Sole crop	185.00	355.60	687.80	619.00	226.40		177.83	358.33	689.83	612.50	301.33		38.78
Aonla+shisham	71.50	154.00	263.33	233.00	133.17	39.96	68.00	144.00	222.80	219.00	125.80	37.59	40.41
Aonla+khejri	74.83	172.17	266.50	242.17	141.17	41.91	71.40	150.40	231.80	223.40	130.00	38.91	41.15
Guava+shisham	72.83	170.00	290.67	239.50	132.50	42.32	66.60	153.20	258.80	225.20	125.00	39.97	42.20
Guava+khejri	73.50	175.50	299.00	248.83	137.50	43.66	67.60	155.20	265.80	228.00	128.00	40.73	
CD (p=0.05)	39.88	44.38	65.87	50.00	17.31		39.61	43.56	54.24	31.77	31.17		
	March 2012						March 2013						
Sole crop	277.50	440.83	641.67	681.17	387.00		266.50	436.50	638.67	687.83	382.50		
Aonla+shisham	102.00	228.67	263.00	253.33	166.83	41.75	96.67	224.67	259.50	247.33	161.83	41.04	41.40
Aonla+khejri	105.50	233.33	277.00	265.00	173.17	43.41	100.00	229.33	272.83	261.00	170.17	42.84	43.13
Guava+shisham	107.00	234.67	268.50	284.50	173.33	43.98	102.00	231.33	260.83	277.83	167.00	43.08	43.53
Guava+khejri	111.50	243.33	296.67	294.17	175.83	46.19	106.83	239.00	294.17	285.33	172.83	45.53	45.86
CD (p=0.05)	38.45	48.63	60.74	97.85	22.89		33.20	49.38	61.56	85.13	24.01		

2008). Kaushik and Kumar (2003) also observed that khejri based agri-silvi system influenced the crop growth and grain yield positively in both *Kharif* and *Rabi* seasons. *Prosopis cineraria* not have any adverse allelopathic effect on plants under its canopy (Goel *et al*., 1989). Guava had positive impacts on crops grown under its canopy. Pateria *et al*. (2005) observed the maximum productivity of wheat grown under guava might be due to the fact that guava improves water holding capacity of the soil and organic carbon stock in the soil (Jalalzai *et al*., 2012). Singh *et al*. (2009) reported that root secretion of guava pushed up the yield of intercrops over its sole cropping.

Light interception: The light intensity recorded under different combinations of agri-silvi-horticulture system as well as in open (sole crops) at different times of the day from the month December to March at the surface of canopy of the crops is presented in Table 3 for the year 2011-12. Incidental solar radiation percentage ranged from 19.99 to 26.82 in December, 35.18 to 44.29 in January, 39.96 to 43.66 in February and 41.75 to 46.19 in March during 2011-12. Here, the maximum incidental solar radiation (ISR) percentage was received in guava + khejri combination and minimum in aonla + shisham combination. The highest light intensity was received at 12 noon followed by at 2PM. The light intensity received was significantly higher in sole crop than in agri-silvi-horticulture systems. Among the agri-silvi-horticulture systems, the light intensity received was at par though the light intensity received in different combinations and at different times was variable. Comparatively khejri based system received more light intensity than the shisham based system. Similar trend of light intensity was recorded during the year 2012-13.

Quality components: The data pertaining to quality parameters of wheat is presented in Table 5. All quality parameters *viz*., protein content, sedimentation value and gluten in wheat were significantly lower in crops grown as sole crop than the crops grown as intercrops with woody trees in different combinations, however, within agri-silvi-horticulture system, the quality parameters were at par during both years of observation. The protein content (11.60 and 11.33%) in sole wheat crop was significantly lower than other treatments, however, there was no significant difference among all combinations under agri-silvi-horticulture system. The increase in protein content might be attributed to prolonged shade under agro-forestry systems. Naeem *et al*. (2012) reported that there was a positive effect of shade on protein content in the cereal crop grains. A high soil moisture level associated with more moderate soil temperature in shade might result in a faster rate of N mineralization litter breakdown, and turnover of N than

Table 4. Effects of agri-silvi-horticulture system on yield and yield attributes of wheat during different years

Treatments	Yield attributes and yield									
	No. of earheads m^{-1}		No. of grains earhead^{-1}		Test weight (g)		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Sole crop	71.01	70.59	43.00	42.30	32.46	33.78	40.67	40.80	47.90	51.07
Aonla+shisham	65.10	66.00	36.12	37.01	24.91	25.85	23.43	25.26	29.29	31.58
Aonla+khejri	65.30	66.21	36.32	37.34	26.68	26.29	25.31	26.00	31.64	32.34
Guava+shisham	67.12	68.54	36.84	38.04	29.47	28.90	29.15	30.14	36.44	37.68
Guava+khejri	67.23	68.80	37.80	38.90	29.54	29.24	30.18	31.30	37.73	39.13
CD (p=0.05)	2.36	2.12	2.49	1.46	2.88	2.04	3.47	3.64	5.50	4.76

Table 5. Effect on quality parameters of wheat crop in agri-silvi-horticulture system

Treatments	Protein content (%)		Sedimentation value (ml)		Gluten (%)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Sole crop	11.60	11.33	35.00	35.33	10.45	10.36
Aonla+shisham	12.46	12.33	37.10	37.86	11.70	11.57
Aonla+khejri	13.10	13.07	37.80	37.92	12.42	12.43
Guava+shisham	12.96	12.83	38.66	38.70	12.11	12.00
Guava+khejri	13.26	13.17	38.90	38.80	12.57	12.60
CD (p=0.05)	0.81	0.90	2.03	2.49	0.94	1.07

Table 6. Economics of agri-silvi-horticulture systems with sole winter crops

Treatments	2011-12				2012-13			
	Gross return	Return over variable cost	Net return	B:C ratio	Gross return	Return over variable cost	Net return	B:C ratio
Sole crop	62566	31847	11953	1.24	68564	37845	17951	1.35
Aonla+shisham	150144	79200	50186	1.50	175857	104913	75900	1.76
Aonla+khejri	147395	76451	47438	1.47	166959	96016	67002	1.67
Guava+shisham	174621	103677	74663	1.75	220386	149442	120428	2.20
Guava+khejri	165327	94383	65369	1.65	212730	141786	112772	2.13

occurred in full sunlight (Humphreys, 1994; Wilson, 1996). The increased crude protein in shaded plants could be associated with reduced cell size caused by shade. Kephart and Buxton (1993) speculated that the reduced cell size, with a near-constant quantity of N per cell, might have a concentrating effect. Humphreys (1994) attributed this phenomenon to increasing N uptake of shaded grasses since he could not account for it by a diversion of N from root to shoot or the enhanced N-fixing activity of shaded plants.

The values of gluten (%) and sedimentation (ml) were significantly higher under agri-silvi-horticulture system than sole crop of wheat (open), however, there was no significant difference among all the combinations under study. Both the components (gluten content and sedimentation value) were directly correlated with each other. The less content of gluten in sole wheat (10.45 and 10.36%) might be due to heat stress. This occurs when the crop is subjected to high temperature during grain filling, particularly in the period just before harvest. This is the critical period when post-translational glutenin polymerization proceeds most rapidly. The comparable effects have been confirmed by earlier workers (Blumenthal *et al.,* 1993; Stone and Nicolas, 1994). It has been earlier reported that dough strength (gluten) increased as daily mean temperature increased up to 30°C during grain filling and then decreased as the temperature increased above 30°C (Randall and Moss, 1990). The heat stress also cause a reduction in the size of glutenin polymers (Ciaffi *et al*., 1996; Stone and Nicolas, 1996).

Economics: The data on economics of sole crops and crops grown under agri-silvi-horticulture system given in Table 6 reveal that the highest gross return of Rs.174621 per hectare was recorded under guava + shisham + wheat combination in 2011-12 and Rs. 220386 in 2012-13. The highest return over variable cost of Rs.103677 per hectare was recorded from guava + *s*hisham + wheat combination in 2011-12. The highest net return (Rs 74663) was recorded in guava + shisham + wheat combination in 2011-12. The benefit cost ratio of agri-silvi-horticulture system was higher than sole crop. Based on two years' average, the data revealed that agri-silvi-horticultural system fetched higher net return as well as benefit: cost ratio over sole crops. This was certainly due to additional yield of fruits from fruit trees and wood from forest trees at the end of rotation. These findings are in close agreement with those of Banerjee *et al.* (2008) and Chauhan *et al.* (2015) for higher productivity of crops under agro-forestry systems and a higher market price of the produce. Kaushik *et al*. (2002) also reported higher returns in agri-horti-silvicultural system.

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Biomass and Carbon Sequestration Potential of *Simarouba glauca* under Dry Land of Hyderabad, Telangana

M. B. Noor Mohamed, G. Rajeshwar Rao[1], P. Sharath Kumar[1] and P. Sathi Reddy[1]

Central Arid zone Research Institute, Regional Research Station, Pali-Marwar-306 401, India.
[1]Central Research Institute for Dryland Agriculture, Hyderabad- 500 059, India.
E-mail: mohamedforester@gmail.com

Abstract: In the present day scenario, the enhancement of atmospheric CO_2 coupled with the rise in temperature is the main reason behind the global climate change. Carbon sequestration through biomass seems to be a cheap and viable option to mitigate the increasing concentrations of green house gases. With this background the study has conducted to estimate biomass and carbon allocation of 10 year old *Simarouba glauca* plantation under different diameter classes in Central Research Institute for Dry land Agriculture, Hyderabad. Higher total biomass recorded in *Simarouba glauca* was 169.0 kg tree^{-1} and 468.1 t ha^{-1} in 20-30 diameter class followed by 10-20 cm (57.81 kg tree^{-1} and 160.1 t ha^{-1}) diameter class. The average total carbon stock was recorded as 36.89 kg tree^{-1} and 102.2 t ha^{-1}. The carbon dioxide equivalent showed an increasing trend with increased diameter class among the different diameter classes. The average total CO_2 equivalent recorded in *Simarouba glauca* was 135.0 kg tree^{-1} and 374.1 t ha^{-1}. The total biomass of ten year old *Simarouba glauca* was 246.2 t ha^{-1} and carbon stock was 103.5 t ha^{-1} and a single tree accounts about 88.91 kg tree^{-1} and 36.89 kg tree^{-1} respectively. The above ground biomass components were contributed 71.82% and below ground components contributed 28.17 % to the total biomass and carbon of the tree. In above ground biomass, secondary branches of *Simarouba glauca* were contributed highest biomass and carbon allocation of 31.92 per cent followed by primary branch, primary root and stem.

Key Words: Biomass, Carbon Sequestration, Carbon Stock, *Simarouba glauca*

Global climate change has been given attention, since long time in many fields, the increasing CO_2 concentration in atmosphere is considered as one of the main driving force for global warming. Carbon dioxide (CO_2) is one of the main greenhouse gases when compare to other greenhouse gases because a huge volume of CO_2 is added to the atmosphere and made itself as a primary agent of global warming. It contributes 72 per cent of the total anthropogenic greenhouse gases, causing between 9-26 per cent of the greenhouse effect (Kiehl and Trenberth, 1997). The IPCC estimates that the level of carbon dioxide in today's atmosphere is 31 per cent higher than it was at the start of the Industrial Revolution about 250 years ago. An atmospheric level of CO_2 has risen from 280 ppm at the pre-industrial to the present level of 375 ppm. The mitigation of climate change demands, determined commitment of scientists to develop strategies to effectively manage the issues of the changing climate through carbon sequestration. Carbon sequestration is ought to be a promising solution for reducing atmospheric carbon dioxide, an important greenhouse gas.

Sequestration of biomass carbon is considered as the most promising approach to mitigate the climate change (Kimble *et al*., 2002). At global level, trees contribute 80-90% of plant biomass carbon and 30-40% soil carbon (Hervey, 2000). Therefore, trees can play important role in carbon di oxide sequestration due to several reasons. The first is that the tree components fixes and stores carbon from atmosphere via photo synthesis. They can function as active carbon for the periods of many years and continue to store the carbon until they are harvested or die. The second reason is that trees can provide a good surface cover which minimizes the loss of nutrients from the surface soil, improve edaphic conditions, increase biomass production, decrease the risk of soil degradation by erosion, leaching and nutrient depletion. Finally trees are one of the viable alternatives to increase forest cover which will widen the area of carbon sink. In the view of the above, a study was conducted on the most demanding commercial and valuable oil yielding species viz., *Simarouba glauca* belongs to the family Simaroubaceae. However, a methodology for evaluating the biological components of carbon flux remains a significant researchable issue. Differences in per cent carbon among different tree species and among wood types within a single tree (Lamlom and Savidge, 2003) indicated that the need to estimate biomass and carbon content for each species and its tree component. Most published studies on this subject have been focused on total aboveground biomass and carbon, whereas discrimination among the different parts of the tree, wood types, and stocking densities by diameter is rarely done.

The present study was therefore designed to estimate that *Simarouba glauca* plantations have potential to significantly support carbon stocks and carbon sequestration and thereby mitigate CO_2 from the atmosphere. The study was planned to estimate growth and biomass production, carbon capture potential and its distribution in the different parts of *Simarouba glauca* in Dryland of Hyderabad, Telangana.

MATERIALS AND METHODS

This study was conducted at Central Research Institute for Dry land Agriculture, Hyderabad at located at $17^{0}27'$N latitude, $78^{o}35'$ longitude with above mean sea level of 515 m. The mean annual temperature is 13.5°-38.6°C and the mean annual rainfall is 755 mm. The experimental soil represented alfisol soil order (typic Haplustalf), with pH slightly acidic to neutral (6.4) and EC 0.085 dS m-1. The soils were low in available nitrogen (145 kg ha^{-1}), medium in available phosphorus (13.0 kg P ha^{-1}) and available potassium (175 kg ha^{-1}). The ten year old S*imarouba glauca* plantation was selected for carbon sequestration study with 6X6m spacing. The experiment was carried out during 15^{th} November, 2014 to 15^{th} February, 2015 in winter season.

Demarcation and enumeration for measurements: The entire field was divided into plots of equal size and within each plot, 25% of the trees were marked representing the population and the growth parameters of these trees were monitored at regular intervals. Trees were harvested during November, 2014 – February, 2015. Entire plantation was divided into three diameter classes *viz,* 0-10, 10 -20 and 20-30cm for measuring the growth parameters. Three representative trees from each diameter class were selected for destructive sampling. Growth variables *viz*., tree height, basal diameter, DBH, crown height and crown width were measured before felling of trees. These measurements were recorded as per established procedure (Plate 1).

Biomass estimation: After recording the total height and DBH of the felled trees, the above ground portions were separated into wood, branches and leaves. For below ground biomass estimation, pits were excavated and complete recovery of roots was done from tree base. Fresh weights of the entire above and below ground tree components were recorded immediately after felling using appropriate spring scales (Plate 1). A small sample (500 gram) of wood, branches and leaves was immediately transferred to the laboratory in double sealed polythene bags. The collected samples were dried at 80 °C till constant weight was obtained. The oven dry weight of the whole sample was calculated using the formula given below (Gnana Mathuram, 2009).

$$\text{Dry weight of the tree biomass} = \frac{\text{Oven dry weight of the sample}}{\text{Fresh weight of the sample}} \times \text{Fresh weight of the whole tree}$$

Biomass carbon estimation of plantation: The plant samples of various components *viz*., stem, branches, leaves and roots of the targeted trees species were collected separately, air dried and oven dried. Oven dried biomass samples were grounded in Willey Mill and carbon concentration in different tree components were determined based on ash per cent and determined by the procedure given by Allen *et al*. (1986).

$$\text{Ash \%} = \frac{(W_3-W_1)}{(W_2-W_1)} \times 100$$

Where,

W_1 = Weight of crucibles

W_2 = Weight of oven dried powdered samples + crucibles

W_3 = weight of ash + crucibles

Carbon per cent estimation in biomass: Carbon per cent in above ground biomass, below ground biomass, litter and dead organic matter was estimated followed by Negi *et al.* (2003) and Dhruw *et al*. (2009) using the follwing formula given below.

Carbon % = 100% - {Ash % + Molecular weight of O_2 (53.3 %) in $C_6H_{12}O_6$}

Biomass carbon stock: The carbon stock in the above ground biomass, below ground biomass, litter and dead organic matter was computed by using the following formula given below (Wani *et al.,* 2014) as Carbon = Biomass x Carbon per cent.

The total biomass carbon was calculated by using the following formula,

Total biomass carbon stock (t C ha^{-1}) = AGB carbon + BGB carbon

Carbon dioxide equivalent (CO_2e): The carbon dioxide equivalent was calculated by multiplying carbon stock by 3.67.

RESULTS AND DISCUSSION

Growth characteristics of *Simarouba glauca*: Among the different diameter classes, the tree height, DBH, basal diameter, crown height and crown width showed an increased trend with increased diameter class. The maximum plant height was as 4.60 m under diameter class 20-30 cm and minimum was 3.40 m under diameter class 0-10 cm during the year 2014-15. The basal diameter was maximum (25.2 cm) in 20-30 cm diameter class and minimum (8.00 cm) 0-10 cm diameter class. Increase in basal area with the increase in diameter class could be due to increase in diameter (Wani *et al.,* 2014). Several other workers also support the current findings for height, basal

Table 1. Descriptive statistics of *Simarouba glauca*

Variables	Minimum	Maximum	Mean
Tree height (m)	3.400	4.600	3.955
Basal diameter (cm)	8.000	25.20	16.12
Number of branches (numbers tree^{-1})	10.00	15.00	12.66
DBH (cm)	3.500	5.600	4.555
Crown height (m)	0.350	0.620	0.464
Crown width (m)	3.800	5.700	4.583
Leaves biomass (kg tree^{-1})	2.000	8.800	4.455
Stem biomass (kg tree^{-1})	4.500	21.00	10.99
Primary branch biomass (kg tree^{-1})	7.280	36.00	18.65
Secondary branch biomass (kg tree^{-1})	11.04	55.53	27.72
Above ground biomass (kg tree^{-1})	27.95	118.8	61.82
Below ground biomass (kg tree^{-1})	48.41	10.34	24.57
Total biomass (above and below ground) (kg tree^{-1})	38.29	167.2	86.40

area, DBH and volume (Heriansyah *et al.,* 2007; Arifin *et al.,* 2008).The mean value of number of branches increased significantly at various diameter classes. The maximum number of branches was recorded in 20-30 cm diameter class (15.00) and minimum in 0-10 cm diameter class (10). Consequently, the DBH was recorded maximum (5.60 cm) in higher diameter class and minimum (3.50 cm) in lower diameter class. The maximum crown height and crown width recorded in higher diameter classes were 0.62 m and 5.70 m, respectively.

Biomass production of *Simarouba glauca:* The results on above and below ground biomass of *Simarouba glauca* suggests that average total biomass (kg tree^{-1} and t ha^{-1}) increased with a corresponding increase in diameter class (20-30 cm) (Table 2 and Fig. 1). Among the targeted species *Simarouba glauca* recorded higher total biomass of 169.0 kg tree^{-1} and 468.1 t ha^{-1} in 20-30 diameter class followed by 10-20 cm diameter class. The lowest total biomass was observed in 0-10 cm diameter class. The average total biomass of *Simarouba glauca* were 88.91 kg tree^{-1} and 246.2 t ha^{-1}. The maximum leaf biomass (8.190 kg tree^{-1} and 22.68 t ha^{-1}), stem biomass (20.62 kg tree^{-1} and 55.45 t ha^{-1}), primary branch biomass (35.75 kg tree^{-1} and 99.02 t ha^{-1}), secondary branch biomass (55.91 kg tree^{-1} and 154.8 t ha^{-1}) and root biomass (48.77 kg tree^{-1} and 136.0 t ha^{-1}) under 20-30 cm diameter class during 2014-15. The differences in the proportions of branches were affected by the form and size of the branches and structure of large and small branch sizes in the canopy (Heriansyah *et al.,* 2007). Among the fractionated plant parts, the average secondary branch biomass was maximum in *Simarouba glauca* (27.96 kg tree^{-1} and 77.54 t ha^{-1}) followed by root biomass, primary branch biomass, stem biomass and leaf biomass. Wani *et al.* (2014) reported that trees produce large root system that needed for uptake of soil resources, thus resulting in higher values in higher diameter class. Several other worker also support this findings (Bhardwaj *et al.,* 2001; Raizda *et al.,* 2007; Yadava, 2010a; Uma *et al.,* 2011) who reported that root biomass is more in higher diameter class as compared to lower diameter class.

Estimation of carbon stock in *Simarouba glauca:* There was a significant difference in carbon content in biomass components of different diameter class. The biomass carbon stock showed an increased trend with the increase in diameter class. The average total carbon stock was 36.89 kg tree^{-1} and 102.2 t ha^{-1}. The average above ground biomass carbon stock was 26.86 kg tree^{-1} and 74.40 t ha^{-1}. Terakunpisut *et al.* (2007) has reported that carbon stock is more in trees having a greater diameter as compared to smaller diameter. Our result was accordance with the findings of Ryan *et al.* (2010) and Rizvi *et al.* (2011). The average secondary branch component and root component of *Simarouba glauca* recorded highest carbon content of 11.92 kg tree^{-1} and 33.04 t ha^{-1} and 10.03 kg tree^{-1} and 27.80 t ha^{-1}. Leaf biomass was lowest carbon stock of 1.549 kg tree^{-1} and 4.291t ha^{-1}. Finally, the carbon stock of fractionated parts *viz*., leaf carbon (2.923 kg tree^{-1} and 8.099 t ha^{-1}), stem carbon (8.122 kg tree^{-1} and 22.49 t ha^{-1}), primary branch carbon (15.23 kg tree^{-1} and 42.19 t ha^{-1}), secondary branch carbon (23.85 kg tree^{-1} and 66.06 t ha^{-1}) and root carbon (19.99 kg tree^{-1} and 55.38 t ha^{-1}) had expressed maximum carbon stock under higher diameter class (20-30 cm). Total carbon stock in 20-30 cm diameter class was 169.0 kg tree^{-1} and 468.1 t ha^{-1}. The average secondary branch component and root component of *Simarouba glauca* recorded highest carbon content of 11.92 kg tree^{-1} and 33.04 t ha^{-1} and 10.03 kg

Table 2. Biomass of *Simarouba glauca*

Basal diameter class	Leaf biomass		Stem biomass		Primary branch biomass		Secondary branch biomass		Above ground biomass		Below ground biomass /root biomass		Total biomass	
	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}
0-10	2.080	5.761	5.346	14.80	10.69	29.61	11.29	31.27	29.40	81.44	10.54	29.19	39.94	110.6
10-20	2.750	7.617	8.302	22.99	15.76	43.65	16.67	46.23	43.50	120.4	14.13	39.63	57.81	160.1
20-30	8.190	22.68	20.62	55.45	35.75	99.02	55.91	154.8	119.8	332.0	48.77	136.0	169.0	468.1
Mean	4.34	12.02	11.22	31.08	20.73	57.43	27.96	77.45	64.25	177.9	24.66	68.30	88.91	246.2

Table 3. Biomass carbon stock of *Simarouba glauca*

Basal diameter class	Leaf carbon		Stem carbon		Primary branch carbon		Secondary branch carbon		Above ground biomass carbon		below ground biomass /root carbon		Total carbon	
	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}
0-10	0.742	2.056	2.168	6.007	4.555	12.61	4.816	13.34	12.28	34.01	4.289	11.88	16.56	45.89
10-20	0.981	2.719	3.368	9.329	6.715	18.60	7.119	19.72	18.18	50.36	5.824	16.13	24.00	66.49
20-30	2.923	8.099	8.122	22.49	15.23	42.19	23.85	66.06	50.12	138.8	19.99	55.38	70.11	194.2
Mean	1.549	4.291	4.553	12.61	8.834	24.47	11.92	33.04	26.86	74.40	10.03	27.80	36.89	102.2

Table 4. CO_2 equivalent of *Simarouba glauca*

Basal diameter class	Leaf CO_2 equivalent		Stem CO_2 equivalent		Primary branch CO_2 equivalent		Secondary branch CO_2 equivalent		Above ground biomass CO_2 equivalent		Below ground biomass / root CO_2 equivalent		Total CO_2 equivalent	
	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}	kg tree^{-1}	t ha^{-1}
0-10	2.717	7.528	7.938	21.98	16.67	46.17	17.62	48.82	44.94	124.4	15.70	43.49	60.64	167.9
10-20	3.593	9.953	12.32	34.14	24.57	68.08	26.05	72.18	66.54	184.3	21.31	59.04	87.85	243.3
20-30	10.70	29.64	29.72	82.34	55.75	154.4	87.29	241.8	183.4	508.2	73.18	202.7	256.6	710.9
Mean	5.670	15.70	16.66	46.15	32.33	89.56	43.66	120.9	98.31	272.3	36.73	101.7	135.0	374.1

Table 5. Per cent allocation in different parts of *Simarouba glauca*

Components	Biomass (t ha^{-1})	Carbon (t ha^{-1})	Per cent contribution
Above ground biomass			
Leaf	12.02	4.291	4.145
Stem	31.08	12.61	12.18
Primary branches	57.43	24.47	23.64
Secondary branches	77.45	33.04	31.92
Below ground biomass			
Primary roots	54.17	23.13	22.34
Secondary roots	10.35	4.422	4.270
Tertiary roots	3.797	1.621	1.566
Total biomass	246.2	103.5	100.0

tree^{-1} and 27.80 t ha^{-1}. Our results corroborate with the findings of Matala *et al.* (2009), Tolunay (2011) and Rizvi *et al.* (2011). The present study also revealed that carbon percentage was more in stem and root when compared to branch and leaf. Similar variation in carbon content was reported by Dhruw *et al.* (2009).

Carbon dioxide mitigation potential (CO_2e) of *Simarouba glauca:* The average total CO_2 equivalent in *Simarouba glauca* tree was 135.0 kg tree^{-1} and 374.1 t ha^{-1}. The amount of carbon held by trees in per tree and hectare basis revealed that *Simarouba glauca* accounted the highest average CO_2 equivalent in root (36.73 kg tree^{-1} and 101.7 t ha^{-1}), secondary branch, primary branch and stem. The lowest CO_2 equivalent was registered in average leaf biomass (5.670 kg tree^{-1} and 15.70 t ha^{-1}). The maximum CO_2 equivalent were registered in the tree components of *Simarouba glauca* viz., root (73.18 kg tree^{-1} and 202.7 t ha^{-1}), secondary branch (87.29 kg tree^{-1} and 241.8 t ha^{-1}), primary branch (55.75 kg tree^{-1} and 154.4 t ha^{-1}), stem (29.72 kg tree^{-1} and 82.34 t ha^{-1}) and leaf (10.70 kg tree^{-1} and 29.64 t ha^{-1}) under higher diameter classes (20-30 cm). The maximum CO_2 equivalent were accounted in total (256.6 kg tree^{-1} and 710.9 t ha^{-1}), above ground (183.4 kg tree^{-1} and 508.2 t ha^{-1}) and below ground biomass (73.18 kg tree^{-1} and 202.7 t ha^{-1}) under 20-30 cm diameter class. In recent study, Yadava (2010b) has reported that CO_2 mitigation potential is more in higher diameter class as compared to lower diameter class because of more biomass in higher diameter class. The results are in conformity with the findings of Lal and Singh (2000), Albrecht and Kandji (2003), Uma *et al.* (2011), Yadava (2011) and Fonseca (2012).

Percent contribution of biomass and carbon allocation in different components of *Simarouba glauca:* There was a significant difference in biomass and carbon allocation in biomass components of different tree species (Table 5). The ten year old *Simarouba glauca* had a total biomass was 246.2 t ha^{-1} and carbon stock was 103.5 t ha^{-1} and a single tree accounts about 88.91kg tree^{-1} and 36.89 91kg tree^{-1} respectively. The above ground components were contributed 71.82% and below ground components contributed 28.17% to the total biomass and carbon of the tree. The secondary branch component of *Simarouba glauca* recorded highest biomass and carbon allocation of 31.92% followed by primary branch, primary root and stem. Similar variation in carbon content was reported by Dhruw *et al.* (2009). The lowest percentage contribution of biomass and carbon was allocated in tertiary roots (1.566%) followed by leaf and secondary roots. The variation in carbon content of different parts of the tree was also reported by Kaur *et al*. (2002), Ludang and Jaya (2007) and Negi *et al.* (2003). They estimated the carbon allocation in different components of some Indian trees and conclude that wood accumulated more carbon content when compare to leaf and bark in different genera of trees pertaining to conifers, deciduous, dicotyledons, evergreen dicotyledons, monocotyledon and exotic tree species.

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Functional Attributes of Herbaceous Vegetation along Altitudinal Gradient in North-Western Himalaya

Amir Bhat , B. Gupta[1] and P. A. Khan

Sher-e-Kashmir University of Agricultural Sciences & Technology-Kashmir, Srinagar-191 210, India
[1]Dr. Y.S.Parmar University of Horticulture and Forestry, Solan-173 230, India
E-Mail: fabamir@gmail.com

Abstract: Functional attributes of herbaceous vegetation along altitudinal gradient in Northwestern Himalaya revealed a total of 89 species from 59 families that include forbs (53), grasses (22), ferns (5), sedges (5) and legumes (4). Distribution of species in different families revealed that most of the families were represented by maximum of three species only. *Poaceae, Asteraceae, Cyperaceae, Lamiaceae, Ranunculaceae* and *Rutaceae* were represented by multiple species in decreasing order. Out of total 89 species, only 13 were common to all forests viz., *Agrostis pilosula, Avena fatua, Chrysopogon gryllus, Heteropogon contortus, Themeda anthera, Urochloa panicoides, Cyperus rotundus, Eriophorum comosum, Desmodium floribundum, Anaphalis busua, Bidens pillosa, Chenopodium album* and *Dicliptra bupleorides.* Biomass of herbage in different elevations varied from 2.48 t ha^{-1} to 4.82 t ha^{-1} in *Acacia* forest, 1.49 t ha^{-1} to 4.90 t ha^{-1} in chir pine forest, 1.67 t ha^{-1} to 2.74 t ha^{-1} in mixed forest, 1.52 t ha^{-1} to 2.70 t ha^{-1} in deodar forest and 1.27 t ha^{-1} to 2.68 t ha^{-1} in fir-spruce forest. These species exhibited wide ecological amplitude which confirms their ability to sustain successfully through different climatic conditions. Thus, relationship between diversity and carbon sequestration could play an important role for the management of these ecosystems that focus on forest conservation and management.

Key Words: Biomass, Carbon sequestration, Forbs, Herbaceous, Northwestern Himalaya

Forest composition, community structure and diversity patterns are important ecological attributes significantly correlated with environmental variables. Insight into floristic composition and structure of forests are essential for providing information on species richness of the plants and the changes that they undergo can be potentially useful for management purposes and assist in understanding ecosystem functioning.

The pattern and relationship between species diversity and ecosystem functioning are the current areas of great ecological interest throughout the world and thus conservation of such diversity has become a major concern for the sustainable development of the society and ecosystem in this context, understanding the qualitative and quantitative information in relation to structural and functional dynamic is essential for biodiversity conservation and sustainable management of fragile ecosystems. Another important significance of plant diversity is of carbon economy. With 1-2%, the contribution of the understorey vegetation to above ground biomass in forest ecosystem is relatively low compared to the tree layer. However, as herbaceous plants have up to threefold higher density concentration than trees, the importance of the understorey vegetation for nutrient cycling is over proportionate to its biomass.

A fundamental characteristic of mountain ecosystem is the pertinent change in vegetation as well as the climate from the base to the summit of the mountain. Each species grows in a certain temperature range above and below which it is replaced by other species, resulting in altitudinal zonation in vegetation hills. Thus, in North-western India, tropical broadleaved forest is found in the plains and lower hills, above this sub tropical pine forest, temperate deodar forest, temperate mixed coniferous forest, oak forest and finally alpine vegetation. The study on relationship between species distribution along the elevation provides the baseline information to measure the effect of climate change. The Himalayas, extending to about 2700 km in length and average 200 km across have played a very important role in evolution of species. These mountain ranges are well known for their climatic, floristic, faunistic and geological diversity. Hence, the present study is undertaken with a view to study dynamics of ground vegetation during the growing season along different elevations.

MATERIAL AND METHODS

The present investigation entitled on functional attributes of herbaceous vegetation along altitudinal gradient in North-western Himalaya was carried out during 2011-12. The study was conducted in Sirmour district of Himachal Pradesh which lies in between $77^{0}\ 01^{'}\ 12^{''}$ to $77^{o}\ 49^{'}\ 40^{''}$ E longitude up to $30^{0}\ 22^{'}\ 30^{''}$ to $31^{o}\ 01^{'}\ 20^{''}$ N latitude in the Northwest Himalaya (India). Total geographical area of this district is 820.02 km^2 with altitude ranging from 600m to

2700m above mean sea level and forest cover of 31.69% area. The area is mostly mountainous lying in and outer middle Himalaya with little south west portion in Siwaliks, divided into two separate regions; trans-Giri region covering north-east and cis–Giri region covering south-western region of the area. The forests does not form a continuous and compact belt but are scattered all over the area that stretch from banks of Ghaggar and Giri rivers to the tops of lofty ranges and exhibit diversity in climate resulting in diversified and rich forest flora starting with riverian to temperate forests (Table 1). The riverian forests are dominated by like *Acacia, Dalbergia,* etc. which are replaced by dry mixed deciduous forests above the banks of stream that continue up to elevation of about 1000m where after it is taken over by *Pinus roxburghii*, *Acer,* etc., which extends up to 2000m beyond which there is continuous stretch of *Pinus wallichiana, Cedrus deodara*, *Quercus floribundum* and ending up with *Picea smithiana*, *Abies pindrow* and *Quercus semicarpifolia* The villagers depend on forest herbaceous growth for maintaining their livestock.

The climate of the study area is sub-humid to sub-temperate. The area received monthly rainfall between 30-262.60 mm with maximum rainfall in the month of July. Monthly relative humidity during study period varied between 67 to 80%. Monthly mean maximum temperature ranged from 27.4 to 29.9°C and mean monthly minimum temperature varied from 9.8 to 19.2°C. The rocks of study area are represented by lower Shiwalik formation and outer Himalayan zone chiefly composed of conglomerate, shale, red marl, sandstone, limestone and clay. The soils in lower zone are shallow in depth and poor in fertility, while soils in upper reaches are formed under coniferous vegetation, are rich in organic matter.

Estimation of herbaceous biomass: Herbaceous vegetation in different forests along altitude was studied in the growing season (July to October). Biomass of all the herbaceous vegetation was estimated by laying down 50cm x 50cm quadrates. Shoot biomass of all herbaceous species was harvested at ground level and root biomass was sampled using 25cm x 25cm x 30cm monolith. The different herb species in each quadrat were packed in paper bags separately and oven dried at 65±5°C for 72 hours to a constant dry weight. The roots of different species were extracted separately, washed in running water using fine mesh on 2.0 and 0.5 mm mesh screens packed in paper bags, oven dried at 65 ± 5°C for 72 hours till a constant dry weight was attained for further calculations. Total biomass was calculated by adding above ground and below ground biomass of each species.

Estimation of carbon stock: Above and below ground carbon of herbaceous vegetation was determined by multiplying above and below ground biomass with carbon conversion factor of 0.45 (Woomer, 1999). Total carbon of each species was determined by adding above ground and below ground carbon.

RESULTS AND DISCUSSION

Floristic composition under different elevations: At elevation E_1, a total of 46 species were recorded with grasses (19), legumes (2), sedges (4) and forbs (22). At elevation E_2 53 plant species were present which included grasses (17), legumes (3), sedges (4), forbs (20) and ferns (2). At elevation E_3, a total of 50 species were recorded including grasses (16), sedges (4), legumes (3), forbs (24) and ferns (3). E_4 was represented by 49 plant speciesout of which grasses (12), sedges (3), legumes (3), forbs (22) and ferns (4) were recorded. While E_5 had a total of 60 plant species consisting of grasses (10), sedges (3), legumes (3), forbs (30) and ferns (3), respectively (Table 2).

Least number of species in at E_2 and E_4 was due to pine needle-litter deposition on the forest floor which might have restricted germination of herbaceous flora (Gupta, 2007). In other parts of north-west Himalaya, comparable numbers of plant species were reported by Dangwal *et al*. (2012) and Shaheen *et al*. (2011) for similar forest communities in north-west Himalaya and Bharali *et al*. (2011) for temperate mixed forest in eastern Himalaya. Different forests had varied herbaceous composition but still some species were common to them like, *Agrostis pilosula, Avena fatua, Apluda mutica, Arundinella nepalensis, Chrysopogon gryllus, Chrysopogon montanus, Heteropogon contortus,*

Table 1. Forests selected for vegetation analysis

Forest	Prominent tree species	Location	Altitude (m)
Acacia	*Acacia catechu, Terminalia bellerica, Butea monosperma*, etc.	Kheri	650 (E_1)
Chir pine	*Pinus roxburghii, Quercus leuchotrichophora Acer oblongum*, etc.	Rajgarh	1000 (E_2)
Mixed conifer	*Cedrus deodara, Pinus roxburghii, Acer, oblongum, Quercus semecarpifolia*, etc.	Phagu	1800 (E_3)
Deodar	*Cedrus deodara, Pinus wallichiana, Quercus floribunda*, etc	Bhathawdhar	2400 (E_4)
Fir-Spruce	*Picea smithiana, Abies pindrow, Cedrus deodara*, etc.	Churdhar	2600 (E_5)

Table 2. Species composition at different elevations

S. No.	Name of the species	Family	E_1	E_2	E_3	E_4	E_5
		Grasses					
1	*Agrostis pilosula* Trin.	Poaceae	+	+	+	+	+
2	*Agrostis royleana* Trin.	Poaceae	-	-	+	+	+
2	*Apluda mutica* Linn.	Poaceae	+	+	+	+	+
3	*Arundinella nepalensis* Trin.	Poaceae	+	+	+	+	-
4	*Avena fatua* Linn.	Poaceae	+	+	+	+	+
6	*Axonopus affinis* Chase	Poaceae	+	-	-	-	-
7	*Brachiaria ramosa* (Linn.) Stapf	Poaceae	+	+	+	-	-
8	*Cenchrus ciliaris* Linn.	Poaceae	+	-	-	-	-
9	*Chrysopogon gryllus* Linn.	Poaceae	+	+	+	+	+
10	*Chrysopogon montanus* Trin.	Poaceae	-	+	+	+	+
11	*Cymbopogon martiniii* (Roxb.) Wats.	Poaceae	+	+	+	-	-
12	*Cynodon dactylon* (Linn.) Pers.	Poaceae	+	+	+	+	-
13	*Dichanthium annulatum* (Forssk.) Stapf	Poaceae	+	+	+	-	-
14	*Digitaria cruciata (*Nees ex Steud)	Poaceae	+	+	-	-	-
15	*Digitaria stricta* Roem & Schult.	Poaceae	-	+	+	+	+
16	*Heteropogon contortus* Linn.	Poaceae	+	+	+	+	+
17	*Oplismenus compositus* (Linn.) P.Beauv.	Poaceae	+	+	+	-	-
18	*Panicum maximum* Kunth	Poaceae	+	+	-	-	-
19	*Paspalum paspaloides* Scribn.	Poaceae	+	-	-	-	-
20	*Themeda anathera* (Nees ex Steud.)	Poaceae	+	+	+	+	+
21	*Trichloris pluriflora* Fourn.	Poaceae	+	-	-	-	-
22	*Urochloa panicoides* P.Beauv	Poaceae	+	+	+	+	+
Total			19	17	16	12	10
		Sedges					
1	*Cyperus rotundus* Linn.	Cyperacae	+	+	+	+	+
2	*Cyperus squarrosus* Linn.	Cyperaceae	+	+	+	-	-
3	*Eriophorum comosum* Wall.	Cyperacae	+	+	+	+	+
4	*Fimbristylis rigidula* Nees.	Cyperacae	**-**	**+**	**+**	**+**	**+**
5	*Pycreus flavescens* (Linn.) P.Beauv.ex. Rchb	Cyperacae	+	-	-	-	-
Total			04	04	04	03	03
		Legumes					
1	*Abrus precatorius* Linn.	Fabaceae	+	-	-	-	-
2	*Desmodium floribundum* G.Don	Leguminosae	+	+	+	+	+
3	*Lespedeza gerardiana* wallich ex Maximowiz	Leguminosae	-	+	+	+	+
4	*Trifolium repens* Linn.	Leguminosae	-	+	+	+	+
Total			02	03	03	03	03
		Forbs					
1	*Acanthus ilicifolius* Linn.	Acanthaceae	-	-	+	-	-
2	*Achyranthes aspera* Linn.	Amaranthaceae	+	+	+	+	-
3	*Achillea millefolium* Linn.	Asteraceae	+	-	-	-	-
4	*Ainsliaea pteropoda* Dc.	Asteraceae	-	-	-	+	+
5	*Amaranthus virdis* Linn.	Amaranthacaea	+	+	-	-	-
6	*Anaphalis busua* (Buch.-Ham.ex D. Don) DC.	Asteraceae	+	+	+	+	+
7	*Anaphalis marganitacea* (Linn.) Benth&Hook.f	Asteraceae	-	-	-	+	+
8	*Angelica glauca* Edgew.	Apiaceae	+	+	+	-	-
9	*Anemone rivularis* Buch-Ham ex Dc.	Ranunculaceae	-	-	-	+	+

Cont..........

10	*Artemisia roxburghiana* Bess.	Asteraceae	+	+	-	-	-
11	*Asclepias curassavica* Linn.	Ascelpiadaceae	+	+	+	-	-
12	*Aster thomsoni* Cronquist	Asteraceae	-	-	+	-	-
13	*Barleria cristata* Linn.	Acanthaceae	-	+	+	+	+
14	*Bergenia ciliata* (Haw.)sternb	Saxifragaceae	-	-	-	+	+
15	*Bidens pillosa* Linn.	Asteraceae	+	+	+	+	+
16	*Bistorta amplexicaulis* (D. Don.) Green	Polygonaceae	-	-	-	-	+
17	*Boenninghausenia albiflora* Reichb.ex Meissn	Rutaceae	-	-	-	-	+
18	*Cannabis sativa* Linn.	Cannabaceae	+	-	-	-	-
19	*Chenopodium album* Linn.;Hook.f.	Chenopodiaceae	+	+	+	+	+
20	*Chirita bifolia* D.Don	Gesneriaceae	-	-	-	+	+
21	*Conyza stricta* willd	Asteraceae	+	+	+	-	-
22	*Delphinium denudatum* Wall.	Ranunculaceae	-	-	+	+	-
23	*Dicliptera bupleuroides* Nees.	Acanthaceae	+	+	+	+	+
24	*Erigeron annuus* (Linn.)Pers.	Asteracae	+	+	+	-	-
25	*Euphorbia hirta* Linn.	Euphorbiacae	+	+	-	-	-
26	*Galium aparine* Linn.	Rubiaceae	-	-	+	+	+
27	*Geranium nepalensis* Sweet.	Geraniaceae	-	-	-	-	+
28	*Gerbera jamesonii* Linn.	Asteraceae	-	+	-	-	+
29	*Gonatanthus speciosa*	Asteraceae	-	-	-	-	+
30	*Hedera nepalensis* K.Koch	Araliaceae	-	-	-	+	+
31	*Ipomea quamocilt* Linn.	Convulvulaceae	+	+	+	-	-
32	*Lepidium ruderale* Linn.	Brassicaceae	+	-	-	-	-
33	*Malaxi acuminata* D.Don	Orchidaceae	-	-	+	-	+
34	*Micromeria biflora* Benth	Lamiaceae	-	-	-	+	+
35	*Oenothera rosea* W.Ait	Onagraceae	+	+	+	-	-
36	*Ophiopogon intermedius* D.Don	Haemodoraceae	-	-	-	-	+
37	*Origanum vulgare* Linn.	Lamiaceae	-	+	+	+	+
38	*Parthenium hysterophorus* Linn.	Asteraceae	+	-	-	-	-
39	*Plumbago zeylanica* Linn.	Plumbaginaceae	+	+	+	-	-
40	*Pouzolzia indica* Benn.&Br.	Urticaceae	-	-	+	+	+
41	*Primula denticulata* Sm.	Primulaceae	-	-	-	+	+
42	*Prunella vulgaris* Linn.	Lamiaceae	-	-	-	-	+
43	*Ranunculus hirtellus* Royle	Ranunculaceae	-	-	-	-	+
44	*Reinwardtia indica* Dum.	Linaceae	-	+	+	+	+
45	*Smilax aspera* Linn.	Smilaceae	+	+	+	-	-
46	*Solanum nigrum* Linn.	Solanaceae	+	-	-	-	-
47	*Sonchus oleraceus* Linn.	Asteraceae	-	-	+	-	-
48	*Tagetes minuta* Roxb.	Asteraceae	-	-	-	-	+
49	*Thalictrum foliolosum* Dc.	Ranunculacae	+	-	-	-	-
50	*Thymus serphyllum* Linn.	Lamiaceae	-	-	+	+	+
51	*Trachelospermum fragrans* (Wall.exG.Don)Hook.f.	Apocynaceae	-	-	+	+	-
52	*Valeriana jatamansi* Jones	Valerianaceae	-	-	-	+	+
53	*Viola biflora* Linn.	Violaceae	-	-	-	-	+
Total			22	20	24	22	30
		Ferns					
1	*Cheilanthes farinosa* Linn.	Sinopteridaceae	-	+	+	+	-

Cont..........

2	*Dryopteris panda* Linn.	Sinopteridaceae	-	-	+	+	+
3	*Onychium contiguum* (Wall.) Hope	Cryptogrammaceae	-	-	-	+	+
4	*Polystichum squarrosum* (Linn.) Kuhn	Dennstaedticeae	-	-	-	+	+
5	*Woodsia elongate*	Woodsiaceae	-	+	+	-	-
Total			00	02	03	04	03
Grand Total			47	46	50	44	49

Where: (+) = present and (-) = absent

Table 3. Above and below ground biomass (g m^{-2}) of herbs at different elevations and months

Elevations (T)	Months (M)				
	July	August	September	October	Mean
		Above ground			
E_1	39.78	60.17	30.33	29.27	39.89
E_2	20.56	40.40	64.49	13.93	34.85
E_3	24.47	38.71	25.48	17.54	26.55
E_4	24.27	34.78	24.47	21.57	26.27
E_5	14.45	31.19	32.53	20.56	24.68
Mean	24.71	41.05	35.46	20.57	
CD (p=0.05)					
		T		4.64	
		M		4.15	
		T×M		4.71	
		Below ground			
E_1	12.50	14.91	8.51	8.35	11.07
E_2	3.19	12.91	14.49	4.35	8.74
E_3	5.55	8.25	5.58	5.18	6.14
E_4	4.81	8.07	8.98	4.13	6.50
E_5	4.34	9.14	10.16	7.35	7.75
Mean	6.08	10.66	9.54	5.87	
CD (p=0.05)					
		T		1.89	
		M		1.69	
		T×M		1.92	

Dicliptra bupleorides, Chenopodium album, Bidens pillosa, Anaphalis busua, Desmodium floribundum, Eriophorum comosum, Cyperus rotundus and *Urochloa panicoides.* The presence of any species in any area is determined by the prevailing environmental conditions and its tolerance and adaptation by it. These species exhibited wide ecological amplitude which confirms their ability to sustain successfully in sub-tropical to temperate climate. The range of niches available and occupied by these species in turn suggests their long biotic range.

Biomass of herbage: The biomass (above ground and below ground) of herbage at different elevations revealed that, it increased gradually from July to August/September and decreased thereafter. The general trend of biomass accumulation was that the contribution of forbs, legumes and sedges to the biomass of herbage was less in comparison to grasses in all forests except the Fir-Spruce where, grasses contributed less in comparison to other plant formations. Biomass accumulation in herbage showed a decreasing trend with an increase in altitude. The above ground and below ground biomass of herbage in *Acacia* forest was significantly higher as compared to other forests (Table 3). Above ground and below ground biomass in mixed, deodar and fir-spruce forests were at par but significantly low in comparison to chir pine forest. Among the different months, Biomass values in August were significant higher than other months. Significantly low biomass was recorded in July and October which were at par with each other. The interaction of months and monthly herbage biomass in different forests revealed that biomass values were significantly higher in chir pine and *Acacia* forests than other interactions.

In general, herbage biomass decreased with elevations in the order: $E_1 > E_2 > E_3 > E_4 > E_5$. This decrease in herbage biomass with forest is the result of corresponding decrease in growth parameters. Along the season, in different elevations herbage biomass increased till August and decreased thereafter. This may be attributed to spurt of growth with the advent of monsoon in June resulting from better growing conditions like relative humidity and soil moisture during this period. Further, enough soil moisture availability for optimum nutrient flow in soil-plant system and congenial air temperature manifested itself into luxurious vegetative growth and increased biomass. Similar role of climatic variables on growth and development of herbage vegetation has been advocated by Kukshal *et al.* (2009); Masoodi (2010); Kharkwal and Rawat (2010); Joshi and Pant (2012).

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Multi-location Evaluation of Variation in Growth of *Salix* Clones in Punjab

Kulwinder Singh[1], Rajni Sharma[2], Sanjeev K. Chauhan[2] and N. B. Singh[3]

[1]*Department of Agriculture Sciences, SGGSWU, Fatehgarh Sahib-140 406, India*

[2]*Department of Forestry and Natural Resources, PAU, Ludhiana-141 004, India*

[3]*Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan-173 230, India*

Email: itschahal54@gmail.com

Abstract: Twenty-two willow clones were planted at three sites in a randomized block design with three replications, to study the growth performance and site x clone interaction. Clones exhibited significant differences for plant height and collar diameter at all the three environments. Clone UHFS-13, UHFS-1 and UHFS-19 showed the maximum growth in plant height and collar diameter at location 1 (Ladhowal), location 2 (Badhian) and location 3 (Alamwala), respectively. The performance of other clones was in the order of UHFS-14, UHFS-3, UHFS-12 and UHFS-19 at location 1, UHFS-11, UHFS-2, UHFS-4 and UHFS-7 at location 2 and UHFS-7, UHFS-3, UHFS-6 and UHFS-11 at location 3. Minimum plant height was recorded of clone UHFS-21 under all three locations, whereas minimum collar diameter was recorded in clone UHFS-10, UHFS-18 and UHFS-21 at location 1, location 2 and location 3, respectively. Clones have been ranked on the basis of incremental growth.

***Key Words*:** Clonal ranking, Environment, Growth, Willow

Salix is light demanding, deciduous trees and shrubs, found primarily on moist soils in cold and temperate regions of the northern hemisphere. *Salix* has adapted to a wide range of climatic and soil conditions, from the heat of the Chinese desert to the cold, windy conditions of the South American Andes (Ball *et al.,* 2005). There are about thirty two willow species in India, of which four exotic willows namely *Salix alba, S. daphnoids, S. fragilis,* and *S. babylonica* and an indigenous willow, *S. tetrasperma* are categorized as tree willows.

In Northern shivalik foothill zone of Punjab, agriculture is mainly rain-fed and plants are used to provide fodder, fuel wood, to control soil erosion on hilly regions, and also to supply wood for neighboring wood industries. In Central Punjab having good irrigation facilities and wood based industries, agroforestry plantations are adopted to supply wood to pulp and paper industries, sports industries and plywood industries. In southern zones of Punjab where there is high water table and problem of water salinity, tree species are used, which can grow in saline and high water table to increase evaporation rate and earn some income. According to the report of BARC (Bhabha Atomic Research Station) out of the 2,462 samples of water collected from tube wells across Punjab, 1,140 samples had tested positive for the presence of uranium and arsenic. The worst affected is southwest Punjab's fertile Malwa belt comprising the districts of Mansa, Bathinda, Moga, Faridkot, Barnala, Sangrur and some parts of Ludhiana (Anonymous, 2012). Willow based plantations can mitigate ground water related problems due to its phytoremediation quality of heavy metals and address to water logging as well. Willow is multipurpose and fast growing tree species which provide a wide range of wood products, non-wood products are well suited for establishment of special purpose plantations like biological control of soil erosion, nutrient cycling, phytoremediation, carbon sequestration, and filtering of sewage and polluted water as it is able to grow over marshy, swampy, compacted acidic and saline soils provided the roots have sufficient moisture content (Verjwist, 2001). Keeping in view the lots of potential in household timber, industry, phyto-remediation, biomass production and plantation in high ground water table and saline area, willow can be introduced for agroforestry under diverse climatic and edaphic conditions of Punjab.

The introduction of unsuitable and less productive species genotype may result into the failure of adoption by the farmers. So, before introduction of the species, the evaluation of different species/clones for adaptability and growth performance at field level under different site conditions in Punjab is essentially required. Phenotype of the plant is an outcome of an interaction between genetic as well as environmental factors. Due to genotype - environment interactions a specific genotype may give different phenotypic expressions under different environments or different genotypes can express themselves differently under a specific environment. So, to determine the stability of the response and the behavior of the clones in different areas selected for cultivation, it is essential to evaluate the importance and consequences of genotype-site interaction in developing breeding programmes for taking appropriate decisions about testing, development and selection strategies.

MATERIAL AND METHODS

The experimental plantation of one year old nursery raised clones taken from University of Horticulture and Forestry, Solan, were planted at three different locations i.e., Location 1 (University Seed Farm, Ladhowal, Ludhiana), Location 2 (Badhian Forest, Range and Division, Dasuya) and Location 3 (Alamwala, Range - Malout, Division - Faridkot). Meteorological data of Location 1, Location 2 and Location 3 during the trial period is given is given in Table 1. Twenty two clones were planted in three replications at each site at spacing of 4m x 4m and depth of 1m in randomizes block design. Soil samples were collected at four depths (0-15, 15-30, 30-60 and 60-90cm) from all the site and detail of the soil physico-chemical properties of Location 1, Location 2 and Location 3 is presented in Table 1.

Assessment of the traits: Height of the plant was measured in meters from the ground level to the apex of the leading shoot by using measuring scale. Collar diameter of the plant was measured with the help of digital calliper at the collar region i.e., 5cm above the soil surface. These traits were measured at the interval of every two months.

Genotype and site interaction: It was studied on the basis of the final and incremental ranking for plant height and collar diameter in all the three environments. First rank was given to clone having highest increase in plant height or collar diameter and lowest rank was given to clone having lowest increase in plant height or collar diameter. Larger the difference in ranking between different environments, larger is the genotype and site interaction and *vice-versa*. Variability, heritability (broad sense) and genetic gain were also worked out through standard procedures.

Statistical analysis: Statistical analysis was done with MVM computer package. Analysis of variance was conducted for all the traits to detect significant differences among the clones with the model for a randomized block design and genetic parameters were calculated for variability, heritability and genetic gain.

RESULTS AND DISCUSSION

Growth performance: Plant height and collar diameter are the important morphological traits, which indicate the growth and development of plant. The perusal of the data in Table 2 showed that at Location 1 the plant height and collar diameter of different clones ranged between 2.24 - 4.00 m and 2.27 - 3.57 cm, respectively. Clone UHFS-13 registered the maximum plant height (4.00m) and collar diameter (3.57 cm).

Table 1. Physico-chemical properties of soil at different environments

Location	Depth (cm)	Texture	N ($Kg\ ha^{-1}$)	P ($Kg\ ha^{-1}$)	K ($Kg\ ha^{-1}$)	OC (%)	EC (mmhos/cm)	pH	Avg. min. temp.(°C)	Avg. max. temp.(°C)	Rainfall (mm)	Avg. relative humidity (%)
University Seed Farm, Ladhowal, Ludhiana	0-15	Loamy sand	150.4	7.25	216.5	0.36	0.22	8.4	16.8	30.0	591.5	62.9
	15-30	Loamy sand	145.6	7.50	214.0	0.35	0.22	8.3				
	30-60	Loamy sand	150.4	6.50	190.5	0.28	0.19	8.4				
	60-90	Loamy sand	148.5	7.00	210.0	0.48	0.20	8.4				
Badhian Forest, Range & Division, Dasuya	0-15	Sandy loam	184.6	5.00	173.0	0.82	0.39	7.3	15.5	29.0	463.9	58.9
	15-30	Loamy sand	190.3	5.00	170.3	0.15	0.40	7.5				
	30-60	Sandy	176.5	4.75	166.4	0.12	0.16	7.4				
	60-90	Sandy	165.6	5.25	160.4	0.12	0.32	7.4				
Alamwala, Range - Malout, Division - Faridkot	0-15	Sandy loam	255.3	9.2	321.2	0.55	0.36	8.4	15.7	30.0	474	65.4
	15-30	Sandy loam	249.4	9.0	320.0	0.54	0.28	8.2				
	30-60	Sandy loam	244.6	8.3	305.6	0.54	0.31	8.3				
	60-90	Sandy loam	232.0	8.8	305.8	0.33	0.25	8.5				

Table 2. Growth parameters of different Salix clones at three variable sites

Clone	University seed farm, Ladhowal, Ludhiana*		Badhian forest, Range and Division, Dasuya		Alamwala forest nursery, Range Malout, Division Faridkot	
	Plant height (m)	Collar diameter (cm)	Plant height (m)	Collar diameter (cm)	Plant height (m)	Collar diameter (cm)
UHFS-1	3.24	2.87	3.62	2.52	3.48	2.97
UHFS-2	3.47	2.73	3.41	2.23	3.13	2.20
UHFS-3	3.48	3.27	2.69	1.88	3.56	3.27
UHFS-4	3.25	2.47	3.20	1.77	3.02	2.17
UHFS-5	3.30	2.90	2.70	1.77	2.74	1.87
UHFS-6	2.86	2.47	2.79	1.93	3.57	2.80
UHFS-7	2.82	2.57	3.15	2.17	3.70	3.03
UHFS-8	2.91	2.57	2.97	1.90	2.53	1.87
UHFS-9	3.21	2.97	2.92	1.85	2.55	1.90
UHFS-10	2.62	2.27	2.57	1.82	2.89	2.13
UHFS-11	3.22	2.47	3.46	2.39	3.54	2.77
UHFS-12	3.59	2.83	2.68	1.67	2.89	1.93
UHFS-13	4.00	3.57	3.17	1.93	2.77	1.90
UHFS-14	3.97	3.20	3.03	1.97	2.78	1.86
UHFS-15	3.21	2.63	2.55	1.72	2.55	2.03
UHFS-16	3.27	2.93	3.10	2.10	2.95	1.77
UHFS-17	3.48	2.73	1.95	1.53	3.36	2.27
UHFS-18	3.59	2.33	2.97	1.82	2.63	1.67
UHFS-19	3.10	3.30	2.46	2.03	5.39	4.82
UHFS-20	3.32	2.50	3.00	1.69	2.48	1.70
UHFS-21	2.24	2.63	1.86	1.70	1.78	1.67
UHFS-22	2.96	2.37	2.28	1.61	2.03	1.75
Mean	3.23	2.75	2.84	1.91	3.01	2.29
Range	2.24–4.00	2.27–3.57	1.86–3.62	1.53–2.52	1.78–5.39	1.67–4.82
CD (p=0.05)	0.72	0.72	0.41	0.33	0.59	0.61
CD (p=0.05) Environments (E)						0.12
CD (p=0.05) Interaction (C×E) for plant height						0.58
CD (p=0.05) Interaction (C×E) for collar diameter						0.57

*Data have been reported by Singh *et al.* (2015) but used here for comparison and interaction effect

UHFS-13 was statistically at par with clone UHFS-2, UHFS-3, UHFS-5, UHFS-12, UHFS-13, UHFS-14, UHFS-17, UHFS-18 and UHFS-20. Similarly for collar diameter, clone UHFS-13 was statistically at par with clone UHFS-1, UHFS-3, UHFS-5, UHFS-9, UHFS-14, UHFS-16 and UHFS-19. Minimum plant height (2.24m) was recorded in clone UHFS-21, whereas, minimum collar diameter was recorded in clone UHFS-10 (2.27cm).

At Location 2, plant height and collar diameter ranged between 1.86 - 3.62 m and 1.53 - 2.52 cm, respectively. Maximum plant height (3.62m) and collar diameter (2.52cm) was recorded in clone UHFS-1. UHFS-1 was statistically at par with clone UHFS-2, UHFS-4 and UHFS-11. Similarly for collar diameter, UHFS-1 was at par with clone UHFS-11 and UHFS-2. Minimum plant height (1.86m) was recorded in clone UHFS-21, whereas, minimum collar diameter(1.53cm) was recorded in UNFS-17. At Location 3, plant height and collar diameter of different clones ranged between 1.78 - 5.39 m and 1.67 cm - 4.82 cm, respectively. Plant height and collar diameter were maximum for clone UHFS-19, which was recorded as 5.39 m and 4.82 cm, respectively. Clone UHFS-19, which had maximum plant height and collar diameter, was significantly different from all other clones for both traits. Minimum plant height (1.78 m) was recorded in clone UHFS-21, whereas, minimum collar diameter (1.67 cm) was recorded in clone UHFS-18 and UHFS-21.

Differences in the overall performance of clone for plant height and collar diameter was also found significant under different environments when compared with critical value (5%) of 0.12 (Table 2). Overall plant height and collar diameter of clones was maximum at Location 1 (3.23m, 2.75 cm, respectively) followed by Location 3 (3.01m, 2.29 cm, respectively) and Location 2 (2.84m, 1.91 cm, respectively). This may be due to the presence of better irrigation facilities at location 1, at location 2 growth was poor because it was on the bank of river and during monsoon season, area was water logged for long time, which led of early leaf fall and reduced growth.

Genotype-site interaction: The genotype and site interactions for plant height were significant when compared with critical value (5%) of 0.58 (Table 2). Perusal of the data in Table 3 showed that the performance of clone UHFS-13 for plant height was in decreasing order from Location 1 to Location 3 (4.00m, 3.17m and 2.77m at Location 1, Location 2 and Location 3, respectively). Increment was high in clone UHFS-14 and UHFS-22 under Location 1 and Location 2, but its performance was poor under Location 3. Clone UHFS-15 and UHFS-20 showed large increase in height at Location 1,

Table 3. Incremental ranking of different clones for plant height and collar diameter

Clone	University seed farm Ladhowal, Ludhiana		Badhian forest, Range and Division, Dasuya		Alamwala forest nursery, Range Malout, Division Faridkot	
	Incremental ranking of plant height	Incremental ranking of collar diameter	Incremental ranking of plant height	Incremental ranking of collar diameter	Incremental ranking of plant height	Incremental ranking of collar diameter
UHFS-1	18	10	11	4	8	6
UHFS-2	21	20	10	6	16	13
UHFS-3	11	4	15	12	2	2
UHFS-4	12	17	9	19	10	9
UHFS-5	14	8	13	17	16	20
UHFS-6	22	20	15	12	3	4
UHFS-7	20	14	5	2	4	3
UHFS-8	8	10	17	15	22	16
UHFS-9	17	6	17	18	9	7
UHFS-10	19	22	3	10	7	7
UHFS-11	13	19	1	1	4	5
UHFS-12	6	8	20	20	12	16
UHFS-13	1	1	6	15	19	20
UHFS-14	2	2	4	3	15	16
UHFS-15	7	10	22	22	20	12
UHFS-16	14	5	2	8	21	22
UHFS-17	10	15	21	20	13	15
UHFS-18	4	17	7	10	6	19
UHFS-19	9	2	13	5	1	1
UHFS-20	5	10	19	9	11	13
UHFS-21	14	7	12	6	14	10
UHFS-22	3	15	8	14	16	11

but increment was very small at Location 2 and Location 3. Clone UHFS-10 and UHFS-11, which showed high increment at location 2, showed poor growth at Location 1 and moderate growth at Location 3. Clone UHFS-16, which registered high increment at Location 2 showed poor growth performance at both Location (1 and 3). Similar results were found for clones, which performed well under Location 3, like clone UHFS-3 and UHFS-6, but registered only small growth at Location 1 and Location 2. Only clone UHFS-18 showed high growth under all three Locations, ranked fourth, seventh and sixth Location 1, Location 2 and Location 3, respectively. Clone UHFS-5 and UHFS-21 also showed only small change in ranking between locations but their performance was poor under all three locations.

Growth of collar diameter of different clones also showed large variation in different environments. Clones, which showed high increment in diameter under one environment showed less increment under other environments and *vice versa.* The genotype and site interactions for plant height were significant among the clones when compared with critical value (5%) of 0.57 (Table 2). Clone UHFS-13, which showed highest increment at Location 1, registered only small increase in collar diameter under Location 2 and Location 3. Clone UHFS-14, which also showed large increment at Location 1 and Location 2, registered poor growth at Location 3. Clone UHFS-3 and UHFS-9 showed high increment at Location 1 and Location 3, but increment was small at Location 2. Similarly, clone UHFS-12, which had high increment in collar diameter at Location 1, showed small increase in collar diameter at Location 2 and Location 3. Similarly clone UHFS-7 and UHFS-11, which showed high increase in collar diameter at Location 2 and Location 3, registered only small increase in collar diameter at Location 1.

Clone UHFS-2, which showed good growth at Location 2, performed poorly at Location 1 and at Location 3. Similarly, clone UHFS-6 and UHFS-10, which showed good growth under Location 3, showed only small increase at Location 1 and moderate increase at Location 2. Clone UHFS-19 showed high increment in collar diameter under all three environments, it was at second, fifth and first position at Location 1, Location 2 and Location 3, respectively, reflecting strong genetic control of the clone, which performed well in all the three environments. Performance of clone UHFS-8, UHFS-15, UHFS-17, UHFS-18 and UHFS-22 was also stable but their performance was poor under all three location (Table 3).

Significant variation may be attributed to the distinct genetic constitution of the clones and their performance in given set of climatic and edaphic conditions (Table 4). In consonance with the present study, significant variations in plant height of willow (Poland cultivars) were recorded by Stolarski *et al.* (2011) at the end of fourth growing season when tested on two different soil conditions. Differences were significant between the locations and between the clones on same location. But in the same study, they reported non-significant differences in diameter of willow clones after four growing season both within the location and between the locations. In a test of 32 clones of cottonwood at three locations, effect of clone x environment interactions on height and diameter growth was quite significant (Randall and Cooper 1973). Stolarski *et al.* (2008) observed huge variation in the performance of seven willow clones within and between the locations. Twenty one clones of seven *Salix* species along with two check clones (*S. tetrasperma* and *S. alba* cv. *coerulea*) was evaluated for growth, wood and physiological characteristics in Solan, Himachal Pradesh. Variations between clones were very high for different traits and performance of seven clones was better than check clones. Sharma *et al.* (2011) reported significant differences in the plant height and diameter of eighteen clones after five years of evaluation in Himachal Pradesh. Tunctaner (2002) also observed large variations in plant height (2.3m to 6.7m) and diameter (1.9cm to 4.7cm) of fifty-three willow clones after two years at Izmit nursery (Turkey), these clones were selected from different locations in Turkey. Arun *et al.* (2010) earlier recorded large variation in height, collar diameter of willow clones collected from different parts of the north India in his study in Punjab at nursery stage. Ladhowal was site has poor relationship between plant height and collar

Table 4. Variability, heritability and genetic gain in clones for growth parameters in three different environments

Parameter	Environment	PCV (%)	GCV (%)	Hbs (%)	Genetic gain (%)
Plant height	I (Ladhowal)	16.78	9.79	34.05	11.77
	II (Badhian)	17.46	14.98	73.61	26.48
	III (Alamwala)	26.34	18.34	48.50	26.32
Collar diameter	I (Ladhowal)	18.08	8.57	22.46	8.37
	II (Badhian)	15.67	11.59	54.72	17.67
	III (Alamwala)	40.84	25.50	38.97	32.79

diameter (Table 5) but at other two sites, relationship was strong. However, growth response and ranking may vary over the time, therefore, there is need for continuous evaluation of these clones at multiple sites.

Table 5. Phenotypic and genotypic relationship between plant height and collar diameter

Coefficient	I (Ladhowal)	II (Badhian)	III (Alamwala)
Genotypic	0.352	0.766	0.907
Phenotypic	0.671	0.768	0.737

Collar diameter and plant height of different clones showed large variation at different environments as the change in the ranking of clones for plant height and collar diameter was recorded among different locations, except clone UHFS-18, UHFS-5 and UHFS-21,which registered almost similar growth for plant height under all three locations and clone UHFS-19, UHFS-8, UHFS-15, UHFS-17, UHFS-18 and UHFS-22 were stable at all the three locations for collar diameter.

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Fresh Herb, Essential Oil Yield and Net Returns from *Ocimum* spp. Grown under Teak (*Tectona grandis* L.f.) based Silvi-medicinal Systems in South Gujarat, India

Mukesh Kumar, N. S. Thakur* and H. T. Hegde

College of Forestry, Navsari Agricultural University, Navsari-396 450, India
**E-mail: dnsthakur74@gmail.com*

Abstract: Three *Ocimum* species namely *O. tenuiflorum*, *O. gratissimum* and *O. basilicum* were grown under 18 year old teak [referred herein as silvi-medicinal system (teak + *Ocimum* spp.)] and sole cropping, to find out the effect of teak plantation on fresh herbage and essential oil yield and the financial flows thereof. The results evinced that land use systems significantly affected the herbage yield of *Ocimum* spp. Maximum total herbage yield (7.2 t ha^{-1}) of *Ocimum* spp. was recorded in sole cropping system compared to silvi-medicinal system. Among intercrops, *O. gratissimum* gave higher fresh yield above ground (6 t ha^{-1}) and total herbage yield (7.04 t ha^{-1}). *O. basilicum* produced higher below ground fresh yield of 1.24 t ha^{-1}. The maximum essential oil recovery, from all the *Ocimum* spp. was under sole cropping as compared to silvi-medicinal systems. Among *Ocimum* spp., the maximum essential oil recovery (0.69%) was from *O. gratissimum*. Oil yield of *Ocimum* species, intercropped under teak and as sole crop differed significantly. The maximum oil yield from *Ocimum* species was obtained from sole cropping system as compared to teak based silvi-medicinal system (30.25 kg ha^{-1}). Among intercrops, significantly maximum oil yield (46.57 kg ha^{-1}) was obtained from *O. gratissimum,* followed by *O. basilicum*. Among *Ocimum* species, highest net returns of Rs. 103327 ha^{-1}, from essential oil were accrued from *O. basilicum* grown under sole cropping system with highest benefit cost ratio (BCR) of 2.56. Although, the fresh herbage and oil yield of *Ocimum* spp. under silvi-medicinal systems was lesser as compared to sole cropping system, but intercropping may provide handsome income, from of sale of essential oil, until teak trees have not attained merchantable size.

Key Words: Agroforestry, Essential oil, Herb, Intercropping, Net returns, *Ocimum,* Silvi-medicinal model

Agroforestry is being advocated to provide multifarious needs. Land use system which can ensure health care of rural people on one hand and requirement of industries like pharmaceutical, cosmetic, perfumery, food flavouring, etc., for raw drugs on the other, may be developed by integrating medicinal and aromatic plants under trees. Traditional systems of medicine in most developing countries depend primarily on the use of plant products either directly or indirectly. Besides serving the healthcare needs of a large number of people, medicinal plants are the exclusive source of some drugs even for modern medical treatment. About 12.5% of the 422000 plant species documented worldwide are reported to have medicinal values, but only a few hundred are known to be in cultivation (Rao *et al*., 2004). Increasing popularity of plant based drugs due to no side effects compared to allopathic medicines has put lot of pressure on the existing resources. These natural healers are harvested from their natural habitats to meet the demand of plant based industries. To conserve these valuable medicinal and aromatic plant species it is important to bring them in to commercial cultivation. Agroforestry involve deliberate inclusion of trees or crops or shrubs therefore this land use system can provide simulated conditions as medicinal and aromatic plants are as provided in natural habitat in the wild (Vyas and Nein 1999; Singh *et al*., 2008a, b; Ravitchandirane and Haripriya, 2011, Thakur *et al*., 2014). Such systems have been termed as silvi-medicinal systems (Zou and Sanford, 1990; Suvera *et al*., 2015). In such systems the woody component to be selected should also have established market and demand to ensure higher economic benefits. Therefore, the present study intended to integrate *Ocimum* spp. under *Tectona grandis* plantation. Attempts have been made to evaluate *Ocimum* spp. under fodder, fruit and grass based (Thakur *et al*., 2009, 2011 Verma *et al*., 2010; Thakur and Verma, 2012) and other tree based agroforestry systems (Suvera *et al*., 2015) in India. *O. americanum*, *O. basilicum*, *O. sanctum* and *O. tenuiflorum* are among the 178 high trade species with estimated annual trade of 500-1000, 1000-2000, 2000-5000 and 2000-5000 MT, respectively (Ved and Goraya, 2007). Teak is recognized for its durable timber. Apart from just making furniture or being used in marine applications and construction work, teak is also used in making gift items and souvenirs. According to world teak conference (Anon., 2013) total area under commercial teak plantation in India is 2561000 ha. In Gujarat, teak is the main timber tree species planted as block plantations, under social forestry, farm forestry as well as mixed plantation with fruit trees (Panchal, 2013 and Bhusara, 2014). Hence, owing to the importance of tree component (Teak) and intercrops (*Ocimum* spp.) present investigation was carried out to evaluate the herbage and essential oil yield and financial flows on account of oil yield from three *Ocimum* spp. under teak plantations.

MATERIAL AND METHODS

The investigation was carried out in the years 2013-2014, in experimental farm of ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat). India, situated at 20.95ºN latitude, 75.90ºE longitude at an altitude of 10 m above the mean sea level. The climate of the area is typically tropical with average maximum and minimum temperatures are 40ºC and 18ºC, respectively and the average annual rainfall is 1220 mm.

Three *Ocimum* species namely *O. tenuiflorum* (O_1), *O. gratissimum* (O_2) and *O. basilicum* (O_3) were intercropped under 18 year old Teak (*Tectona grandis*) plantation. The agroforestry systems so formed were named as silvi-medicinal systems (*Tectona grandis*+*Ocimum* spp. =LU_1) and sole cropping system or open land use (*Ocimum* spp. in open=LU_2). Farm yard manure @ 20 tonnes/ha was applied to all the plots uniformly at the time of land preparation. Nitrogen (in the form of urea) @ 20 kg ha^{-1} was applied uniformly to all the plots as a basal dose. Light irrigation was given after transplanting to facilitate establishment of seedling. Necessary agro-techniques were followed to maintain good health of the intercrops. The available N and P_2O_5 (kg ha^{-1}) were estimated following Subbiah and Asija (1956) and Olsen *et al*. (1954) whereas, K_2O (kg ha^{-1}), organic carbon (%) electrical conductivity and pH were estimated following Jackson (1973), under both the land use systems. The light intensity under silvi-medicinal and open land use was measured with digital Lux meter, at 10.00, 13.00 and 16.00 hours, during the investigation period, at five days interval.

Ocimum species were harvested at full bloom stage in the first week of March, 2014. Fresh herbage yield (stem, branches, leaves and inflorescence) was recorded after harvesting the intercrops. Oil recovery was estimated by hydro distillation method using Clevenger Apparatus (Clevenger, 1928) by taking chopped sample of 100 g in 500 ml capacity flask half filled with water. Distillation was done for about one and half hour and the reading of oil collected in burette was recorded. The oil yield per hectare was estimated by extrapolating the oil recovered with total fresh herb yield of each species. The total oil yield obtained was converted to kilogram per hectare multiplying litter per hectare by specific gravity of oil of individual species (*O. tenuiflorum* = 0.9255, *O. gratissimum* = 0.9105 and *O. basilicum* = 0.955). The gross and net returns, from oil of three *Ociumum* spp., were calculated on the basis of cost of cultivation (based on the prevailing market prices of inputs and outputs) and cost of distillation (Table 1).

RESULTS AND DISCUSSION

The average height and DBH (diameter at breast height) of teak trees was 13.30 m and 21.90 cm, respectively. The average crown spread was 3.80 (E - W direction) and 4.10 m (N - S direction).

Soil physico-chemical status: The available N, P_2O_5, K_2O (kg ha^{-1}) and organic carbon (%), electrical conducivity and pH under silvi-medicinal system (teak + *Ocimum* spp.) was 238.67, 35.46, 340.31, 0.88, respectively and the respective values in open field (sole *Ocimum* spp.) were 197.46, 31.28,

Table 1. Cost (Rs.) of cultivation and oil distillation of *Ocimum* species

A.	Price inputs	Cost (Rs.)
1	*Ocimum* species seed per kg	1000.00
2	Fertilizer (Urea) N per kg	5.60
3	Farm Yard Manure (FYM) per tones	300.00
4	Tractor hiring charges per hour	450.00
5	Labour wages per day	130.00
B.	Price of outputs	
1.	Dry herb (Panchang) of Tulsi per kg*	20.00
2.	Essential oil price per kg	
	O. tenuiflorum #	4060.00
	O. basilicum #	4060.00
	O. gratissimum #	2030.00
C.	Cost of cultivation	
1.	Seed	150.00
2.	Land preparation and layout	2050.00
3.	Farm Yard Manure (FYM)	6000.00
4.	Nursery bed preparation, raising and maintenance	1430.00
5.	Transplanting	800.00
6.	Weeding and hoeing	1800.00
7.	Application of fertilizer 20 kg N ha^{-1}	240.00
8.	Irrigation	1800.00
9.	Plant protection measures, watch and ward	1400.00
10.	Harvesting	1200.00
11.	Managerial cost 10 % of total cost	1687.00
12.	Interest on working capital @ 12 %	2024.40
	Total cost	20581.40
D.	Cost distillation per tonne of fresh herb of *Ocimum* spp.*	3500.00

* Ved and Goraya, (2007); #http://www.alibaba.com
http://superpage.com; ** Anonymous. (2008a)

311.23 and 0.59. The soil reaction was above neutral (7.7) with electrical conductivity of 0.36 DS m^{-1}. The soil physic-chemical analysis evinced that, nutrient and organic matter status was better under silvi-medicinal systems (teak+*Ocimum* spp.). Improved soil physico-chemical properties in teak plantations as compared control have been reported in earlier studies (Dinakaran and Krishnayya, 2010; Imoro *et al*., 2012). Banerjee *et al*. (2013) and Suvera *et al*. (2015) have reported improved soil conditions under *Pongamia* based agroforestry systems.

Light intensity: The mean monthly light intensity [recorded from October 2013 to March 2014 (6 months, cropping period of *Ocimum* spp.)] under silvi-medicinal systems was less as compared to sole cropping system and it increased from planting time to final harvest (Fig 1).

Above ground fresh herb yield: Above ground fresh herbage yield of *Ocimum* species intercropped under teak based silvi-medicinal and sole crop system differed significantly (Table 2). The maximum above ground fresh herbage yield of *Ocimum* species was recorded in open condition (5.9 t ha^{-1}) as compared to silvi-medicinal system (4.8 t ha^{-1}). Amongst *Ocimum* species, maximum above ground fresh herbage yield was recorded for *O. gratissimum* (6 t ha^{-1}) followed by *O. basilicum* (5.14 t ha^{-1}) under sole cropping system. The interaction effect due to two land use systems i.e. silvi-medicinal and sole crop was non-significant.

Below ground fresh herb yield: Below ground yield of intercrops, under silvi-medicinal systems and sole crop as well as amongst *Ocimum* species, varied significantly (Table 2). Higher below ground fresh yield (1.3 t ha^{-1}) of *Ocimum* species was recorded when grown in open condition as compared silvi-medicinal system (1.01 t ha^{-1}). Among *Ocimum* species, maximum below ground fresh yield (1.24 t ha^{-1}) recorded for *O. basilicum*, followed by *O. tenuiflorum* (1.21 t ha^{-1}). The interaction effect showed non-significant differences.

Total fresh herbage (Panchang) yield: Significant difference was observed in total fresh herbage yield i.e. Panchang (stem + leaves + inflorescence + seed +root) obtained from silvi-medicinal system and sole crop, and also among the *Ocimum* species (Table 2). The maximum *herb* yield (7.2 t ha^{-1}) recorded in open condition (LU_2) as compared silvi-medicinal system (LU_1). Among intercrops, *O. gratissimum* produced maximum *Panchang* (7.04 t ha^{-1}), followed by *O. basilicum* (6.38 t ha^{-1}) Interaction effect due to land use systems and intercrops did not show any significant difference. Herbage yields of *O. basilicum* and *O. gratissimum*, obtained in the present study, are within the range reported by Pushpagandan and Bradu (1995). The detrimental effect of silvi-medicinal land use system on herbage yield may be ascribed to negative tree-crop interface (above and below ground) i.e. competitive effect of teak (light, moisture and nutrient). The intensity of shade experienced by the understory medicinal and aromatic plants (MAPs), growing under tree plantations, affects their growth and herbage yield (Singh *et al*., 1990). Lower herbage yield of medicinal and aromatic plants, cereals and vegetables, under different agroforestry systems have been reported in various studies (Harinkheda and Mishra, 2009; Nagarajaiah *et al*., 2012). In contrary to our results, Suvera *et al*. (2015) reported increased yield of four O*cimum* species when grown under *Pongamia pinnta* due to positive interface both above and below ground.

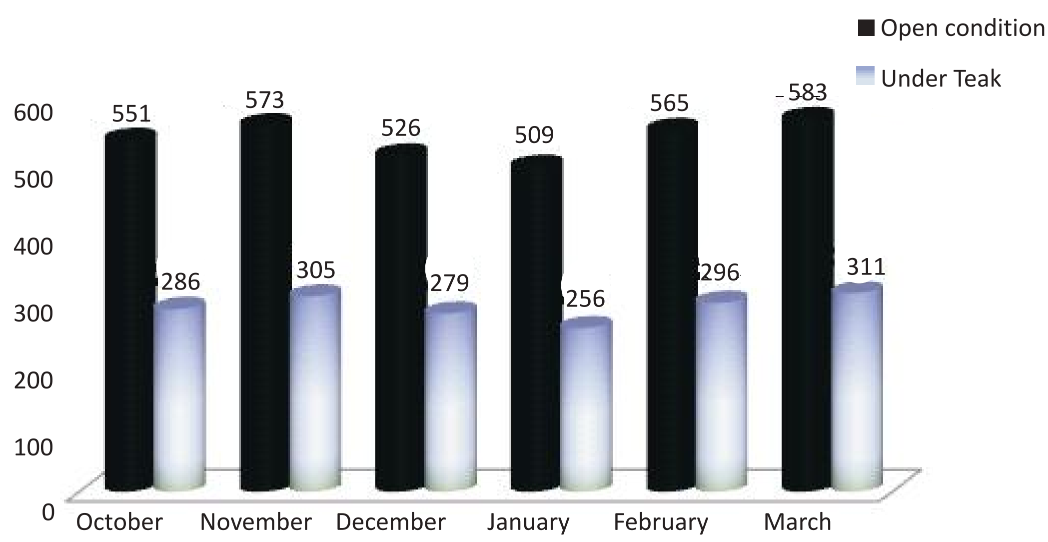

Fig. 1. Average light intensity during intercropping period

Oil recovery (%): The oil recovery (%) in fresh above ground biomass of *Ocimum* species grown under open condition and teak based agroforestry system did not bear any significant difference (Table 2). Essential oil recovery from three *Ocimum* species varied significantly. *O. gratissimum* gave higher oil content (0.69%), followed by *O. basilicum* (0.62%). The interactions effect due to land use system and intercrops was statistically non-significant for oil recovery. The oil recovery in the present study is well within that recorded by Thakur *et al.* (2009) and Suvera *et al.* (2015) from *Ocimum* spp. grown under agroforestry systems.

Oil yield (kg ha^{-1}): Oil yield of *Ocimum* species, intercropped under teak and as sole crop, varried significantly (Table 3). The maximum oil yield (38.43 kg ha^{-1}) from *Ocimum* species was in sole cropping system as compared to teak based silvi-medicinal systems. Among intercrops, significantly maximum oil yield (41.17 kg ha^{-1}) was obtained from *O. gratissimum,* followed by *O. basilicum* (31.71 kg ha^{-1}). Interaction due to land use system (silvi-medicinal and sole cropping) was statistically non-significant. The oil recovery in the present investigation fall within the range obtained in earlier studies. Jeba and Vaidyanathan (2011) reported the percentage of essential oil obtained from fresh leaves of *Ocimum sanctum* (1.45% w/w) and *O. basilicum* (0.98 % w/w), which is higher compared to present values. The higher oil recovery from *Ocimum* species under sole cropping may be attributed to better growing conditions like full sunlight and other resources as compared with plants growing under shade. Harinkheda and Mishra (2009) have also reported significant effect on essential oil recovery from *O. basilicum* grown with *Cajanus cajan.* The variation in essential oil yield among the species may also be ascribed to genetic makeup of individual species.

Net returns accrued from essential oil: Among *Ocimum* species, *O. basilicum* gave highest net returns of Rs 103327 per hectare under sole cropping system and hence the

Table 2. Fresh herbage yield (tonnes/ha) *Ocimum* species grown under *Tectona grandis* based silvi-medicinal and sole cropping systems

Land use systems	Above ground (t ha^{-1})			Mean	Below ground (t ha^{-1})			Mean	Total (*Panchang*) (t ha^{-1})			Mean
	O_1	O_2	O_3		O_1	O_2	O_3		O_1	O_2	O_3	
LU_1	4.45	5.33	4.64	4.80	1.07	0.86	1.10	1.01	5.52	6.24	5.73	5.83
LU_2	5.37	6.68	5.65	5.90	1.35	1.16	1.38	1.30	6.72	7.84	7.03	7.20
Mean	4.91	6.00	5.14		1.21	1.01	1.24		6.12	7.04	6.38	

Sources	CD (p=0.05)	CV (%)	CD (p=0.05)	CV (%)	CD (p=0.05)	CV (%)
LU	0.38		0.08		0.44	
Ocimum spp.	0.47	8.26	0.11	8.52	0.53	7.68
LU x *Ocimum* spp.	NS		NS		NS	

LU_1 = Teak + *Ocimum* species, LU_2 = sole crops, O_1 = *Ocimum tenuiflorum*, O_2 = *O. gratissimum* and O_3 = *O. basilicum*

Table 3. Essential oil recovery (%) and yield (kg/ha) of *Ocimum* species grown under *Tectona grandis* based silvi-medicinal and sole cropping systems

Land use systems (LU)	Oil recovery (%)			Mean	Oil yield (kg ha^{-1})			Mean
	O_1	O_2	O_3		O_1	O_2	O_3	
LU_1	0.61	0.67	0.60	0.63	26.94	35.78	28.02	30.25
LU_2	0.62	0.70	0.63	0.65	33.33	46.57	35.39	38.43
Mean	0.61	0.69	0.62		30.14	41.17	31.71	

Sources	C. D. at 5%	C. V. (%)	C. D. at 5%	C. V. (%)
LU	NS	4.47	2.65	8.86
Ocimum spp.	0.03		3.24	
LU x *Ocimum* spp.	NS		NS	

LU_1 = Teak + *Ocimum* species, LU_2 = sole crops, O_1 = *Ocimum tenuiflorum*, O_2 = *O. gratissimum* and O_3 = *O. basilicum*

Table 4. Net returns (Rs.ha^{-1}) from essential oil of *Ocimum* species grown under *Tectona grandis* based silvi-medicinal and sole cropping systems

Land use systems	Oil yield (kg ha^{-1})	Cost of cultivation (Rs.)	Cost of oil distillation (Rs.)	Total Cost (Rs.)	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BCR
Intercropping							
O. tenuiflorum	26.94	20581.40	15575.00	36156.40	109376.40	73220.00	2.03
O. gratissimum	35.78	20581.40	18655.00	39236.40	72633.40	33397.00	0.85
O. basilicum	28.02	20581.40	16240.00	36821.40	113761.20	76939.80	2.09
Sole crop							
O. tenuiflorum	33.33	20581.40	18795.00	39376.40	135319.80	95943.40	2.44
O. gratissimum	46.57	20581.40	23380.00	43961.40	94537.10	50575.70	1.15
O. basilicum	35.39	20581.40	19775.00	40356.40	143683.40	103327.00	2.56

highest benefit cost ratio (BCR) of 2.56, followed by same species grown under teak based silvi-medicinal system with net returns of Rs. 76939.80 per hectare giving BCR 2.09 (Table 4). The net returns accrued due to essential oil of *Ocimum* species in the present study are higher as compared to those reported from palmorosa (Rs. 34500) and Vetiver oil (Rs. 45000) and isabgol husk (Rs. 50000), cultivated in the parts of Gujarat, Rajasthan, Haryana and Punjab (Prasad and Patra, 2004) and other traditional crops (Deshpande *et al.,* 2008).

After establishing the cause and effect of land use systems, intercrops, edapho-climatic factors, and tree crop interface and their substantiation with earlier evidences, the findings of the present investigations bring out that among three *Ocimum* species, *O. gratissimum* produced higher fresh herb and essential oil, suggesting the better intercrop with teak. The fresh herb yield and hence the oil, of all the *Ocimum* spp. was significantly reduced when grown under teak. But, the intercropping of *Ocimum* spp. under middle aged teak plantations (which have not attained merchantable size) could be highly remunerative.

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Effect of Different Spacings of Poplar Based Agroforestry System on Soil Chemical Properties and Nutrient Status in North-West India

K. K. Bhardwaj, R. S. Dhillon, A. S. Godara, K. S. Bangarwa Sushil Kumari and R. N. Sheokand[1]

Department of Forestry, [1]Computer Section, CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: krishansoils@gmail.com

Abstract: Field experiment was conducted to evaluate the effect of different spacings of 8 years old poplar plantation on soil chemical properties. Poplar based agroforestry system had better available nutrients status in comparison to sole crop. The organic carbon was observed highest under different poplar spacings as compared to control. Among different spacings organic carbon was found maximum under 5×4 m spacing. Soil pH and the electrical conductivity were also lower from its initial status. The magnitude of decrease was maximum in 5×4 m as compared to other spacings and control. The available soil N, P and K increased significantly under different spacings of poplar based agroforestry system in all the treatments from its initial values. The highest available soil N (350.2 kg ha^{-1}), P (18.3 kg ha^{-1}) and K (364.3 kg ha^{-1}) were recorded under 5×4 m spacing as compared to 10×2 m and 18×2×2 m spacing and sole cropping.

Key Words: Agroforestry, Leaf litter, Nutrient status, Poplar, Spacing, Soil properties

Agroforestry as alternative land management system addresses many of the global challenges, including deforestation, unsustainable cropping practices, loss of biodiversity, increased risk of climate change, as well as rising hunger, poverty and malnutrition (Garrity, 2004). Intercropping with high density short rotation tree species is the best option to meet increasing food and industrial raw material requirement through sustainable utilization of natural resources (Sarvade *et al*., 2014; Srinidhi *et al.,* 2007). Agroforestry systems are believed to arrest land degradation and sustain soil productivity (Jose, 2009; Tsonkova *et al.,* 2012) and can re-establish some of the forests ecological goods and services like timber production, potentially improves agricultural productivity, soil fertility improvement, carbon sequestration and enhances biodiversity (Montagnini and Nair, 2004; Sharma *et al*., 2004; Chauhan and Ritu, 2005). Trees under agroforestry besides providing the tree products, improves soil productivity through ecological and physico-chemical changes (Chauhan *et al.,* 2012, 2015a). The large root system of trees potentially accumulates nutrients from a large volume of soil, while litter fall concentrates nutrients near the soil surface. Addition of litter fall and fine-root in the soil turnover may increase soil organic matter concentration. A large quantity of litter fall is added through tree species which upon its decomposition affects the organic carbon and nutrient status of soil. The quantity and quality of litter produced by trees depend on the species, age and density of trees (Moshin *et al.,* 1996; Durai *et al.,* 2009). Rate of decomposition of litter is directly related to the moisture availability, temperature, soil micro-organisms and physico-chemical properties of soil. Tree species have variable impact on soil organic carbon, nutrient status and other soil properties (Patel and Singh, 2000).

Poplar (*Populus deltoides*), is an important source of plywood, pulp and match splint industries and extensively grown in north westerns states. However, because of its fast growth, poplar depletes the soil more than the slow growing and long rotation trees. But being a winter deciduous tree, it produces a substantial quantity of litter fall in the winter season. The litter fall is an important input for replenishment of soil organic matter. It is one of the most important pathways for maintaining the soil fertility of plantations. Beside the addition of organic matter in the soil, poplar also provides alternate sources of income and employment to the rural poor (Puri and Nair, 2004; Singh and Sharma, 2007; Rani *et al.,* 2011; Chauhan *et al*., 2015b). Increased above and below ground organic matter inputs, nutrient cycling, protection of soil from erosion and nitrogen fixation by the poplar tree results in enhanced soil fertility. However, meagre information is available related to relationships between soil properties and poplar plantations. This study tries to assess the influence of poplar based agroforestry system on soil chemical properties and nutrient status.

MATERIAL AND METHODS

The present study was conducted in research farm of Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana is situated at 29°10' N latitude and 75°40' E longitudes at an elevation of 215 m above mean sea level. The climate of the study area is semi-arid and mainly characterized by a hot summer, a short rainy season and a cold winter. Maximum rainfall is received during June to September (monsoon season). The site received 447.9 mm rainfall during the experimental period. However, Hisar district consists of plain land, 90% of its cultivated area is irrigated, whether under agriculture or agroforestry systems and the source of irrigation is good quality canal or tube well water. The investigation was conducted in already established 8 years old poplar plantation at 5×4 m, 10×2 m and 18×2×2 m (paired row) spacings. The rabi and kharif crops were raised as usual after poplar plantation with the recommended cultural practices under different spacing of poplar. The textural class of the soil is 'sandy loam' and the soil chemical properties and available nutrient status of soil at the time of poplar plantation (2007) are depicted in Table 1.

Four soil samples were collected randomly under different spacings in three replicates from surface soil (0-20 cm). The soil samples were taken before sowing of crops and also from control field for the study of various soil chemical properties (pH, electrical conductivity and organic carbon) and available nutrients (nitrogen, phosphorus and potassium).The samples were air dried, ground in a wooden pestle with mortar, passed through a 2 mm stainless steel sieve and stored for subsequent analysis. The soil pH and electrical conductivity were determined in soil: distilled water suspension (1:2). The available N in the soil was determined by alkaline permanganate method (Subbiah and Asija,1956), organic carbon by partial oxidation method (Walkley and Black, 1934), available P by sodium bicarbonate method (Olsen *et al.,* 1954) and available K by neutral normal ammonium acetate method (Jackson, 1973).

Litter fall was collected in litter traps placed randomly under the poplar trees before initiation of the litter fall in the month of October at monthly interval till the trees sheded whole of their leaves. The collected samples were oven driedat 60±2°C to a constant weight. Representative samples were drawn, ground and stored in paper bags for subsequent determination of concentration of nutrients in the litter and total addition of nutrients. Nitrogen of litter was determined after digesting the samples by the method described by Hesse (1971). The samples were digested in perchloric-nitric acid di-acid mixture and analysed for phosphorus by the phosphomolybdate colorimetric procedure and potassium by flame photometry (Jackson, 1973). Data were analysed by using standard statistical procedures (Panse and Sukhatme, 1989).

RESULTS AND DISCUSSION

Initial chemical properties and available soil nutrients given in Table 1 shows significant differences in soil pH among different spacing and tree-less control. The similar pattern was also observed in soil electrical conductivity. However, the organic carbon was higher under poplar plantation. The available nitrogen varied from 192.3 to 255.3 kg ha^{-1} in control and 5×4 m spacing. The available phosphorus in these soils is low with the mean value of 10.6 kg ha^{-1}. The potash content at the experimental site also differed significantly among different treatments.

After 8 years of plantation, the soil pH was found at par among all the spacings of poplar and control (Fig. 1). However, there was a decrease in soil pH as compared to its initial value in 2007. The magnitude of decline in soil pH was greater in the tree-integrated plots than the sole wheat plots. The lowest (7.1) value of soil pH was recorded under 5×4 m spacing. Among different spacings, the highest pH (7.9) recorded in 18×2×2 m spacing. The electrical conductivity of soil was not significantly influenced by different poplar spacings and control (Fig. 2). But it also decreased from its initial value among different treatment combinations. The electrical conductivity of soil decreased from 0.42 to 0.12 dSm^{-1}under 5×4 m spacing of poplar and from 0.52 dSm^{-1} to 0.28 dSm^{-1} in control. The soil electrical conductivity was lowest under 5×4 m spacing closely followed by 10×2 m, 18×2×2m spacing of poplar and control. The magnitude of decrease of electrical conductivity was maximum (67%) under 5×4 m spacing followed by 10×2 m and 18×2×2m spacing with a reduction up to 63 and 61%, respectively. Under sole crop, 46% reduction of electrical conductivity was observed from its initial status.

The reduction of soil pH and EC under the tree cover can be attributed to accumulation and subsequent

Table 1. Initial chemical properties and available nutrient status of the field soil before transplantation of poplar

Spacing (m)	pH (1:2)	EC (dSm^{-1})	Organic carbon (%)	Available nutrients (kg ha^{-1})		
				N	P	K
5×4	7.8	0.42	0.54	255.3	12.2	240.4
10×2	8.0	0.44	0.48	229.4	11.2	232.3
18×2×2	8.2	0.46	0.38	209.2	10.1	227.2
Control	8.5	0.52	0.32	192.3	8.8	195.4
CD (p=0.05)	0.3	0.05	0.09	15.4	1.2	12.5

decomposition of organic matter which releases organic acids (Gupta and Sharma, 2009). Corroborative results were reported by Aguiar *et al*. (2010) with six month study on litter production under poplar. Newaj *et al*. (2007) also observed very nominal changes in soil pH under agroforestry system after 4 years as compared to initial value.

The soil organic carbon was significantly influenced by tree spacing and it also increased from its initial status under different spacing of poplar based agroforestry system and control (Fig. 3.). The organic carbon in soil increased with the decrease in tree spacing and was maximum (0.72 %) under 5×4 m of poplar spacing and it followed the order of 5×4 m >10×2 m>18×2×2 m>control. The lower organic carbon content under the sole cropping systems may be attributed to scant vegetation and continuous cropping with subsequent removal of plant residues. The average contents of organic carbon in 5×4 m, 10× 2 m, 18×2×2 m spacing were higher by 64, 50, and 41%, respectively over sole crop. High organic matter content in the intercropping treatment could be ascribed to the fact that leaf fall before and during crop sowing period on the soil, which incorporates in to the soil through tillage practices and their partial decomposition adds to the soil organic matter. These results are similar with the results reported by Gupta and Sharma (2009), Das and Chaturvedi (2005) and Yadav *et al.* (2008).

Data regarding available nitrogen of soil from different spacing of poplar based agroforestry system and sole crop are depicted in figure 4. Available soil nitrogen increased significantly under different spacing of poplar based agroforestry system and sole crop from its initial values. As like organic carbon, available nitrogen was significantly influenced by tree spacing because amount of N depends upon organic matter. Available N content was maximum (350.2 kg ha^{-1}) under 5×4 m spacing and it decreased with the increase in the spacings. The magnitude of increment in available N was highest under 5 × 4 m spacing and lowest in control. Under 10 x 2 m and 18×2×2 m spacings the magnitude of the increment was at par and it was 34 and 32%, respectively. The increase in N content of soil under poplar agroforestry systems is attributed to addition of organic matter in soil in the form of litter fall and fine root biomass. The mineralization of organic matter releases nutrient into the soil (Osman *et al*., 2001). Chaudhry *et al*. (2007) also reported similar results under poplar based agroforestry systems.

Available phosphorus of soil also exhibited similar trend like soil nitrogen (Fig. 5). Available phosphorus in sole crop was10.1 kg ha^{-1} while it ranged from 13.4 to 18.3 kg ha^{-1}in different poplar spacing treatments. Among all the different tree spacings, the highest available soil P (kg 18.3 ha^{-1}), was recorded under 5×4 m of poplar while it was lowest under control (10.1 kg ha^{-1}).The available phosphorus in the soil increased substantially and it was more than two times both under poplar based agroforestry system and control after 8 years of poplar plantation. Potassium content of soil, where poplar trees were intercropped with wheat was higher as compared to the sole crop (Fig. 6). In case of available potassium content of the soil, an increase was observed up to 52, 49, 46 and 36 per cent under 5×4 m, 10×2 m, 18×2×2 m and control, respectively over its initial values.

The higher nutrient status under closer spacing might be due to the addition of large quantity of leaf litter. The higher decomposition of leaf litter favours the higher nutrient status of the soil. Similar findings were also observed by Singh and Sharma (2007). The higher available nutrient content in poplar based agroforestry system over the agriculture system may be attributed to litter-fall addition from poplar trees as well as addition of root residues of crops and trees. These findings were supported by (Gupta and Sharma,2009; Das and Chaturvedi, 2005; Yadav *et al.,* 2008). On account of recycling of organic matter, higher organic carbon and available N, P and K contents were observed in the soil under intercropped poplar plantations than at a site without trees and the contents varied depending upon the intercrops (Singh *et al.,* 1989; Moshin *et al.,* 1996). The impact of agroforestry systems on soil fertility in terms of higher organic matter content, total nitrogen, available phosphorus and potash in the top soil has been reported by Rizvi *et al.* (2011).

Leaf litter fall was varied significantly with spacings of poplar trees; it decreased with increase in spacing (Table 2). The highest leaf litter fall (6.2 t ha^{-1}) was recorded under 5×4 m spacing which was significantly higher over that recorded from 10×2 m and 18×2×2m spacings. Higher leaf litter fall under 5×4 m is attributed to more number of plants accommodated per unit area. Leaf litter fall sampled from different spacing was found statistically uniform in nutrient content (N, P and K) and it did not differ much at different spacings. Addition of nutrients contents (Table 3) through leaf litter varied significantly with spacings of poplar trees. The maximum nitrogen (81.8 kg ha^{-1}) was added under 5×4 m spacing which was significantly higher over other poplar geometries. Similar trend was also observed in respect of addition of phosphorus and potassium. Quantity of nutrients added in soil through leaf litter is cumulative effect of nutrient content and quantity of leaf litter fall. Higher addition of nutrients under 5×4 m spacing is ascribed to more quantity of leaf litter fall added in soil under this spacing. In agroforestry systems, litter is one of the important pathways for nutrients to the soil. Poplar is winter deciduous tree which produces

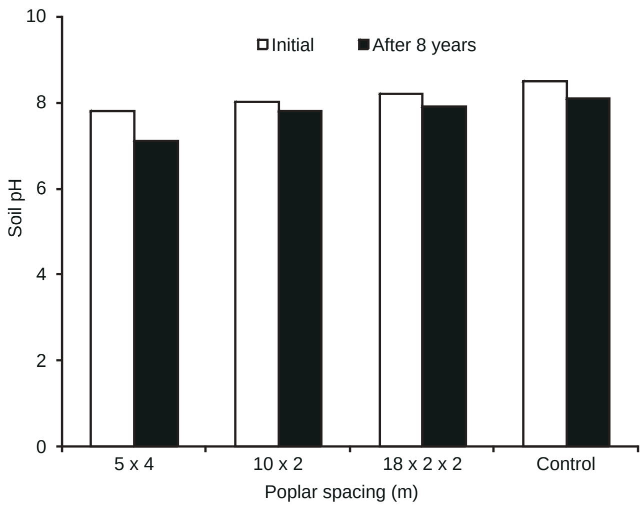

Fig. 1. Soil pH under poplar plantation

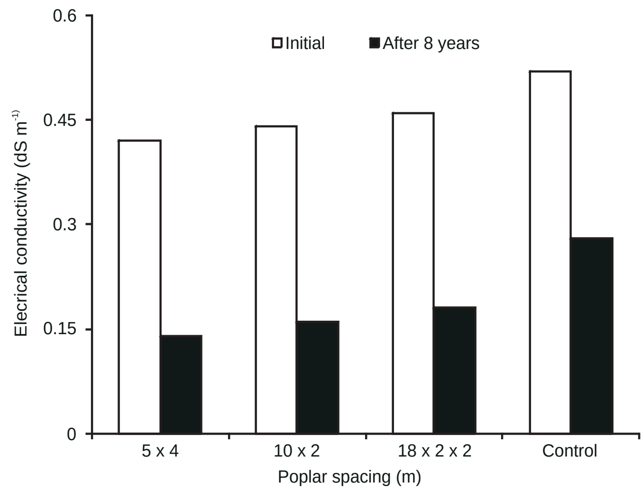

Fig. 2. Electrical conductivity (ds m^{-1}) of soil under poplar plantation

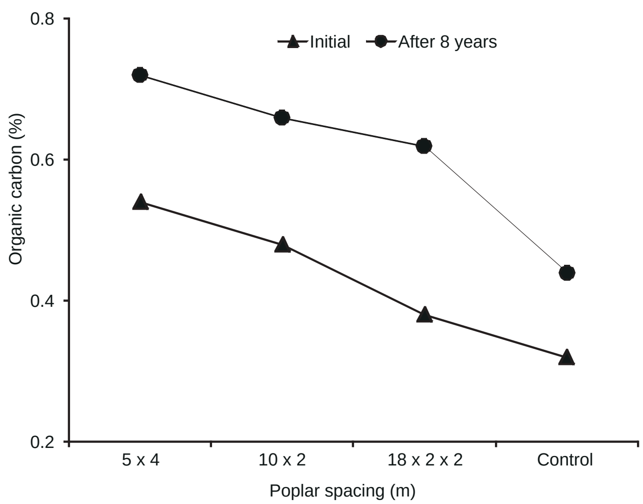

Fig. 3. Organic carbon (%) in soil under poplar plantation

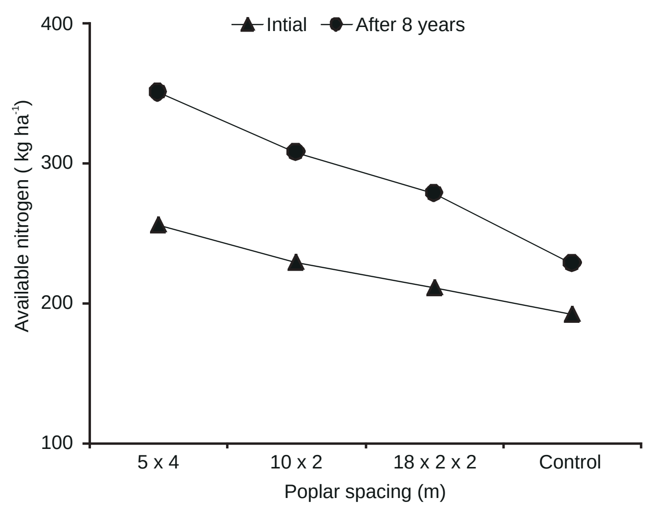

Fig. 4. Available nitrogen (kg ha^{-1}) in soil under poplar plantation

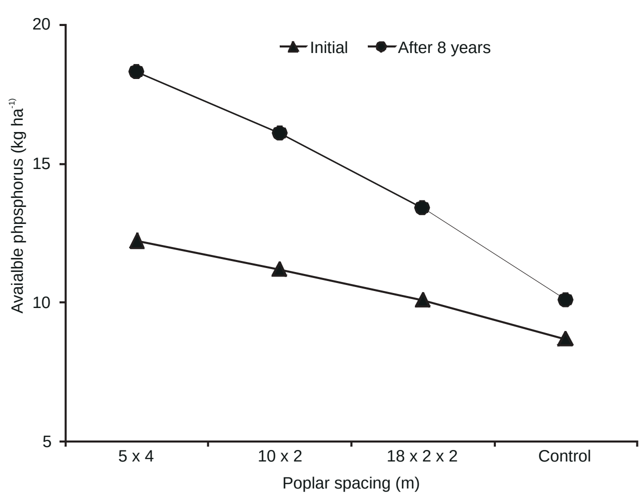

Fig. 5. Available phosphorus (kg ha^{-1}) in soil under poplar plantation

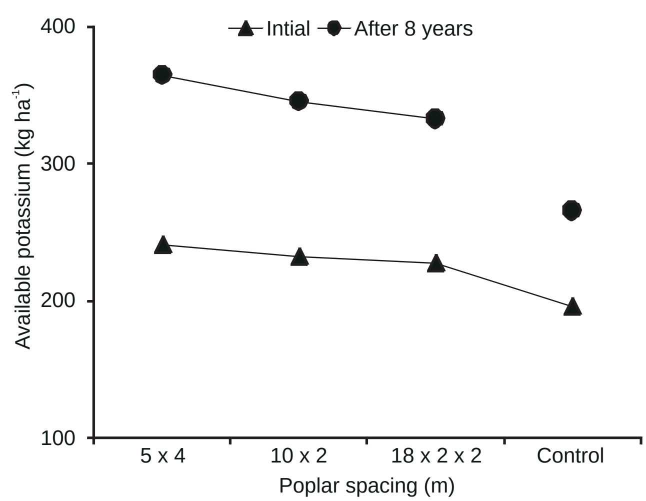

Fig. 6. Available potassium (kg ha^{-1}) in soil under poplar plantation

maximum litter in a single flush (Lodhiyal *et al*., 2002). Similarly poplar being shallow rooted tree contributes more root biomass to the soil (Mohsin *et al.*, 2000). Therefore, litter fall and fine roots are major components for maintaining the soil fertility in agroforestry systems.

Table 2. Litter fall and nutrient concentration in litter fall as affected by different spacings of poplar plantation

Spacing (m)	Leaf litter fall (t ha^{-1})	Leaf litter nutrient content (%)		
		N	P	K
5×4	6.2	1.32	0.15	0.62
10×2	4.6	1.30	0.14	0.62
18×2×2	2.5	1.28	0.14	0.64
CD at 5%	0.91	NS	NS	NS

Table 3. Addition of nutrients through litter fall as affected by different spacings of poplar plantation

Spacing (m)	Addition of nutrients (kg ha^{-1})		
	N	P	K
5×4	81.8	9.3	38.4
10×2	59.8	6.4	28.5
18×2×2	32.0	3.5	16.1
CD at 5%	9.4	1.2	5.8

CONCLUSION

After 8 years of poplar plantation, soil physico-chemical properties (pH, EC, organic carbon, N, P and K) were improved under different spacing of poplar based agroforestry system. The effect was more pronounced under 5×4 m spacing, therefore, more suitable for improving the soil fertility by the addition of leaf litter with the advancement of tree age.

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Biological Yield and Carbon Sequestration in Prominent Traditional Agroforestry Systems in Valsad District, Gujarat, India

J. B. Bhusara, N. S. Thakur and H. T. Hegde
College of Forestry, Navsari Agricultural University, Navsari-396 450, India
E-mail: jigneshbhusara@gmail.com

Abstract: Three major agroforestry systems (AF) i.e., agri-silviculture (AS), agri-horticulture (AH) and horti-pasture (HP) systems are practiced by majority of farmers, in Valsad District of Gujarat. The system types were teak + rice, teak + sugarcane, teak + banana and teak + okra; mango + rice, mango + banana, and mango + chili and mango + maize and mango + sorghum under major AF systems. Among woody components, teak (teak + rice systems type) accumulated maximum biological yield (50.59 t ha^{-1}), whereas among intercrops, banana in teak + banana system type gave maximum biological yield (29.73 t ha^{-1}). AS system with teak + rice gave maximum total biological yield (53.12 t ha^{-1}). Highest carbon (25.48 t ha^{-1}) was sequestered in AS (teak + rice) system. The AF system with woody perennials having lesser age had less contribution to total biomass and carbon sequestration as compared to systems with more aged woody component.

Key words: Agroforestry, Biological yield, Carbon sequestration

Incorporating trees in to farming systems leads to greater prosperity at the farm level. Trees provide farmers marketable products such as timber, building poles, firewood, animal fodder, fruits and medicines for their own consumption and additional income by selling the surplus. Release of carbon into atmosphere is one of the main causes of climate change. Ever since the Kyoto Protocol, agroforestry has gained increased attention as a strategy to sequester carbon (C) and mitigate global climate change. Increasingly agroforestry is viewed as potential agro ecosystem to deliver multiple products on one hand and environmental benefits on the other. The multifunctional role of agro ecosystems has also been emphasized by both the Millennium Ecosystem Assessment (2005) and the International Assessment of Agricultural Science and Technology for Development (2008). There is also a great deal of interest in providing financial benefits to landowners and farmers for land-use practices that maintain environmental services value to the wider society (FAO, State of Food and Agriculture Report, 2007). Traditional agroforestry systems not only help in achieving the productivity and sustainability objectives but also hold great potential to store carbon both in woody and non woody components (Thakur *et al*., 2011a) besides meeting the diversified needs of farmers (Thakur *et al*., 2004; 2005; 2007;2011b). Few studies have appeared in recent years that report carbon sequestration potential of traditional agroforestry systems. It is important to divulge the production as well as carbon sequestration potential of agroforestry systems being practiced by farmers at regional level. Local carbon inventories will be helpful in estimation of carbon stocks and removal by particular tree-crop combinations. Therefore, the present study was undertaken to know the biological yield and carbon sequestration status under prevalent agroforestry systems in the Valsad District, Gujarat, India.

MATERIAL AND METHODS

Description of study area: Valsad district is located in the south eastern part of Gujarat state in the coastal lowland along Auranga river. The district has five Tehsils (Talukas) namely Valsad, Dharampur, Kaprada, Pardi and Umargoan. Soils are medium black sandy loam type. The climate is typically tropical characterized by fairly hot summer, moderately cold winter and warm humid monsoon. Generally monsoon commences in the second week of June and ends in September. Most of the precipitation is received from south west monsoon, concentrating in the months of July and August. Average annual rainfall of this region is about 1500 to 2500 mm. Maximum and minimum temperature range from 42°C to 10°C. The eastern part of the district is hilly, undulating, degraded and rainfed farming area.

Biological yield of woody perennials and agricultural crops: The agroforestry systems were identified through field survey following stratified random sampling in five Talukas of district. Since the agroforestry system studied in the present investigation, varied in composition, magnitude and age with respect to woody perennials, the data on height, and DBH (diameter at breast height) is the mean values of 10 trees in respective agroforestry system. Standing volume of timber trees was calculated as: Total volume (m^3) = ð $(D/2)^2$ X h, Where, ð = 3.141592; D = DBH (m) and h = Height of tree (m). The above ground biomass was calculated: Biomass = volume X specific gravity of wood.

The biomass of fruit trees was calculated by multiplying volume of main stem and bigger branches with specific gravity. The below ground biomass of timber and fruit trees was calculated using IPCC (2003) default value (0.26.). To estimate the biological yield of agricultural crops, plants were uprooted to the depth possible in 1m^2 plot (mean of three plots/system/intercrop) under each AF system. Fresh weight (above and below ground) was taken and hereafter, the representative samples, from all treatment and replications were taken and brought to laboratory and dried in oven at 60 ^{0}C till the constant weight to record dry weight. Biological yield was calculated using formula:

$$\text{Biomass of branch/leaves} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times \text{Total fresh weight of branch/leaves}$$

The carbon sequestration in respective agroforestry systems was calculated by using default value 0.48 for Indian conditions (Chaturvedi, 1984).

RESULTS AND DISCUSSION

The agroforestry systems indentified were classified on the basis magnitude of the system components. The survey of all the five Tehsils (Taluka) revealed that among woody components mango and teak are major species. Other fruits like sapota, cashew nut and coconut and timber species like *Terminalia tomentosa*, *Acacia catechu*, *Mytragyna parvifolia* etc., are also allowed to grow by few farmers. Major agroforestry systems and system types being practiced by the farmers are: agri-horticulture (AH), agri-silviculture (AS), and horti-pasture (HP) system. Three system types viz., mango + rice, mango + banana, and mango + chili are being practiced under major system AH. Under AS system, the system types were: teak + rice, teak + sugarcane, teak + banana and teak + okra. The third major agroforestry system *i.e.,* HP include mango + maize and mango + sorghum as system types. The study revealed that teak is planted on boundary and intercrops like rice, sugarcane, banana, okra, etc., are cultivated depending upon the season. Boundary plantation systems (AS) are more prevalent followed by mango based AH systems.

The factors like edapho-climatic variability, local needs, industrial set up, infrastructure facilities etc., to a large extent leads to variation in structure and composition of agroforestry systems. The present study revealed that mango and teak are the major woody components in AF systems in the study area, among other woody perennials (others being *Terminalia tomentosa*, *Acacia catechu*, *Mytragyna parvifolia,* etc.). Varadaranganatha and Madiwalar (2010) reported six prominent agroforestry systems practiced in the three distinct agroecological situations in Uttara Kannada district, Karnataka. In all the three situations, bund planting was the most prominent agroforestry practiced by farmers, followed by horti-silviculture system and less prominent practice was block plantation. Mango was found as dominant fruit tree species. Panchal (2013) reported teak as major woody perennial being planted on boundary with different tree-crop combinations in Southern Gujarat. The intercrops in the present study fall in the category of traditional as well as cash crops (okra, banana) along with systems to meet green fodder requirement (mango + maize/sorghum).

Biological Yield

Woody components: Teak, under AS system type teak + rice attained higher above and below ground and total biomass to the tune of 40.15, 10.44 and 50.59 t ha^{-1}, respectively, followed by mango under AH (mango + banana) system Under AH (mango + chili) system mango trees recorded with minimum above and below ground and total tree biomass. The comparative analysis evinced that difference in biological yield and contributions by woody and non woody components may be attributed to age of woody components (Table 1). In system types, mango + rice and mango + chili the age of mango trees was only 2 years.

Amongst intercrops, under different agroforestry systems, banana under AS (teak + banana) system produced maximum above ground (23.60), below ground (6.13) and total biomass (29.73 t ha^{-1}) followed by sugarcane under AS (teak + sugarcane) and minimum from rice under AH (teak +rice) system.

Maximum total biological yield (53.12) was o from AS system with components teak + rice followed by mango + banana (52.88) and minimum (2.96) was from AH (mango + rice) system (Table 2). The variation in total biological yield under AF systems in present study may be attributed to nature of woody component, age and number of individuals. The net area available for intercropping and nature of intercrops also influenced the total biological yield. The biological yield recorded for maize and sorghum under mango + maize/sorghum system type in the present study is in confirmation with the yield obtained by Surve *et al*. (2012) in Navsari district (Southern Gujarat). Further data express that with increasing age of woody perennials the their contribution to total biological yield increases considerably.

Carbon Sequestration

Woody component: Maximum above ground (19.27), below ground (5.01) and total sequestered carbon (24.28 t ha^{-1}) was recorded for Teak in AS (teak + rice) system, followed by mango under AH (mango + banana). Minimum were obtained from mango in ah (mango + chili) system (Table 3).

Table 1. Structure, composition, magnitude and spatial arrangement of woody and non woody components in prevalent AF system in Valsad district, Gujarat

Major Systems	System types	Woody perennials			Intercrops		Area occupancy (m^2)	
		Spacing (m)	Age	No. ha^{-1}	Spacing	No.ha^{-1}	Woody perennials	Intercrops
AS	Teak + rice	2.5 plant to plant	20	160	20x20 cm	-	1600	8400
	Teak + sugarcane		10		30x90 cm	-	1000	9000
	Teak + banana		20		**	3906	1600	8400
	Teak + okra		15		30x90 cm	-	1200	8800
	Teak + okra		10		30×90 cm	-	1000	9000
AH	Mango + rice	8x8	2	156	20x20 cm	-	3600	6400
	Mango + banana	10x10	20	100	2x2 m	3906	642	9358
	Mango + chili	8x8	2	156	60x45 cm	-	642	9358
HP	Mango + maize*	6.5x6.5	5	236	30x90 cm	-	1406	8594
	Mango + sorghum*	8x8	10	156	**	-	3900	6100

*Green fodder; **Sown broadcast; AS=Agri-silviculture; AH=Agri-horticulture; HP=Horti-pastutre
Botanical names: Teak (*Tectona grandis*); Rice (*Oryza sativa*); Sugrcane (*Saccharum officinarum*); Banana (*Musa paradisiaca*); Okra (*Abelmoschus esculentus*); Chili (*Capsicum annum*); Maize (*Zea mays*); Sorghum(*Sorghum bicolour*).

Highest above (11.32 t ha^{-1}), and below ground (2.94 t ha^{-1}) and total carbon (14.26 t ha^{-1}) was recorded for banana grown in AS (teak + banana) followed by banana under AH (mango + banana) system with respective values for above ground, below ground and total carbon as 7.95, 2.06 and 10.01t ha^{-1} (Table 3). Rice intercropped with teak under AS (teak + rice) system, sequestered minimum carbon (0.96, 0.24, 1.2 above ground, below ground and total carbon, respectively).

Total carbon sequestered (t ha^{-1}): The maximum carbon to the tune of 25.48 t $ha^{-1}$was sequestered under AS (*Teak + rice*) system, followed by AH (mango + banana) system type (25.37) and it was minimum (1.41 t ha^{-1}) from AH (mango + rice) system.

Among woody perennials in different agroforestry systems, owing to higher biomass production and age (20 years), maximum stem carbon was found to be sequestered by teak trees under teak + rice system however branch and leaf + twig carbon was maximum in mango trees under AH (mango + banana system type) system. Further the mango tree under later system sequestered higher above ground, below ground and total carbon per tree. Data evinced that per tree carbon sequestration was more in fruit trees because more branches are retained in fruit trees for higher fruit yield. Bohre *et al*. (2013) estimated per tree carbon stocks to the tune of 76.6 kg $tree^{-1}$ at the age of about 20 years in teak plantations. In the present investigations under boundary plantation, the carbon sequestered by teak trees under teak + rice system is higher whereas it is lower in teak + banana AF system. This may attributed to type of land use system, management practices adopted and age of the trees.

Among intercrops, banana in AS (teak + banana) sequestered higher above ground, below ground and total carbon kg/m^2. The study revealed that total carbon sequestered by woody component was maximum [above ground (19.27), below ground (5.01) and total sequestered carbon (24.28t ha^{-1})] for teak in AS (teak + rice) system, followed by mango under AH (mango + banana) system with. Whereas, among intercrops, integrated under different agroforestry system types, Banana sequestered highest above ground (11.32 t ha^{-1}), below ground (2.94 t ha^{-1}) and total carbon (14.26 t ha^{-1}) under AS (teak + banana) followed by banana under AH (mango + banana). Amongst 10 agroforestry system types, investigated in present study, maximum carbon was sequestered under AS (teak + rice) system, followed by AH (mango + banana) system type and it was minimum from AH (teak + rice) system. In both the systems the age of woody component was 20 years thus woody individuals had put more biomass as compared lesser aged individuals in rest of the AF system types.

The study evinced that biomass and carbon stocks contribution of woody perennials is higher in systems involving more aged trees (timber as well as fruit trees). In the initial years, the woody component owing to its lesser in number per hectare has less carbon stock however with growing age C stocks increase considerably thereby increasing the total share in overall carbon stock of AF system (Fig. 1). Average sequestration potential in agroforestry systems has been estimated to be 25 tC ha^{-1} (Sathaye and Ravindernath, 1998). In the present study, the carbon sequestered in teak + rice and mango + banana is well within the average potential. Carbon sequestered under AS system involving eucalyptus + wheat in Himalayan Tarai region has been estimated to be 14.42 t ha^{-1} and about 32 t ha^{-1} under various agroforestry systems involving poplar as woody component (Yadava, 2010) is higher as compared to the present findings. In present study, there was accountable variation in carbon sequestration potential of different agroforestry practices. The amount of C sequestered largely depends on the agroforestry system put in place, the structure and function of which are, to a great extent, determined by environmental and socio-economic factors. Other factors influencing carbon storage in agroforestry systems include tree species and system management (Albrecht and Kandji, 2003; Yadava, 2010).

Table 2. Biological yield (DM t ha^{-1}) of woody and non woody components under prevalent AF systems in Valsad district, Gujarat

AF systems/system types	Woody component			Intercrops			Total of AF system
	Above ground	Below ground	Total	Above ground	Below ground	Total	
Agri-silviculture (AS)							
Teak+rice	40.15	10.44	50.59	2.01	0.52	2.53	53.12
Teak+sugarcane	5.75	1.49	7.24	11.07	3.04	14.11	21.35
Teak+banana	12.08	3.14	15.22	23.60	6.13	29.73	44.95
Teak+okra	3.72	0.96	4.68	8.8	2.28	11.08	15.76
Teak+okra	9.11	2.36	11.47	7.38	1.91	9.29	20.76
Agri-horticulture (AH)							
Mango+rice	0.11	0.02	0.13	2.25	0.58	2.83	2.96
Mango+banana	25.41	6.60	32.01	16.57	4.30	20.87	52.88
Mango+chili	0.09	0.02	0.11	5.98	1.55	7.53	7.64
Hortipasture (HP)							
Mango+maize	4.89	1.27	6.16	10.05	2.61	12.66	18.82
Mango+sorghum	16.05	4.17	20.22	9.15	2.37	11.52	31.74

Table 3. Carbon sequestered by woody and non woody components in different AF systems (t ha^{-1}) in Valsad district, Gujarat

AF Systems/system types	Woody component			Intercrops			Total of AF system
	Above ground	Below ground	Total	Above ground	Below ground	Total	
Agri-silviculture (AS)							
Teak+rice	19.27	5.01	24.28	0.96	0.24	1.2	25.48
Teak+sugarcane	2.76	0.71	3.48	5.31	1.45	6.76	10.24
Teak+banana	5.80	1.51	7.30	11.32	2.94	14.26	21.56
Teak+okra	1.78	0.46	2.25	4.22	1.09	5.31	7.56
Teak+okra	4.37	1.13	5.51	3.54	0.91	4.45	9.96
Agri-horticulture (AH)							
Mango+ rice	0.052	0.01	0.06	1.08	0.27	1.35	1.41
Mango+banana	12.20	3.17	15.36	7.95	2.06	10.01	25.37
Mango+chili	0.04	0.01	0.05	2.87	0.74	3.61	3.66
Horti-pasture (HP)							
Mango+maize	2.35	0.61	2.96	4.82	1.25	6.07	9.03
Mango+sorghum	7.70	2.00	9.70	4.39	1.13	5.52	15.22

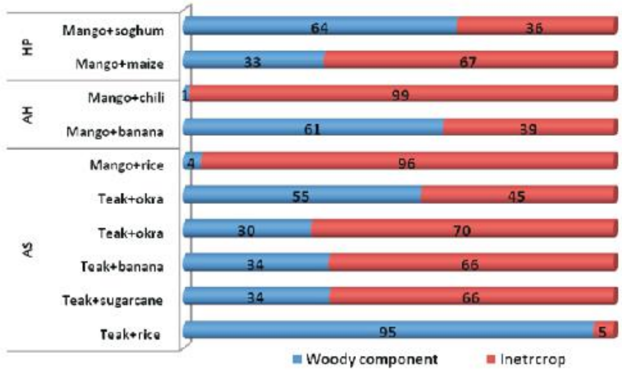

Fig. 1. Per cent contribution of woody and non woody components to total biomass and carbon sequestered by different AF systems

CONCLUSION

The present study revealed that, Valsad District three major agroforestry systems i.e. agri-silviculture (AS), agri-horticulture (AH) and horti-pasture (HP) system were practiced by majority of farmers with teak + rice, teak + sugarcane, teak + banana and teak + okra; mango + rice, mango + banana, mango + chili and mango + maize and mango + sorghum as system types/models. The biomass accumulation status, biological yield per hectare, carbon sequestered under different AF system types varied considerably and highest values for above attributes were recorded under teak + rice and mango + banana. Similarly, biological yield was higher under these later two system types. The contribution of woody perennials to total biological yield, carbon sequestration and net returns was considerably more as compared to intercrops in systems with woody components having attained harvestable size or are in full fruit bearing stage.

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Performance of Wheat as Intercrop Under Different Spacings of Poplar Plantations in Semi-Arid Ecosystem of Northern India

R. S. Dhillon, K. K. Bhardwaj, R. S. Beniwal, K. S. Bangarwa, Sushil Kumari, A. S. Godara and R. N. Sheokand

CCS Haryana Agricultural University, Hisar-125 004, India
E-mail: rsdhillon67@gmail.com

Abstract: The quantitative performance of wheat crop under different spacings of eight years old poplar plantations in semi-arid ecosystem was studied to ascertain the biological yield of tree and crop. The height of poplar was not affected significantly at different spacings under agroforestry. However, different spacings had significant effect on the girth of poplar. The growth and yield of wheat decreased significantly with the decrease in poplar spacing. The rate of decrease in grain yield of wheat crop was more under 5x4 m spacing. On an average, the grain yield decreased up to 51.2 % under 5 x 4m spacing as compared to the sole wheat (4.3 t ha^{-1}). However, the rate of decrease in straw yield was comparatively lower than grain yield under different poplar spacings. Protein content in wheat increased with the decrease in spacing of poplar and maximum protein content (10.7 %) in wheat was recorded under 5 x 4 m spacing closely followed by 10 x 2 m (10.4 %) spacing and minimum in control. The gluten was significantly higher under different spacings of poplar based agroforestry than sole crop of wheat.

***Key Words*:** Agroforestry, Growth, Poplar, Spacing, Wheat, Yield

Poplar based agroforestry systems are economically viable and more profitable than many of the other crop rotations (Jain and Singh, 2000; Chauhan and Mangat, 2006). It is usually managed in 6-8 year rotation cycle under agroforestry system. Owing to its rapid growth, high biomass, adoptability, early economic returns and compatibility with crops prompted to introduce poplars in agroforestry systems. Wheat (*Triticum aestivum* L.) is generally intercropped with poplar in northern states of India. Intercropping with high density short rotation tree species is the best option to meet increasing food and industrial raw material requirement through sustainable utilization of natural resources (Sarvade *et al*., 2014). Cropping with tree species is an ancient practice and very important tool to achieve goal of National Forest Policy (1988). It has been reported as an important component of the 'evergreen revolution' movement in the country (Puri and Nair, 2004). The tree species behave differently at different planting densities. Spacing and planting layout of the tree species influence growth and yield of annual crops. Appropriate selection of tree and crop species helps to increase yield, improve soil fertility, and promote land sustainability and resource use efficiency (Dhyani *et al*., 2009; Antonio and Gama- Rodrigues, 2011).

Growth of poplar depends upon various factors such as clone, quality of planting stock, spacing of trees, intercrops, site quality, climate and management practices (Tewari, 1995; Chauhan *et al*., 2012a, 2015a). Its popularity with the farmers is mainly due to its fast growth, multi-utility wood, high market prices, less competition with associated crops and pruning-tolerant nature. Poplar based agroforestry systems are economically viable and more profitable than many of the other crop rotations in the region (Jain and Singh, 2000; Chauhan *et al*., 2012a,2015b)). It benefits the farmers both economically and from soil physical fertility point of view. Poplar has been reported to play a significant role in improving the soil physical environment following the loss of top soil from an erosion event (Escobar *et al.,* 2002). The past three decades have witnessed the rapid increase in poplar based agroforestry as an alternate land use practice in north-western states of India. It is a general practice to combine agricultural crops with poplar plantations. Poplar being deciduous in nature, a winter crop, predominantly wheat, is intercropped throughout rotations but needs the quantification under different spacings of poplar plantations. Therefore, the present investigation was undertaken to evaluate the performance of wheat under different spacings of poplar based agroforestry system.

MATERIAL and METHODS

The present study was conducted during 2014-15 in an already established 8 years poplar plantation spaced at 5 m x 4 m, 10 x 2 m and 18 x 2 x 2 m at CCS Haryana Agricultural University, Hisar ($29^{o}09^{'}$ N latitude and $75^{o}43^{'}$ E longitude at an elevation of 215 m above mean sea level), situated in the semi-arid region of North-Western India. The climate is subtropical-monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and

June whereas, December and January are the coldest months (lowest January temperature as low as 0°C). The site received 447.9 mm rainfall during 2014-15. The textural class of the soil is 'sandy loam' and the soil of the experimental site is medium in organic carbon, available N, P and K (Table 1).

The trees at random on in all the spacings were measured for their top height and girth at breast height (GBH). The total height was measured from ground to top of the trees. The girth at breast height (1.37 m above the ground level) was taken. For soil sampling, surface (0-20 cm depth) soil was sampled from four random spots. Soil samples were taken before sowing of wheat in October from different spacings of poplar and also from control field for the study of various soil properties like pH, EC and organic carbon and available N, P and K. The samples were air dried, ground in a wooden pestle with mortar, passed through a 2 mm stainless steel sieve and stored for subsequent analysis. The soil pH and electrical conductivity were determined in soil: distilled water suspension (1:2). The available N in the soil was determined by alkaline permanganate method (Subbiah and Asija 1956), organic carbon by Walkley and Black (1934) method, available P by Olsen (1954) method and available K by neutral normal ammonium acetate method (Jackson 1973).

The wheat cultivar HD-2967 was sown during the first week of November keeping a row to row distance of 22.5 cm with a seed rate of 100 kg ha^{-1}. One half of the nitrogen and whole of phosphorous was applied at the time of sowing and remaining N was applied to wheat crop under various spacings of poplar plantations and control after the first irrigation. Wheat crop was estimated in terms of growth and yield parameters (plant height, effective tillers, grains per ear and 1000 grain weight and grain/straw yield) by quadrate method at different time of plant growth and at harvest. Five quadrates of $1m^2$ were selected per replication between rows of poplar. The yield of the produce (grain and straw) was extrapolated to be expressed in t ha^{-1} by bringing the produce at 14 per cent grain moisture content. Protein content was estimated using Micro-Kjeldahl's method (AOAC, 1990) and gluten content was assessed in percentage using hand washing method.

RESULTS AND DISCUSSION

Growth of poplar: The mean height and GBH of poplar increased from 6.59 m and 16.92cm (1 year old plantation) to 19.55 m and 77.94 cm (8 years plantation), respectively. The height of poplar after 8 years of plantation was not affected significantly at different spacings under agroforestry (Table 2). However, different spacing's had significant effect on the girth of poplar. Paired row planting (18x2x2 m) of poplar resulted in significantly lesser girth (70.9 cm) than planting of poplar at 10x2 m (81.53 cm) and 5x4 m (81.38 cm) spacings due to increased competition among plants for different growth resources. However, statistically non-significant variation for girth was observed between 10x2 m and 5x4 m spacings. Mean annual increment (MAI) also exhibited non significant variations for height but significant differences for girth under different spacings of poplar. Interestingly, more than 9.0 cm MAI for girth was estimated at 10x2m and 5x4m spacings indicating that these spacings are convivial for optimal increase in girth of poplar plantations under agroforestry system. Similar trends in growth of poplar under

Table 1. Soil chemical properties of the experimental field before sowing of wheat crop

Spacing (m)	pH (1:2)	EC dS m^{-1}	OC (%)	Available nutrients (Kg ha^{-1})		
				N	P	K
5 x 4	7.8	0.12	0.72	340	18.3	364
10 x 2	7.8	0.10	0.66	317	16.1	345
18 x 2 x 2	7.9	0.14	0.62	278	13.4	332
Control	7.9	0.22	0.39	228	9.5	285

Table 2. Growth performance of poplar under agroforestry system

Spacing (m)	Tree height (m)			GBH* (cm)		
	1 year age	8 years age	MAI	1 year age	8 years age	MAI
5 x 4	6.55	19.60	1.86	17.65	81.38	9.10
10 x 2	6.62	20.15	1.93	17.59	81.53	9.13
18 x 2 x 2	6.60	18.90	1.76	15.51	70.90	7.91
Mean	6.59	19.55	1.85	16.92	77.94	8.71
CD (p=0.05)	NS	NS	NS	0.5	2.6	0.9

*Girth at breast height (1.37 m above ground level) different spacings in irrigated eco-system with slight variable values have been reported by several research workers (Nissen *et al.*, 2001; Dogra *et. al.*, 2007; Khan and Chaudhary, 2007 and Chauhan *et. al.*, 2012b)

Wheat growth and yield attributes: In poplar based agroforestry system, different spacings showed significant variation for initial plant population (10 days after sowing) of wheat (Table 3). There was significantly higher plant population of wheat under control (devoid of poplar trees) than poplar based agroforestry system (Table 3). The minimum plant population (152.2 m^{-2}) in 5x4 m spacing may be due to absolute covering of soil surface by highest leaf fall in this spacing which delayed the germination. The plant height in control was significantly higher than under different spacings of poplar plantations. On an average, 34.2, 31.4, 25.0 and 20.5% decrease in plant height of wheat was observed after 30, 60, 90 and 120 days, respectively under poplar based agroforestry system as compared to the wheat crop in open due to the availability of more sunlight. The wheat plant growth was significantly varied with respect to different spacings. The plant growth of wheat was significantly higher at different intervals under 18 x2 x 2m (paired row) spacing than 5 x 4m and 10 x 2 m spacings. The number of tillers m^{-2} (Table 4) followed the trend of plant height under different spacings of poplar plantations. The rate of decrease in number of tillers m^{-2} varied from 4.90 under paired row to 12.5 per cent under 5 x 4m spacings as compared to the control and this decrease was reflected in the ultimate grain yield. Dry matter accumulation per square meter also followed the above pattern under different spacings of poplar plantations. The crop growth is mainly affected by light and nutrient availability. Leaf litter inputs from agroforestry trees could provide sufficient nutrients and organic matter to sustain crop growth (Lehmann *et al.*, 2002; Bhardwaj *et. al.*, 2005; Durai *et al.*, 2009). Negative tree-crop interactions for light, moisture and nutrients at closer spacing reduces crop growth rate. At closer spacing tree species utilize more resources for their growth and development. Sharma *et al.* (2000) also reported that close spacing of poplar inhibit the crop growth of wheat. Corroborative results were also reported by Chauhan *et. al.* (2015a).

The yield attributing parameters exhibited significant differences under different spacings of poplar (Table 4). The number of ear heads/m^2, number of grains/ear head and test weight were recorded significantly lesser under 5x4 m spacing due to more shade and competition for moisture and nutrients between annual and perennial plants. However, the differences were non significant between 10x2 and 18x2x2m spacings for number of grains/ear head and 1000 seed weight. The yield attributes mainly depends on the crop growth and are significantly affected by tree spacing. Similar results were earlier reported by Sharma *et al*. (2000), Kumar and Rajput (2003) and Chauhan *et. al.* (2012b) in wheat as intercrop with poplar.

Wheat grain and straw yield: The grain yield of wheat crop was observed maximum under control plots (4.3 t ha^{-1}) and it was statistically higher than the crop under different spacings of poplar plantations. The crop grain yield declined significantly with decrease in spacing (Fig. 1). The rate of decrease in grain yield of wheat crop was sharp under 5x4 m spacing. On an average, the grain yield decreased up to 51.2 % under 5 x 4 m spacing as compared to the control plot. Less

Table 3. Plant population and plant height at different time intervals of growth in wheat under different spacings in poplar based agroforestry system

Spacing (m)	Plant population (m^{-2})	Plant height (cm)			
		30 DAS	60 DAS	90 DAS	120 DAS
5 x 4	152.2	17.7	33.5	58.3	64.7
10 x2	175.7	21.6	40.4	68.2	75.5
18 x 2 x 2	191.4	26.1	49.8	77.5	82.1
Control	213.6	33.2	60.1	90.7	93.5
CD (p=0.05)	10.8	3.4	2.8	3.7	3.2

Table 4. Growth and yield attributing parameters of wheat under different spacings of poplar

Spacing (m)	Tillers m^{-2}	Dry wt m^{-2} (g)	No. of ear heads m^{-2}	No. of grain per ear head	Test weight (g)
5 x 4	304.4	939.2	298.1	27	29.4
10 x2	316.5	993.8	310.2	34	35.1
18 x 2 x 2	330.5	1022.5	325.6	38	38.1
Control	347.7	1164.3	343.8	47	47.3
CD (p=0.05)	12.3	19.9	9.6	4.7	3.7

growth and yield under poplar plantation may be due to the increase in competition for different resources (moisture, nutrients, etc.) and microclimatic changes (light, temperature, humidity, etc.). Wheat yield reduction under poplar plantations had also been recorded earlier (Newman *et al*., 1995; Burgees *et al*., 2004; Sharma *et al*., 2005).

The rate of decrease in straw yield was comparatively lower than grain yield under different poplar spacings (Fig. 1). The straw: grain ratio was estimated to be 0.9 under control, whereas, the values varied from 1.0 to 1.19 under different spacings of poplar plantations, which is not significant higher than the control value. The winter cereals are normally suited to partner deciduous trees. The crop grows strongly during the initial period (November to mid March), when shading is not a problem. By the time, poplar have developed their foliage, the wheat crop has virtually entered into reproductive phase/completed its vegetative growth and the reproductive phase is affected by the shade and even the ripening of the crop is delayed by a fortnight. That's why the affect on the straw yield is comparatively lesser than the grain yield. However, the biological yield increased with increase in poplar spacing (Fig. 2). These results are also in conformity with the earlier findings (Ralhan *et al*., 1992; Sharma *et al*., 2000), where the decrease in biological yield decreased with decrease in tree spacings. The decrease in spacing and increase in age of poplar is associated with root and canopy closure, this caused intense competition for light, nutrients and water, and thus, reducing the wheat yield. Also with the decreasing poplar spacing , the amount of poplar leaf litter mulch also increases, which hinders the germination of seed and comparatively the tiller number per unit area are less under the tree canopy.

Protein and gluten content: The average protein content of wheat was maximum under different spacings of poplar plantation (Fig. 3). However, the highest protein content (10.7 %) was estimated in wheat grown under 5 x 4m spacing. The increase in protein content under agroforestry may be due to reason that a high moisture level associated with more moderate temperature in shade may result in a faster rate of mineralization, litter breakdown, and turnover of N than occurs in full sunlight (Wilson, 1996). Naeem *et al*. (2012) also reported that a positive effect of shade on protein content in the cereal crop grains. The values of gluten per cent in wheat were significantly higher under different spacings of poplar based agroforestry than sole crop of wheat; however, there was no significant difference among all poplar spacings under study. The less content of gluten in sole wheat (10.57 %) might be due to more heat stress. Randall and Moss (1990) reported earlier that during grain filling, dough strength (gluten) increases with the increase in

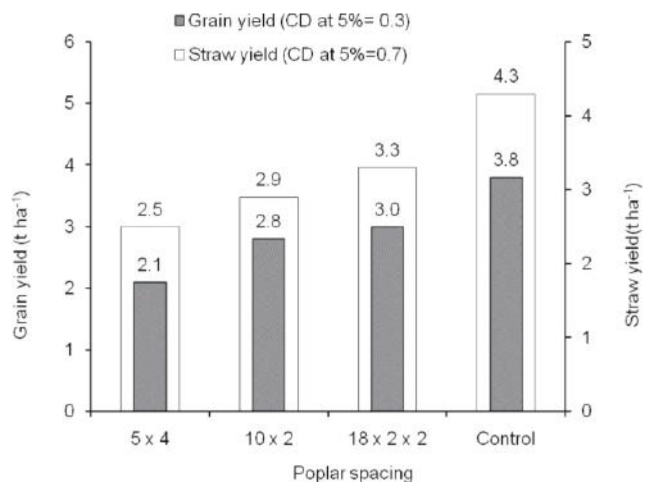

Fig 1. Grain and straw yield of wheat under different spacings of poplar and control

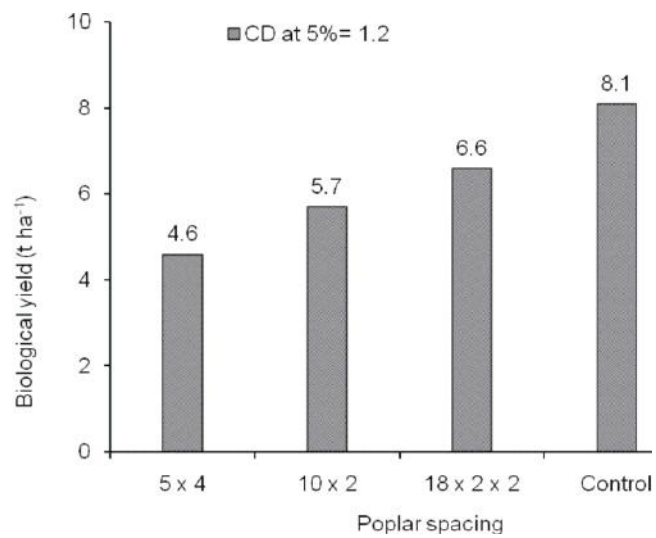

Fig 2. Biological yield of wheat under different poplar spacings and control

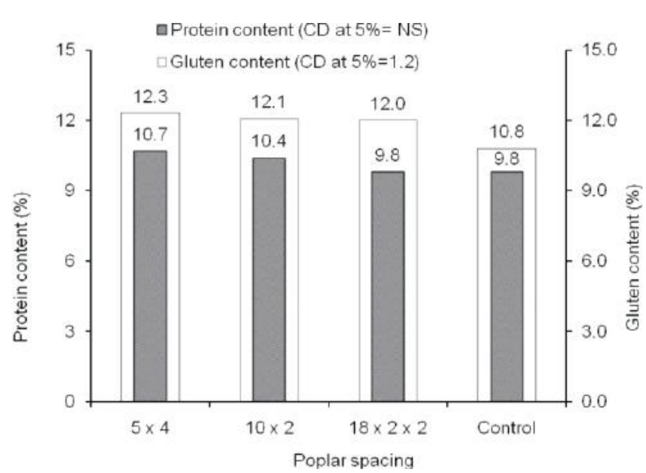

Fig 3. Protein and gluten content in wheat under poplar based agroforestry system and control

daily mean temperature up to 30°C however it decreases with further increase in temperature. The heat stress due to increased temperature causes a reduction in the size of glutenin polymers (Blumenthal *et al.,* 1995).

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An Economic Analysis of Tangible and Intangible Benefits in Agroforestry Production in Tamil Nadu

R. Sangeetha, T. R. Shanmugam and S. Menaka

Department of Agriculturtal Economics, Tamil Nadu Agricultural University, Coimbatore-641 003, India
E-mail: Sangeethaagri@live.in

Abstract: The study used primary data from 240 randomly selected agroforestry farmers. Sample agroforestry farmers were classified as Agri-silvicultural farms and Silvicultural farms who were adopting teak and tamarind as sole cropping; teak with maize, tamarind with sorghum as inter-cropping. The respondents were aware of the economic and environmental benefits of agroforestry practices and had favourable attitude towards those practices. Indirect use values obtained through ecological services contribute the largest share (54.02%) to theoretical framework (TEV). The values are high since the proxies used for valuation namely carbon value have high market prices. The overall capital invested on agro-forestry yield more returns than agricultural crops, indicating economics of scale in agroforestry system.

***Key Words*:** Agroforestry, Benefit cost ratio, IRR value, Profitability, Tangible/intangible

Forests provide a variety of tangible and intangible benefits to the economy. Earlier, the valuation of forests was carried out in terms of tangible benefits like timber, non-timber and forest products. The economic value of intangible benefits such as soil and water conservation and ecosystem services were under-estimated or ignored by the policy makers. This led to a biased decision in favour of a number of development projects such as construction of roads, industrial units, large dams, etc. As a result, many of the world's natural forests have been severely damaged. The benefits aimed by many projects have been overshadowed by the long-term ecological costs (Manoharan, 1998). The low forest area coupled with the low productivity of Indian forest has ushered in a total mismatch between the demands and supply of both domestic wood and secondary timber besides creating environmentally disequilibrium and de-stability in India.

MATERIALS AND METHODS

The study was carried out in the Dharmapuri district as it is the one of the major agroforestry production in Tamil Nadu. Dharmapuri district occupies an area of 4497.77 square kilometres.

Data collection: The study used cross-sectional primary data collected from 240 agroforestry farmers randomly selected from a list of tree growers in the Pennagram and Morappur taluks for during the 2013-2014 production season. In each taluks, 120 tree growing farmers were randomly selected. Structured questionnaire was the main instrument used to collect the primary data. The data were analyzed by using multiple regression analysis to estimate the factors affecting the adoption rate of agroforestry technologies in the Dharmapuri district of Tamil Nadu

Theoretical framework (TEV): Theoretical frame work of agroforestry is dominated by various intangible benefits such as recreation, watershed benefits, ecological services, evolutionary processes, and biodiversity (Table.1). The use values of the forest include: tree outputs that can be consumed directly, functional benefits, and future benefits. The non-use values include the value of the forest as a natural resource to future generations and values from knowledge of continued existence.

Table 1. Tangible and Intangible costs and benefits from agroforestry

Tangible costs	Cost of cultivation
Tangible benefits	Firewood Soil and water conservation Timber Agricultural productivity Nitrogen fixing
Intangible costs	Cost of birds scaring
Intangible benefits	Waste assimilation Carbon store Litter Fall

In determining private and social returns of agroforestry by calculating NPV, BCR, and IRR, both private and public cost and benefit streams were used.

Birds scaring: Trees provided shelter to birds, have a longer gestation period and they attract more birds. According to Shanmugam *et al.* (2001) bird scaring constitutes 5-7% in Dharmapuri district. Moreover, birds feed sorghum and

maize seeds, which in turn leads to reduce productivity in agri-silviculture in the study area. Several methods are suggested in the literature to quantify intangible benefits and intangible costs of forests (Dixon and Sherman, 1990; Pearce and Moran, 1994). .

Analytical framework : Analysis of the data was done using the discounted measures of project worth. The net present value (NPV), the internal rate of return (IRR) and the benefit-cost ratio (BCR) were used to estimate the tangible benefit and cost of agroforestry production in the Dharmapuri district of Tamil Nadu.

RESULTS AD DISCUSSION

Experience in farming activities of sample farmers: Farming experience helps farmers in the adoption of modern farm technology. The farmers with 10-30 years of farming experience was highest with 57.92 per cent followed by farmers with less than 10 years of experience with 25.41 per cent of total sample farmers (Table 2). Among the total sample farmer only farmers having more than 30 years of experience, which was low. Hence, it could be concluded nearly 57.92 per cent sample farmers are having more than 10-30 years of experience in family. Age of the farmer was directly related to their farming experience.

Table 2. Experience in farming activities of sample farmers

Farmingexperience	No. of sample farms		Total	Percentage to the total
	Pennagram	Morrapur		
<10 years	31	30	61	25.41
10-30 years	68	71	139	57.92
> 30 years	21	19	40	16.67
Total	120	120	240	100.00

Agroforestry and farm size of study area: The average area under agroforestry per farm was 26.48% and 39.5% under agri-silviculture. The average area, under forestry per farm formed 61.6% and 52.15% in silviculture. The size of the farm increased the area under agroforestry increased. It could be seen that the farmers shifted from agri-silviculture to silviculture as farm size increased.

Social benefit and social cost (Teak): The costs and benefits were estimated by using 12 per cent discount rate (Shanmugam *et al.*, 2001). Present worth of benefits for the period of one to six years was assumed zero because during this period, teak trees generally do not bear matured timbers. Discounted cost, discounted return and net present worth were estimated to be Rs. 24208, Rs. 173876 and Rs. 149668 per hectare over the life time of teak + maize cultivation. The benefit cost ratio and internal rate of return was 7.19 and 58 per cent, respectively showing that investment in teak + maize cultivation can be considered as substantial and economically justifiable over the period. The investment in teak production is profitable**,** it could be seen that the intangible cost included cost of birds scaring only. It was higher in case of teak since these crops provided shelter to birds, have a longer gestation period and they attract more birds. Intangible benefits are realized due to soil and water conservation, agricultural productivity of intercrops, nitrogen fixation, waste assimilation and carbon storage. In the Social economic analysis, when carbon sequestration and soil water conservation benefits are incorporated, it provides very high NPVs. The mean annual litter fall (leaves, seeds plus flowers, twigs) amounted to 882 kg ha^{-1}, 90% of which was leaf litter. The litter was analyzed for major nutrients, and the mean annual litter fall contained the following amounts of plant nutrients: N 4.2, P 4.6, K 24.8, Ca 52.1 and Mg 6.6 kg ha^{-1}.

The crop yield increase fetches more financial benefits than the cost. This will result in an increase in NPV implying that the use of more productive lands for forest plantations is attractive. Thus, at 12 per cent social discount rate all the ventures provide very high NPV, and provides the highest economic NPV and as such the investment in agroforestry is financially viable.

Social cost and benefit in tamarind + sorghum cultivation: Table 5 shows the costs and returns do not serve as true yardsticks for making a decision to go for investment in tamarind production. This is due to the fact that costs incurred in and returns from tamarind cultivation are not comparable without discounting such costs and returns. The present worth of costs and benefits was estimated by using 12% interest rate or discounting rate. Present worth of benefits for the period of one to three years was assumed to be zero because during this period, tamarind trees generally do not bear fruits (if fruiting occurs in some years and in negligible amount). Discounted cost, discounted return and net present worth were estimated to be Rs. 43931, Rs.

Table 3. Agroforestry and farm size of study area

Model	Crops	Area under agroforestry (ha)	Farm size (ha)	Percentage of agroforestry area to total operational area
Agri-silviculture I	Teak intercropped with maize	1.12	4.23	26.48
Agri-silviculture II	Tamarind intercropped with sorghum	1.43	3.62	39.50
Silviculture I	Teak	3.24	5.26	61.60
Silviculture II	Tamarind	2.67	5.12	52.15

Table 4. Social cost and social benefit- teak with maize cultivation (Rs. ha^{-1})

Age	Bird scaring	Carbon biomass	Soil water conservation	Agri. production	Oxygen supply	Leaf litter	Total social benefit	Discount factor (12%)	Discount cost	Discount benefit	NPW
1	1441	0	5706	8860	1882	0	16448	0.893	1287	14686	13399
2	1585	0	5706	8676	1882	0	16264	0.797	1264	12966	11702
3	1744	0	5706	7379	1882	0	14967	0.712	1241	10653	9412
4	1918	0	5706	0	1882	0	7588	0.636	1219	4822	3603
5	2109	0	5706	5324	1882	0	12912	0.567	1197	7326	6130
6	2319	0	5706	4874	1882	0	12462	0.507	1175	6314	5139
7	2550	0	5706	0	1882	0	7588	0.452	1153	3432	2279
8	2804	35850	5706	-1442	1882	0	41996	0.404	1132	16962	15829
9	3084	0	5706	3868	1882	0	11456	0.361	1112	4131	3019
10	3392	0	5706	0	1882	0	7588	0.322	1092	2443	1351
11	3731	0	5706	2687	1882	0	10275	0.287	1073	2954	1881
12	4104	14938	5706	2427	1882	0	24953	0.257	1053	6405	5351
13	4514	0	5706	0	1882	0	7588	0.229	1034	1739	704
14	5055	0	5706	1117	1882	0	8705	0.205	1034	1781	747
15	5560	0	5706	591	1882	0	8179	0.183	1016	1494	478
16	6115	8547	5706	0	1882	0	16135	0.163	997	2632	1634
17	12229	0	5706	4056	1882	0	11644	0.146	1781	1696	-85
18	12351	0	5706	3774	1882	0	11362	0.130	1606	1478	-129
19	12351	0	5706	0	1882	0	7588	0.116	1434	881	-553
20	12474	14504	5706	1731	1882	642589	666412	0.104	1293	69085	67792
									24194	173880	149686
									BCR	7.19	
									IRR	58%	

Table 5. Social cost and social benefit - tamarind + sorghum cultivation (Rs. ha^{-1})

Age	Cost	Soil water conservation	Agri. productivity	Waste assimilation	Carbon biomass	Total benefit	Discount factor (12%)	Discount cost	Discount benefit	NPW
1	3181	7054	4914	997	0	12965	0.890	2840	11576	8736
2	3499	7054	5013	997	0	13064	0.800	2789	10414	7625
3	3848	7054	0	997	0	8051	0.710	2739	5731	2992
4	4232	7054	5215	997	24650	37916	0.640	2689	24096	21407
5	4655	7054	5320	997	0	13371	0.570	2641	7587	4945
6	5120	7054	0	997	0	8051	0.510	2594	4079	1485
7	5631	7054	5534	997	0	13585	0.450	2547	6145	3598
8	6194	7054	5645	997	0	13696	0.400	2502	5532	3030
9	6810	7054	0	997	0	8051	0.360	2456	2903	448
10	7490	7054	5873	997	32160	46084	0.320	2412	14838	12426
12	8238	7054	5991	997	0	14042	0.260	2114	3604	1490
13	9061	7054	0	997	0	8051	0.230	2077	1845	-231
14	9967	7054	6233	997	0	14284	0.200	2039	2923	883
15	10963	7054	6357	997	0	14408	0.180	2003	2632	629
16	12059	7054	0	997	34512	42563	0.160	1967	6943	4976
17	13264	7054	6614	997	0	14665	0.150	1932	2136	204
18	14590	7054	6746	997	0	14797	0.130	1897	1924	27
19	16048	7054	0	997	0	8051	0.120	1863	935	-928
20	17652	7054	7019	997	36712	51782	0.100	1830	5368	3538
								43931	121211	77280
								BCR	3.00	
								IRR	32%	

Table 6. Summary of social benefit and social cost

Tree crops	Discounted benefit (12%)	Discounted cost (12%)	NPV	BCR	IRR
Teak	173876	24209	149668	7.19	58
Tamarind	121211.7	43931.41	77280.27	3.00	32

121211 and Rs. 77280 per hectare over the life time of tamarind trees. The BCR came to be 3.00 showing that investment in tamarind cultivation can be considered substantial and economically viable. Internal rate of return was found to be 32 per cent over the period.

It could be seen that the intangible cost included cost of birds scaring only. It was higher in case of tamarind since these crops provided shelter to birds, have a longer gestation period and bring fruit crops, they attract more birds. Composition of intangible benefits is presented in Table 1. Intangible benefits are realized due to soil and water conservation, agricultural productivity of intercrops, nitrogen fixation, waste assimilation and carbon storage.

Results of social benefit and social cost analysis are presented in Table 6. External benefits are higher in teak (58%) and tamarind (32%). The result indicated that if the externalities associated with agroforestry were internalized, these systems would be more attractive as investments. Moreover, the economic valuation of agroforestry systems is dominated by intangible social benefits.

Total economic valuation: The economic valuation of agroforestry systems is dominated by intangible social benefits than tangible social benefits. The valuation components of tangible benefits were produces, grazing, agricultural productivity, timber and fruits which contribute 45.97% to the total economic value. Furthermore, valuation components of intangible social benefit are soil and water conservation, carbon bio mass, waste assimilation and oxygen supply which contribute 54.02% to the total economic value in the study area.

Earlier research suggested that indirect use value from agroforestry may be significant. At the same time, they must be interpreted with caution due to data limitations and lack of empirical studies on indirect use value on agroforestry. On the other hand, this valuation includes only a few indirect values, such as soil and water conservation, carbon bio mass, leaf litter and oxygen supply, and this may balance a potential overestimation. The indirect values used in this study are therefore most likely higher than average.

As farm size increased the area under agroforestry increased in the study area. It could be seen that the sample farmers shifted their practices from agri–silviculture to silviculture as farm size increased. Capital invested on agroforestry yielded more returns and production than agricultural crops. Majority of the agroforestry units were sources of livelihood to the households as evident in milk, poles, timber, animals and poultry. The produce supplements household income and especially during emergency need for cash.

Table 7. Totals economic valuation-component value

Value components	Rupees (Rs.)
Direct use value	
Produces	261541
Grazing	32850
Agricultural productivity	11363
Timber	149950
Fruits	127883
Sub Total	583587 (45.97)
Indirect use value- ecological services	
Soil and water conservation	5706
Carbon biomass	32000
Leaf litter	642589
Oxygen supply	1882
Sub Total	682177 (54.02)
Total	12,65,764 (100.00)

Policy implications: Based on the analytical results and the established conclusions, the following policy prescriptions were drawn.

Measures need to be taken to include the economic value of ecological services in the cost-benefit analysis framework for developmental projects in the study area. Motivating tree growers toward conservation by creating awareness on the benefits the ecosystem provides is essential. Benefits of agroforestry (source of livelihood, environmental, medicinal, economic and socio-cultural benefits) sustain households. However, the practice has the potential to provide even greater economic, social, health, environmental and other opportunities, which would enhance household income, livelihood opportunities, food security, aesthetics and soil conservation. The rural households' participation in trainings on agroforestry is fundamental in order to access information on the best practices and its management for optimal benefits.

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Effect of Planting Seasons, Age of Planting Stock and Hydrogel on Survival and Growth of *Populus deltoides* Under Degraded Sites of North Western Himalayas

Tahir Mushtaq and Rakesh Banyal
Faculty of Forestry, Benhama, Ganderbal, Sher-e-Kashmir University of Agricultural and Technology, Kashmir-191 201, India.
E-mail: tahirmushtaq333@gmail.com

Abstract: The plantation of *Populus deltoides* using different plantation and moisture conservation techniques was done on three types of land namely: degraded underutilized (scrub dominated), degraded pastures/grazing lands, barren rocky/stony waste. The experimental site falls in a mid to high altitude characterized by hot summers and very cold winters. Two planting seasons, two planting stocks and five hydrogel levels (20 treatment combinations) for moisture conservation were analyzed for survival and growth of plantation. Results showed that out of two planting seasons studied, autumn planting was better compared to spring planting. Among two planting stocks, two year old plantss were observed to perform better on the experimental site. Survival and growth parameters were recorded higher in liquid application 3 g $plant^{-1}$ compared to control, solid application 3 g $plant^{-1}$, liquid application 1.5 g $plant^{-1}$ and 4.5 g $plant^{-1}$.

Key Words: Degraded site, Growth, Hydrogel, Plantation, Survival, Stock

Land is one of the most important resource on which human beings depend and rate of soil degradation is continuously increasing with the advancement of science and technology, industrial expansion, urbanization and population explosion. The most important cause of land degradation is destruction of forests and other vegetation from sloping lands, river sides and other areas sensitive to damage (Pramod and Mohapatra, 2012). Anthropogenic activities like over grazing, wood cutting and burning have intensified land degradation results in soil deterioration all over the world (Jin, 2002). Vegetation acts as a protective cover against the forces of wind and water, protecting the soil from being washed or blown away and preserving the physical and hydrographic balance of nature (Jain and Singh, 1998). Plantations can conserve soil on degraded lands by reducing nutrient loss, increasing soil organic matter and improving the soil texture (Thapa, 2003). The forestry is ecologically as well as economically more viable option then traditional forestry and technology of fast growing species mainly poplar and eucalyptus have been taken up by farmers and institutions to boost wood production in the world. Tree plantations present an economically attractive alternative to natural forests and might also be a practical option for production on degraded lands and contribute considerably in terms of carbon sequestration, increased soil organic carbon and conservation of biodiversity (Bremer and Farley, 2010).

In temperate regions particularly in Kashmir valley, farmers possess small land holding which is mostly under the cultivation of agricultural crops. Therefore, farmers are left with only option to plant trees on degraded lands. As the availability of land for tree plantation is insufficient, people have to grow short rotation crops and are seen viable option to produce better income and biomass in a short time and in a sustainable way (Bentsen and Felby, 2012). The most important exotic species used for this purpose in the region is *Populus deltoids* and is most common in community and household woodlots. In an environment suffering from land degradation and deterioration, fast growing and resilient *Populus deltoides* perform better than most indigenous tree species. Small holders show a clear preference for this poplar which is multiple in use (Jagger and Pender, 2003). Therefore, an attempt was made to utilize degraded lands for plantation of poplar to address the problem of land degradation with social commitment.

MATERIAL AND METHODS

The plantation of *Populus deltoides* was done on degraded land of the Faculty of Forestry, SKUAST-Kashmir, Benihama Campus, Ganderbal, Jammu and Kashmir at an altitude of 5850 feet above mean sea level. The existing land of the experimental site was pertaining to three types of land problems namely: degraded underutilized (scrub dominated), degraded pastures/grazing lands, barren rocky/stony waste. The experimental site falls in a mid to high altitude characterized by hot summers and very cold winters. The average precipitation is 690 mm most of which was received from December to April in the form of snow and rains. The metrological data for the plantation season was obtained from the meteorological observatory Ganderbal. The total rainfall (mm) during the experimentation period was

Domestication and Intensive Management of Poplar (*Populus deltoides*) Clonal Plantation under Agroforestry to Maximise Yield and Improve Environment through Carbon Sequestration and Climate Change Mitigation in North India, Historical Perspective and A Case Study

M. S. Haque
Ex-Head, Forestry, National Bank for Agriculture and Rural Development, Mumbai-400 051, India
E-mail.haque.ms@rediffmail.com

Abstract: A study was undertaken in Chahal village of Nawanshahr district of Punjab to ascertain poplar management practices and marketing opportunities. Discussions were held with the farmers and plywood manufacturers and then we met two progressive farmers, who possessed 20 hectare land and raised poplar in such a way that every year they could harvest 2 ha plantations. The clone G48 was planted at a spacing of 5m x 4m and the plantations were regularly manured, weeded, irrigated and harvested in 6th year, when trees reached an average height of 18m and girth of 90cm, which yielded 180 ton wood per ha and clocked an income of Rs. 7.2 lakh at a sale price of Rs.4000 per ton. Sugarcane and wheat were intercropped. Today poplar based agroforestry has established benchmarks of high economic returns and many poplar growers are earning around Rs.2.5 lakh income per ha per annum with timber prices touching Rs.11,000 per ton in Yamunanagar timber market. It was concluded that poplar based clonal agroforestry worked wonders and both the farmers and wood industries used it sustainably along with improving the local environment through carbon sequestration and climate change mitigation.

Key Words: Climate change mitigation, High yield, Poplar agroforestry

Systematic domestication research in poplar was started by Forest Research Institute, Dehra Dun and Uttar Pradesh Forest Department in the year 1951 and onwards with various species and cultivars, however they were not successful under extensive introductory field trials, mainly due to unmatched climatic conditions, except one clone each of *Populus cassale* and *P. deltoides* clone IC. Although in India, there are six indigenous *Populus* sp.viz. *P.ciliata, P.euphratica, P.gamblei, P. alba, P. glauca and P. saveolens* (Mathur and Sharma, 1983) mainly distributed sporadically in the Himalayan regions, none performed well under field trials. WIMCO (Western India Match Co.) was facing difficulty in procuring raw materials for their unit, hence introduced *P. deltoides* clones out of selections made at Grafton in Australia in the 1980s. Out of these exotic clones, G-3 and G-48 outperformed all other clones and laid the foundation of the success story of commercial scale poplar plantations by farmers under irrigated agroforestry systems in north Indian states of Uttar Pradesh, Punjab and Haryana (Chauhan and Mangat, 2006).

Although WIMCO started cultivating poplar clones under farmer's land with assured buyback guarantee at remunerative prices, farmers asked for finance to meet the cost of cultivation, which was beyond the means of WIMCO, hence approached NABARD (National Bank for Agriculture and Rural Development) for funding. Realizing the importance of agroforestry in the country, NABARD, partnering with WIMCO, farmers and 13 commercial banks under PPP (Public-Private-Partnership) model promoted and funded a very big clonal poplar plantation project under agroforestry systems from 1984 to 1995 in the states of Punjab, Haryana, Uttar Pradesh and Uttrakhand. The partners agreed to assist the poplar growers as follows:

i) Supply of quality planting stocks i.e. ETPs (Entire Trans Plants) to the farmers
ii) Provide technical and extension services to the farmers for raising and maintaining poplar plantations
iii) Buy back guarantee to the farmers to purchase poplars on maturity by 8th year with assured support price
iv) Provide long term finance to farmers through 13 Commercial banks with refinance assistance from NABARD
v) R & D support for developing new poplar clones and identification of suitable agricultural crops for cultivation under poplar plantings.

The umbrella project was a huge success and today, poplar is a household name in the region and almost every farmer raise it on their farmland either as border or block planting under agroforestry. In fact, the success of this mega project put poplar under complete domestication by the farmers. Poplar wood is used for match splints, plywood, packing cases, sports gods, pulpwood, furniture, toy manufacturing etc.

MATERIAL AND METHODS

Due to over production and related issues, the price of poplar wood started falling in the year 2002 and reached the lowest price of Rs. 800 per metric ton in 2004. The farmers were highly disappointed and stopped growing poplar. Then in the year 2006, the Hon'ble Supreme court of India banned the felling of trees above 1000 M msl and poplar resurfaced again, this time with much vigor and vengeance. To ascertain the clear picture about poplar plantings, availability of quality planting stocks, its yield, income, intercrops, bank loan and marketing, the author undertook a study in Chahal village of Balachaur block in Nawanshahr district of Punjab state in 2010 along with WIMCO and other NABARD officials and held discussions at length with a number of farmers and poplar wood industrialists. After this, we went to the field and observed that excellent plantations were raised by the farmers by procuring clonal ETPs from WIMCO Seedlings Ltd. (WSL). The scientists of WSL had produced many high yielding poplar clones through selection and interspecific and interclonal hybridization in their research station at Rudrapur in Uttarakhand state viz. Uday, WSL-22, WSL-32, WSL-39, etc. But it was observed that the most successful and high in demand was introduced clone G-48, which was favoured by many farmers. Later, we met two very progressive poplar farmers named Sri Surjeet Singh and Sri Gurmeet Singh, interacted with them, inspected their series of plantations on their farm including infrastructure.

RESULTS AND DISCUSSION

The farmers, actually landlords, had 20 hectare irrigated land and planned poplar plantings in such a way that every year they could harvest a minimum of two hectares plantations, thus they possessed 1,2,3,4,5 and 6 year old plantations and the spacing followed was strictly 5 m x 4 m, planting materials were mainly G -48 clone obtained from WSL, followed a rotation of six years, when trees had reached an average height of 18m and girth of 90cm, yielded 180 tone wood per ha, clocking an income of Rs. 7.2 lakh based on a price of Rs. 4000 per metric ton. Poplar was the main crop, sugarcane was additional crop and intercropped only for 3 years. The plantations were excellent and were both fertilized and irrigated by channel method. The farmers were very happy with the plantations since marketing was not a problem, because there were more than 1000 poplar based wood industries located in Yamunanagar, Haryana. Besides, more than 200 poplar based industries were also located in Jalandhar and Ludhiana in Punjab. It might be mentioned here that before introducing poplar, there was not a single wood factory there, but today it has the largest congregation of factories manufacturing wood products worth Rs.5000 crores annually. The middlemen visited the area regularly and harvested the trees on their own and carried to the wood factories. Normally poplar attained an average girth of 15cm/year/ tree, but till date the best yield in poplar was achieved by late Captain Ratan Singh, when his trees attained an average girth of 18cm year^{-1} tree^{-1}. A table with growth measurements recorded in a series of poplar plantations is provided in Table 1. It was further observed that although in NABARD scheme, poplar harvesting was fixed at eighth year, the farmers harvested in sixth year because of good growth and high demand. Another important finding was that the small and marginal farmers were not involved in poplar agroforestry.

Poplar was raised in loamy, fertile and well drained soils with neutral to alkaline pH and irrigated frequently through water channel system. Each row of trees had an independent channel throughout the rotation age and intercrops were grown in the area between the rows The plantations were irrigated at an interval of 10 days in summer months to avoid water stress. The nutrient requirements of poplar was standardized for different age groups of trees and recommended to apply whole of P and one-third N during May after harvesting of intercrops, one-third N in July and the remaining one-third in September. Zinc sulphate heptahydrate was applied to overcome zinc deficiency. Poplar leaf defoliators sometimes attacked the plantations, hence Quinalphos was recommended to spray dissolved in water. Besides, regular weeding, mulching etc. were undertaken. The annual nursery production of ETPs were around 30 to 40 million, out of which, only 15 per cent were supplied by WSL, the rest were produced from unauthorised nurseries. Genetically improved poplar ETPs of WSL were the most sought after in the area and the farmers had to book in advance with part payment. Even the forest departments of Punjab and Haryana states booked WSL clones in advance.

The world's largest poplar plantation today is in the north Indian states of Punjab, Haryana, Uttar Pradesh and Uttrakhand under agroforestry and which is growing every year. It was estimated that in Punjab alone there were 12.90 million poplar trees (Forest Survey of India, 2006). Experts in wood industry now believe that there would not be any recurrence of glut in the market, because demand of poplar wood has grown tremendously with population growth and the farmers are also highly experienced and plant poplar clones after proper planning. An earlier study report by (Saigal and Kashyap, 2002) in Uttar Pradesh concluded that the success of *P. deltoides* clones and *Eucalyptus sp.* based agroforestry could be termed as second green revolution of India. The author in his earlier study (Haque and Kannapiran, 2003) stressed the need for popularizing poplar based

Table 1. Average growth of poplar in the studied plantations in Punjab State

Tree Nos.	Year wise growth of Poplar trees in a series of plantations (1 acre) Years, Girth in cm					
	1	2	3	4	5	6 (Harvesting)
1	17	38	55	60	76	
2	18	45	54	59	75	
3	21	40	55	51	78	
4	19	42	58	58	68	
5	16	46	69	62	78	
6	18	38	63	63	78	
7	20	50	52	63	75	
8	15	52	54	66	80	
9	18	47	51	65	95	
10	21	48	50	60	90	
Average girth in cm	18.3	44.6	56.1	60.7	79.3	

NB:

i. Average height	After 5 year's growth Poplar reached an average height of 18 m & girth of 80 cm.	
ii. Best girth	Achieved 95 cm by Late Captain Ratan Singh, Average year wise growth was 18 cm yr^{-1} $tree^{-1}$	
iii. Agricrops	Ist year :	Sugarcane
	2nd year	Ratoon sugarcane
	3rd year :	Wheat onwards
iv. Harvesting	It was not done by the farmers, the middlemen visited the farms regularly & purchased the trees, cut into pieces, uprooted the stump and then carried to the plywood industries.	
v).Marketing	Marketing was not a problem, since there was a good marketing network for industrial uses of poplar wood	
vi. Industrial uses	i) More than 50% of Poplar woods were consumed by industries in Yamunanagar, where 1000 plywood factories were established	
	ii) 40% of Poplar wood went to Ludhiana and Jalandhar where more than 200 plywood factories were located	
	iii) 10% used locally,mainly in Ropar	

agroforestry in a big way in north Indian states by involving institutional credit. A study by a group of authors (Chauhan *et al.*, 2009) indicated that some progressive farmers of Punjab state with intensive management of poplar earned Rs.75,000 to 87,000 ha^{-1} $year^{-1}$ income from poplar based agroforestry against Rs.30,000 to 37,000 ha^{-1} $year^{-1}$ from rice-wheat rotation, which was two and a half times more income than crop cultivation alone. It was also reported that wheat grain yield showed a decreasing trend with height growth of poplar trees. On an average, reduction in grain yield was 20.10 per cent under one year old plantation, which increased to 54 per cent under four year old plantation. Farmers had adopted poplars due to their short rotation of 6 -8 years, easy regeneration, easy availability of genetically improved clones, good market demand, handsome economic returns, restricted cultivation advantage and their compatibility with agricultural crops especially wheat and sugarcane. Dhillon *et al.* (2001) reported annual net return of Rs. 55,390 and Rs. 73,330 ha^{-1} without intercropping and with intercropping respectively from poplar over the entire rotation. The higher return in case of poplar with intercropping was mainly due to higher productivity of poplar with higher after care with intercropping than poplar without intercropping. A recent study indicated that poplars under agroforestry had changed the landscape of many districts of Punjab, North- western Uttar Pradesh, Terai areas of Uttarakhand and parts of Haryana states (Lal, 2010).

Poplar is now totally integrated in social, agricultural, silvicultural, ecological, industrial, economical and financial applications of the region and therefore, transforming rural economy through its commercial cultivation as cash crop in agroforestry (Dhiman, 2012). A recent visit undertaken by the author in Uttrakhand state, where large number of poplar clonal agroforestry plantations were raised also revealed similar high wood yield and handsome returns (Haque, 2014).

National Agriculture Policy (2000) stressed the need for agroforestry for efficient nutrient cycling, nitrogen fixation, organic matter addition and for improving drainage. Planning Commission, Govt. of India (2001) stated that in order to bring 33 per cent land under tree cover, 28 million ha revenue land were proposed to be brought under agroforestry, besides rehabilitating 15 million ha degraded forest land in 10 years. NABARD, thus promoted several successful agroforestry projects with *Eucalyptus*, *Casuarina, Leucaena* and Bamboos, in association with wood based industries, but the per ha wood yield and income was much less as compared to poplar, although genetically improved *Eucalyptus* clones proved to be more efficient in wood production under unirrigated conditions and might be considered as second best for India (Haque and Karmakar, 2006). It can be concluded from the case study and our wide experiences in promoting and implementing agroforestry projects throughout India, that it was the clones that worked wonders and neither tissue cultured plants nor seedlings were that much productive and it was again the poplar clones, which outsmarted all other tree clones under agroforestry. Today, the Poplar based agroforestry has established benchmarks of high economic returns in India. Many of the average poplar growers are now realizing around Rs.10 lakh per acre per year net returns with timber prices touching an all time high of Rs. 11000 per MT in Yamunanagar poplar timber market (Dhiman, 2012). This might be the highest income from agroforestry plantations anywhere in the world (Haque, 2014). A recent study on the growth performance of 12 new clones in Punjab state indicated that clone WSL 39 had achieved the best growth and maximum volume attaining diameter of 14.74cm, height of 14.42 m and volume of 0.1040 cubic meter tree^{-1} at the age of 3 years (Luna *et al.,* 2012).

A study carried out in India on carbon sequestration potential of AR (Afforestation and Reforestation) projects reported a sequestration potential in the ranges of 1.42 to 2.54tC ha^{-1} year^{-1} (Gera *et al.,* 2006). On the contrary, the highly efficient poplar clonal plantations with yield of 180 metric ton wood under six year rotation can sequester more than 15tC ha^{-1} year^{-1} and can be an effective tool for climate change mitigation. Recently released National Agroforestry Policy (2014) states that agroforestry can become an important tool to build resilience of farmers and rural people against threats of climate change and natural calamities. This can also help in greening the rural areas and initiate rural development opportunities by providing agroforestry tree produce based economic activities. Today, the 4 North Indian states have more than a billion ha poplar plantations and every year millions of poplar ETPs are planted. Besides WSL, quality planting stocks are also supplied by Forest Research Institute, Dehra Dun, Punjab Agricultural University, Pragati Biotech etc. With India's population touching 1250 million, demands for poplar wood products are likely to remain high. Regarding marketing, no problem is envisaged in near future, since Yamunanagar has emerged as the plywood capital of India (Sapra and Bhojavaid, 2014). The town is a hub of the wood based industries, as one-third of farm grown wood arrives from Haryana and two-third arrives from the adjoining poplar growing states of Punjab, Uttar Pradesh and Uttarakhand. At present annual turnover of this wood market is Rs 10 billions, which is likely to grow further.

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281.2 and 418.80 during 2013 and 2014, respectively. The minimum temperature (°c) ranged from -1 to -6 and 3.4 to 14.1, and temperature from 17.7 to 24.4 and 21.7 to 32.5 and the average maximum relative humidity (%) from 74.5 to 95.1 and 70.4 to 90.8, whereas, mean minimum from 43.1 to 78.7 and 37.1 to 80.1% during the plantation season of autumn 2013 and spring 2014, respectively.

Plantation details: The ETPs of *Populus deltoides* were planted to evaluate the effect of planting season, age of planting stock and different levels of hydrogel on growth and establishment of the species. Two planting seasons viz. autumn planting and spring planting were compared to evaluate the best planting season for the species, plantss of two different ages were tried viz. one year old (A_1) and two year old (A_2) to evaluate the most appropriate age of plantss of *Populus deltoides* for best growth in both the planting seasons. Five levels of hydrogel viz. H_0 (control), H_1 (solid application 3 g plant^{-1}), H_2 (liquid application 1.5 g plant^{-1}), H_3 (liquid application 3 g plant^{-1}) and H_4 (liquid application 4.5 g plant^{-1}) were tried to elucidate best level for *Populus deltoides* on problematic sites in both the season

The experiment was raised in factorial randomized block design with 20 treatment combinations in three replications with two plants per replication. One and two year old plants of *Populus deltoides* were uprooted from the nursery beds and ETPs were planted at a spacing of 2 m by line planting in the experimental field.

RESULTS AND DISCUSSION

There were significant variations for survival percentage between two seasons. Autumn planting recorded highest survival (70.99%) followed by spring planting (69.99%). The age of planting stock in both the seasons significantly affected plant survival. Highest survival was for second year plants due to long tap root system of two year old plants, which helps in better moisture absorption. The hydrogel application to the plantation significantly affected survival percentage of plants. Highest survival percentage was recorded for liquid application 3 g plant liquid application, followed by liquid application 1.5 g plant liquid application, 4.5 g plant liquid application, solid application 3 g plant liquid application and control in both the seasons.

The present investigation reveals that plant height increment is significantly influenced by planting season, age of planting stock and different levels of hydrogel application. Maximum plant height increment (26.99 cm) was recorded for autumn planting and minimum (26.31 cm) for spring planting. The reason might be availability of abundant moisture in autumn, which was responsible for early plant establishment compared to spring planting. The irrigation requirement in autumn planting is far less than spring planting. The table that age of planting stock significantly affected plant height increment. Maximum height increment was recorded for second year planting stock compared to first year planting stock in both the seasons. The hydrogel application to the plantation significantly affected plant height increment in both the seasons. Maximum plant height increment was observed in liquid application 3 g plant liquid application, followed by liquid application 1.5 g plant liquid application, 4.5 g plant liquid application, solid application 3 g plant liquid application and control.

Collar diameter increment was influenced by planting season, age of planting stock and different hydrogel levels. Both the planting seasons significantly affected the collar diameter increment. Highest collar diameter increment (5.34 mm) was for autumn planting and lowest for spring planting. The age of planting stock significantly affected collar diameter increment. The hydrogel application to the plantation significantly affected collar diameter increment. Maximum collar diameter increment was observed in liquid application 3 g plant liquid application, followed by liquid application 1.5 g plant liquid application, 4.5 g plant liquid application, solid application 3 g plant liquid application and control.

The leaf area of *Populus deltoides* was significantly affected by planting season, age of planting stock and different hydrogel levels. Highest leaf area growth (888.91 cm^2) was recorded for autumn planting and minimum (887.11 cm^2) for spring planting. The leaf area growth was affected by age of planting stock and highest leaf area growth was recorded for second year planting stock (A_2) and minimum for first planting stock (A_1) in both the planting seasons. Second year planting stock possess greater number of branches because of more shoot length, so greater leaf area. Different hydrogel levels applied to the *Populus deltoides* plantation significantly affected leaf area growth in both the seasons. Leaf area of plants increased with increase in hydrogel concentration upto certain limit and then decreases. The liquid hydrogel application was found more effective than solid application and reason for this might be easy expansion of rootlets, which otherwise is somewhat difficult in solid application.

The current study suggested that out of two planting seasons, survival and growth parameters was better in autumn planting compared to spring planting. Second year planting stock recorded better survival and growth compared to first year planting stock. Among the hydrogel levels applied, liquid application 3 g plant liquid application was quite effective.

Table 1. Effect of planting season, age of planting stock and hydrogel on *Populus deltoides*

Age	Autumn planting		Mean	Spring planting		Mean	Factor means					
Hydrogel	A_1	A_2		A_1	A_2		Hydrogel		Age		Planting season	
Survival (%)												
H_0	50.00	66.66	58.33	50.00	50.00	50.00	H_0	54.16	A_1	69.99	S_1	79.99
H_1	66.66	83.33	74.99	50.00	66.66	58.33	H_1	66.66	A_2	79.99	S_2	69.99
H_2	83.33	83.33	83.33	66.66	83.33	74.99	H_2	79.16				
H_3	100	100	100	83.33	100	91.66	H_3	95.83				
H_4	83.33	83.33	83.33	66.66	83.33	74.99	H_4	79.16				
Mean	76.66	83.33	79.99	63.33	76.66	69.99						
CD (p = 0.05)	H=1.48,	S =2.43,	A=3.54,	H×S =2.58,	H×A= 3.68,	S×A=3.11,	H×A×S=NS					
Plant height increment (cm)												
H_0	26.11	26.20	26.16	26.00	26.05	26.03	H_0	26.09	A_1	26.59	S_1	26.99
H_1	26.33	26.54	26.44	26.16	26.25	26.21	H_1	26.32	A_2	26.71	S_2	26.31
H_2	26.88	27.00	26.94	26.31	26.39	26.35	H_2	26.65				
H_3	28.27	28.39	28.33	26.66	26.92	26.79	H_3	27.56				
H_4	27.01	27.13	27.07	26.12	26.26	26.19	H_4	26.63				
Mean	26.92	27.05	26.99	26.25	26.37	26.31						
CD (p = 0.05)	H= 0.08,	S =0.11,	A= 0.13,	H×S = 0.12,	H×A= 0.11,	S×A= 0.12,	H×A×S= 0.13					
Collar diameter increment (mm)												
H_0	5.08	5.21	5.14	5.00	5.07	5.04	H_0	5.09	A_1	5.31	S_1	5.34
H_1	5.30	5.38	5.34	5.18	5.24	5.21	H_1	5.27	A_2	5.34	S_2	5.32
H_2	5.40	5.42	5.41	5.32	5.40	5.36	H_2	5.38				
H_3	5.50	5.55	5.52	5.77	6.00	5.89	H_3	5.70				
H_4	5.28	5.37	5.32	5.05	5.13	5.09	H_4	5.20				
Mean	5.31	5.38	5.34	5.26	5.37	5.32						
CD (p = 0.05)	H= 0.09,	S =0.10,	A= 0.12,	H×S =0.11,	H×A=0.10,	S×A= 0.12,	H×A×S=0.13					
Leaf area (cm^{-2})												
H_0	886.60	887.10	886.85	885.13	885.98	885.56	H_0	886.20	A_1	887.71	S_1	888.91
H_1	888.33	888.98	888.66	886.09	886.42	886.26	H_1	887.46	A_2	888.31	S_2	887.11
H_2	889.42	889.67	889.55	887.33	887.91	887.62	H_2	888.58				
H_3	890.54	891.80	891.17	888.10	888.94	888.52	H_3	889.85				
H_4	888.10	888.52	888.31	887.42	887.78	887.60	H_4	887.96				
Mean	888.60	889.21	888.91	886.81	887.41	887.11						
CD ($p \leq 0.05$):	H=1.01,	S = 0.28,	A= 1.00,	H×S = 1.23,	H×A= 1.38,	S×A= 1.21,	H×A×S= 1.					

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Productivity and Carbon Sequestration of Community Managed and Reserve Forests of Kumaun Himalaya

Nidhi Bhakuni and Neelu Lodhiyal
Kumaun University Nainital - 263 002, India
E-mail: nidhi.kunainital@gmail.com

Abstract: Comparison of productivity and sequestration rate of community managedforest sites and reserve forest sites in presented here. The soil of both sorts of the sites was sandy loam textured and slightly acidic in nature. The young trees accounted for more biomass and shared more carbon sequestration as compared to the old trees, because of more density of young girth class than old trees. The average carbon stock in community and reserve forest was 277 and 228 $tCha^{-1}$ worth US$ 1385, US$ 1140 annually at the current rate of US $5 per ton. The Net Primary Productivity of the community and reserve forest ranged 13.8-25.1 $tha^{-1}yr^{-1}$, 7.9-17.7 $tha^{-1}yr^{-1}$ respectively. The carbon sequestration rate in community and reserve forest ranged 6.5-11.8 $tCha^{-1}yr^{-1}$, 3.7-7.4 $tCha^{-1}yr^{-1}$ respectively. The participatory monitoring has proved to be flourishing, reliable and cheap, and improved the condition of community forest, community work more effectively. The study illustrates an efficient conservation and management of community forests and reserve forest through effective collaboration of local community and forest department.

Key Words: Basal area, Biomass, Carbon sequestration, Community managed forest, Soil organic matter

Among the greenhouse gases, increasing CO_2 concentration is blistering challenge for scientific world. The forests are the most convenient alternative for sink of CO_2 concentration in atmosphere. In 1992, Kyoto Protocol was proposed to some of industrialized countries, including India, for controlling and regulating the emission of greenhouse gases. The most capacious green house gas formed by human in CO_2 in calculating overall carbon emission, the protocol deducts certain removal of carbon by native forest and soil carbon sink. Thus it is one option for mitigation green house gases emission and therefore possible to carbon stored in forest (Gorte, 2009). Progress in developing a forest carbon compensation mechanism for tropical countries under the United Nation frame work convention on climate change (UNFCCC 2010) is commonly referred to as reduced emission from deforestation and forest degradation. Reducing emissions from deforestation and forest degradation has spark further research on establishing reliable method for carbon estimation in tropical ecosystem (Malhi and Phillip 2004; Saatchi *et al.*, 2007). The atmospheric CO_2 concentration has globally raised from 285 ppm to 366 ppm between 1850 and 1998, an increase of about 28% (IPCC 2000). About two-thirds of terrestrial C, exclusive of that sequestered in rocks and sediments, is sequestered in the standing forests, forest understory plants, leaf and forest debris, and in forest soils (Sedjo *et al.*, 1998; Upadhyay *et al.*, 2005). Community managed forests in Himalayan region became an important strategy for enhancing carbon pool in the region for climatic perspective. Carbon sequestration reveals enduring storage of CO_2 to diminish global warming and avoid hazardous climate change (Sharma *et al.*, 2015). Community assisted active forest management can substantiate a significant aid to increase the carbon sequestration. The objective of the study was to assess comparative account of forest productivity and carbon sequestration rate managed by community and forest department. The study has revealed equal participation of local communities in forest management and conservation which escalation of the forest productivity and carbon sequestration.

MATERIAL AND METHODS

The studied sites of Kumaun Himalaya are located in Sunderkhal community forests and Paharpani reserve forests with an area 206 ha and 308 ha respectively and situated at 29°19' to 29°33' N latitude and 79°43' to 79°58' E longitude and 1600 to 2200 m elevation from above sea level. The average annual rainfall is 1977.2 mm, minimum temperature varies from 5 to 2.3 °C and maximum temperature varies from18 to 21.3 °C (Indian Veterinary Research Institute, Mukteshwar, Utarakhnad) (Fig. 1).

For the estimation ofcarbon stock and carbon sequestration rates in the studied forest sites we measured Cbh (circumference at breast height, 1.37m from the ground level) of trees in 2012 and marking for re-measurement was done in 2013. Measurements of a circumference were taken on the same marked trees in

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Integrated Approach of Resource Management in Chipko Movement: A Retrospective Study

Chhatradhar Das
Lalbaba College, Belurmath, Howrah-711 202, India
E-mail: chhatradhar@yahoo.co.in

Abstract: Chipko Movement was a milestone to raise voice against global plundering of forestry resources and is considered as the first environmental movement in independent India achieving success. The present study aims to understand the traditional knowledge of the local people for safeguarding the Himalayan ecology. The field work has been carried out through direct communion with the villagers for smelling the efficacy of the movement in the present context. This study highlights the need of plantation programme which is regarded as an integrated approach of resource management. The plantation programme in Chamoli and other neighbouring districts of the hills has been a driving force to ensure the protection of environment. The respondents put maximum stress on safeguarding forest and forestry resources. Considering the fragile nature of the soil of Chamoli, the respondents gave emphasis on extensive plantation programme. The mounting pressure on environment caused by global warming and climate change is considered as a world-wide menace. The afforestation programme should be taken to the extent of social movement and need is to employ suitable management programme for natural resources to establish ecological harmony.

Key Words: Afforestation, Global warming, Traditional knowledge

The human concern about the rapid change in global environment has started since after the World War II and is well substantiated from the establishment of International Union for the Protection of Nature (IUPN) in 1948. The on-going global alertness about environment also gave birth to International Union for the Conservation of Nature and Natural Resources (IUCN) in 1957 which demanded preservation of natural resources, in addition to nature. In the context of the relation between man and environment, an international conference was also held in 1956 in Chicago, U.S.A. to evaluate "Man's role in changing the face of the earth". Man's concern and thereby rise of different organizations devoted to environmental consciousness in national and international levels prompted to lead environmental movements around the globe to ensure sustainable harmony among the components of the earth i.e., land, sea, air, animals, plants and human beings. In the advent of environmental aggression, human beings were concerned about the global environmental hazards and thus began to conscious of their ecological rights as well. Subsequently, Rachel Carson sparked the right to consciousness as the contemporary ignition to the people about the risks of pesticides in her book entitled "*Silent Spring*" (1962).

Environmental resource management is also an issue of increasing concern in socio-political frameworks which aims to ensure that ecosystem services are protected and maintained for future generations and also to maintain ecosystem integrity through considering ethical, economic and scientific variables. It may be mentioned that during the last two centuries, consumption of fossil fuels has elevated CO_2 levels from a concentration of 280 ppm to more than 375 ppm (Fedorov *et al.*, 2006). Global climate was changing slowly over a long period of time. But the rate of change jumped up suddenly during last century and more rapidly since the World War II. It reflected upon the earth's environment which was already worn out. Anthropogenic factors that increase the CO_2 levels due to emissions from fossil fuel combustion, other factors, including land use, ozone depletion, and deforestation also add to the climate change. Consequently upon, *environmental problems* soon *became more complex.*

The Garhwal Himalayan region has already experienced two prominent environmental movements during the last four decades to protect man's rights on land and forest resources and to maintain ecological harmony of life support system. During the last few decades, there has been rapid destruction of forest resources threatening the livelihood of millions of forest-dwellers and those poor people who used to live in the vicinity of the forests. According to Malhotra (2005) the forest plays an important role in nurturing prosperity of any nation and her people. The National Forest Policy (1988) of India envisages that one-third geographical area of the country should be left under forest cover. It is now well established that forests serve as the abode of wildlife and support biodiversity. It has now emerged as a challenging task to manage and conserve the valuable forest resources sustainably under ever increasing population pressure as well as eco-degradation to ensure the livelihood of the forest dependent community. The present study aims to throw light on the efficacy of the Chipko movement upon the society of that region. It also aims to understand the traditional knowledge of the local people for safeguarding the Himalayan ecology and identify the challenges in response to the search for efficient and environmentally sustainable development strategies.

MATERIAL AND METHODS

A retrospective study on the status of Chipko Movement is carried out. Stakeholders' perception is a powerful tool for policy analysis and has considerable potential in forestry tree plantation programme. Thus, perception of the local people as well as that of environmental activists and leaders of the movement has been recorded through field survey in different places of Garhwal Himalayan Region. Secondary data also have been collected from different official sources and from different literatures. In order to acquire the conceptual basis of the genesis of environmental movements in global perspective relevant literature have been studied. There have been considerable researches on the Chipko Movement as it was the first revolt in independent India against environmental destruction. A good number of research papers and articles have already been published on the subject. A large amount of information on this movement is available in website too.

People's perceptions were discerned through participatory discussions covering 100 respondents distributed in different villages like Gopeshwar, Mandal, Reni, Tapovan and Lata which are located in the climax zone (Chamoli district) of the Chipko Movement. Not that all of them were in the forefront, but they spontaneously participated in the agitation, procession, demonstration in whatever way the movement was organized. They all belonged to common class. They still bear their perception and feeling of the Chipko Movement. The field work has been carried out through direct communion with the villagers for smelling the efficacy of the movement in the context of the present time. Hence, the field work has basically been concentrated in Chamoli District.

The process of interview was based on random sampling. Breaking in the way of conventional method, the researcher darted at the person whoever was available without discriminating his/her status or qualification; but the researcher considered the respondents of not less than 45 years of age to judge their personal attachment and/or experience with the movements.

RESULTS AND DISCUSSION

The Chipko Movement and Anti-Tehri Dam Movement that took place in Garhwal Himalayan region during last four decades have assumed great significance so far the environmental consciousness is concerned. In studying the genesis of Chipko Movement, it is observed that the bone of contention began with the forestry resources which confer a possession right to the local people. But in reality, the forest is exploited commercially for yielding unscrupulous profit.

The Chipko Movement was a series of demonstrations in the Garhwal region that varied in participation, methodology and ideology. The movement has widened their focus from basic survival needs to ecological concerns (Sethi, 1993, Gadgil and Guha, 1994). Economic and political demands published in handbills in 1973 which were put up on trees in Chamoli district were: (a) Abolition of the auction/ contractor system and the formation of forest labour cooperatives, (b) People's participation in forest management and protection to be institutionalized through the Gram Sabha, (c) Establishment of local, small-scale forest-based industries to generate employment, (d) A new forest settlement to determine the people's rights to forest produce, such as fuel wood and fodder, (e) Assistance to village efforts for afforestation, and (f) Ban on felling green trees in areas critical for the protection of water sources and the prevention of landslides (Krishna, 2002). Thus, people's main demand in the protests was that the benefits of the forest, especially the right to fodder, should go to local people (Bahuguna, 1990). The economic and ecological demands indicate that such type of contracts which exploits forest resources should not be given to the outsiders.

Perception on Chipko movement: According to the respondents, the Chipko Movement is an ideal environmental movement, which is considered as the first environmental movement in independent India achieving success. Most of the respondents directly participated in the movement.

According to 99% respondents (Table 1), Chipko Movement was significant for protecting the environment in Garhwal Himalayan Region. The devastating flood of 1970 which was a terror to the hilly people, the Chipko Movement emerged as a saviour to them by the way of protecting environment from further destruction. It gave residents a conviction of living peacefully by safeguarding forest and forestry resources. Therefore, 86% people take the movement as a vital means of living in harmony with nature. According to them, the formation of the Himalayas stretching over Chamoli is fragile. Unless the forestry resources is

Table 1. Perceptions on different issues

Issues	Responses	% of responses
Perception on movement	Protect environment of this region	99
	Beneficial movement	86
	Ecological movement	60
Perception on main issues	Protection of forest	91
	Protection of livelihood	83
	Forest right to local people	77
	Commercialization of forest	56
	Stabilization of Himalayan ecology	51
	Flood control	44
Perception on main challenges	Consistency in plantation	66
	Environmental integrity/harmony	63
	Global warming/climate change	57
	Sustainable development	33
	Stabilization of Himalayan ecology	28
Perception on present activities	Afforestation programme	83
	Save seed movement	10
	Formation of own nursery	5
Views and suggestions	Conservation of seeds	59
	Plantation for stabilization of Himalayan ecology	51
	Species specific forest	37
	Forest right to Forest Protection Committee (FPC)	23
	Comprehensive planning for sustainable development	19

protected and secured, any devastation may visit the said area in any time.

Perception on main issues: Some of the activists were deeply engrossed with the movement from the very inception while few others were involved later on. At that time, the Dasholi Gram Swarajya Mandal (DGSM) had been participating in different programs in the perspective of Gandhiji's 'Sarvodaya Bhavana' throughout the villages. Many people, being attracted by the Gandhiji's concept, involved themselves in the DGSM programme with a view to alleviate poverty, unemployment and to eradicate social injustice among the people. Subsequently they became associated in the Chipko Movement.

Some members of the activist were infatuated sensing the urge for preserving natural environment. They had a thought that the movement would make common people alert against perpetual destruction of Nature. Therefore, the movement would organize people to work for environmental protection with responsibility.

A section of the common mass being driven by their consciousness for environment came in close contact with the movement for preventing environmental degradation. Some also opined that the people depending on forest for their livelihood will face hard challenge if wanton destruction of forest is continued. Hence, the Chipko movement will give them an assurance of their existence.

The theme of the Chipko movement was to grow alertness about environment and a good many people involved themselves with the movement to save environment. They also believe that the success of the Chipko Movement can probably mitigate the harmful effect of changing climate.

The respondents put maximum stress on safeguarding forest and forestry resources in the Garhwal-Himalayan region. They have the feeling of protecting forest to ensure green environment but they, at the same time, put emphasis on protection of livelihood by protecting forest. They think that the lower middle class people of the locality mostly depend on forestry resources for their earning bread. They will be deprived of their earnings if reckless destruction of forest be allowed.

According to 56% respondents the revolt generated to protest against commercialization of forest. Stabilization of Himalayan ecology is another important issue which is supported by 51% respondents. 44% respondents also consider flood checking is an important issue among others to initiate Chipko Movement.

While discussing the perception on main

challenges, the respondents opined that plantation programme in this region is not consistent enough and therefore, environmental integrity or harmony is still a big challenge. Among them, 57% referred to global warming or climate change is a big challenge, 33% favored the implementation of sustainable developmental programme. They opined that the Himalayan ecosystem is most fragile and the developmental programme usually fails to suit the condition of the Himalayan region. In the opinion of the 28% of the respondents the total Himalayan ecology is affected by mere dressing of wounds without adopting proper steps for healing it.

Perception on present activities: It is evident that the people who participated directly or indirectly in the Chipko movement are still scrupulous to safeguard environment against any degradation. Though Chipko movement ceased long before, most of the people are engaged in plantation programme to keep the green unhurt. They think that the degradation of ecology can be checked by the implementation of social forestry programme.

There are few people (Table 1) who are involving themselves in the Save Seed Movement for the demand of permanent ecological stability. Many of the activists are also still involved with the movement. According to them, many of the species of plants on the Himalayas are either threatened or on the verge of extinction or already extinct. If the species of economic importance are only cultivated, it cannot save Himalayan ecology. Most of the respondents gave priority on plantation for bringing stability in the Himalayan topography. Considering the fragile nature of the soil of Chamoli, the respondents gave emphasis on extensive plantation programme. According to them, the plantation should be done depending on regional climatic condition under which plants of specific species can flourish. Thus, biodiversity in its totality should be conserved. The save seed movement is an effective step in this context. Some of the people have developed nurseries of their own. The saplings grown in these nurseries are used in plantation programme.

A number of environmental activists played a signal role in 'Anti Mining Movement'. Series of mining work has made the structure of the hills weak. Therefore, not only deforestation, mining programme also affects the environment to a great extent. As a protest, the Anti-Mining Movement cropped up.

The respondents also suggest formulating scientific plan for developing species specific forest. This kind of forest will be able to protect Himalayan topography and climate. They also suggested an overall scientific scheme for upbringing sustainable development on the hills otherwise permanent ecological stability will not be achieved.

While supporting the quest of Himalayan protection as principal task, some respondents referred the issue of rights on forest for making good use of forestry resource for their livelihood. According to them, the slogans of Chipko movement included the issue of rights on the forest among others. They found success in Chipko movement but people's right on the forest still remains unachieved. Therefore, in order to ensure villagers' right on the forest, forestry rights should be transferred to Forest Protection Committee (FPC) for better management. It is also recommended to frame out a suitable management programme for natural resources to ensure ecological harmony.

Issues of the today's environmental movement: The forestation programme in our country is yet to come up in the limelight of social movement and plantation programme under government scheme were nothing but window-dressing of balance sheet. In all parts of the district Chamoli the plantation programme gradually developed into an organized social movement. In a report it is found that the number of saplings supplied as much as twenty five lac but destruction of 4300 hectares of forest land already been made in the Chamoli during the last few decades for different developmental activities. The plantation programme of DGSM has been able to reinstate 2900 hectares of land under forestry.

Positive outcome: The imposition of law prohibiting deforestation on hills for further 15 years is a great victory resulted from the movement and unless there was Chipko movement, not a single plant would have survived on the hills which could have caused eco-disaster. The outcome of the movement ultimately aroused environmental consciousness among the people. Women renaissance in the field of environment is another outcome of this movement. Moreover, the Chipko movement influenced the global environmental movement to a considerable extent. Indirect result of the movement was the check of soil erosion and thus ecological harms were prevented to some extent.

Limitations: The present state of developmental activities influenced the destruction of forest on the hills. As there is no definite plan, the environment cannot escape from its harmful effect. The Chipko movement may be considered as an ideal movement and consistent with the culture of the hills, if local people achieved their forest right. The schedule of the movement was included the rights of forestry resources to the families depended on forest; but the said right has not yet been established. The joint forest management system has been introduced but it needs further attention. Involving the rural folk to the developmental activities or to employ the income from forestry resources towards the development of rural people has not been given due attention.

Message to environmental activists of new generation: Both the two legendary leaders of the Chipko movement, Chandi Prasad Bhatt and Sunder Lal Bahuguna, put stress on plantation programme. Bhatt suggested that the environmentalist of the present generation should take a responsibility of developing forest for each village. He also recommended the arrangement of garden for each quarter where urban development has already been established.

CONCLUSION

Plantation programme had already been accepted as a social movement, especially in Chamoli District. Here, the activists remain engaged in afforestation programme throughout the year. Dasholi Gram Swarajya Mandal (DGSM) took up the plantation programme at least twice in a year. Community-based natural resource management comprises both the agricultural and forestry components of agroforestry production. Life supporting materials such as food, fodder, fruits, fuel, resin, herbal medicine etc. are available from the forest. The Chipko movement prevented commercialization of forest but could not safeguard the Himalayan environment effectively. Environmental integrity or harmony is still a big challenge. Global warming or climate change is also responsible for causing environmental degradation. Consequently, Uttarakhand state had witnessed a significant impact of climate change in June 2013 where unprecedented cloud burst causing massive destruction to life and property. Activists, therefore, suggest massive plantation programme which will maintain ecological balance in a sustainable manner. In different parts of the hills, 'Save Seed Movement' is continued along with traditional plantation programme. Everybody advocated the necessity of plantation /afforestation programme. It is also recommended to frame out a suitable management programme for natural resources to ensure ecological harmony.

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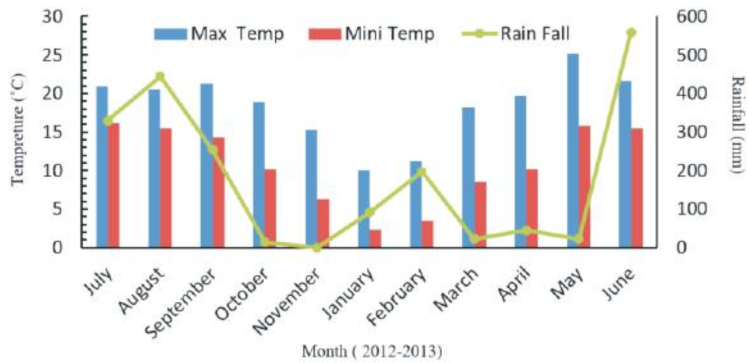

Fig. 1. Meteorological data shown temperature (Cº) and rainfall (mm) of the forest sites

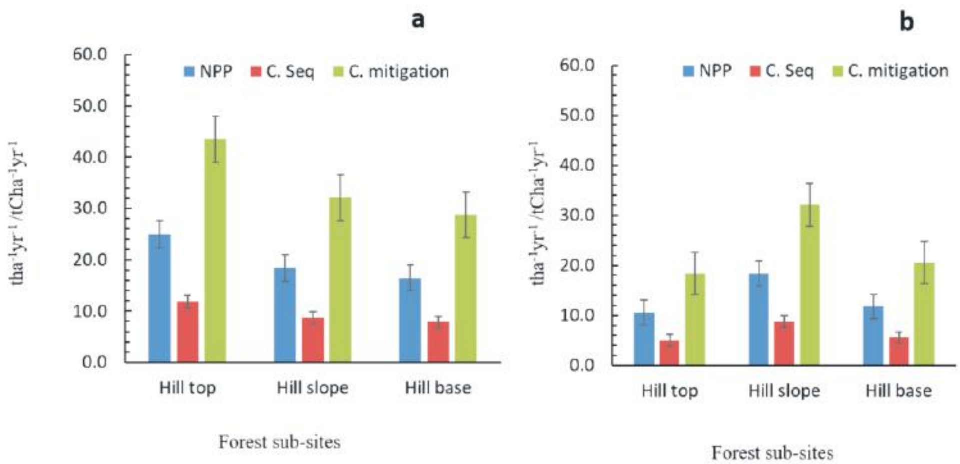

Fig. 2. Net primary productivity (NPP), carbon sequestration rate (carbon sequestartion) and carbon mitigation of the forest sites (a. community forest; b. reserve forest)

quadrats again in 2013 and biomass was computed. Change in biomass (ÄB = B2-B1) was taken as annual biomass accumulation. The sum of ÄB values for different components was taken for accretion of biomass in trees. For the estimation of trees, shrubs and herbs biomass, 10 m x 10 m, 5 m x 5 m and 1 m x 1 m quadrats were randomly placed, respectively on each site. Biomass was estimated on the basis of allometric equations developed by Rawat and Singh (1988) and Chaturvedi and Singh (1987). For the estimation of litter biomass the quadrats of 50x50 cm mwere placed randomly on each site. The biomass of herbs at all sites was determined during rainy season (the peak growth period). The herbs in each quadrat were harvested and the litter from each quadrat were placed in paper bags and brought to the laboratory. The samples were oven dried at 80°C to constant weight. The net primary production for tree, shrub, herb and litter layers was calculated in each site (Rana *et al* .1989). Carbon stock and carbon sequestration rates were estimated as 50% of the dry weight of biomass and 50% of net primary productivity, respectively (Hamberg 2000; Brown, 2001). The Carbon was converted to CO_2 mitigation by multiplied the total carbon storage with factor 3.67.

RESULTS AND DISCUSSIONS

The soil of both the sites was found to be sandy loam textured and slightly acidic in nature (Table 1).

Biomass and carbon stock: Total evaluated tree density and basal area of community forest ranged from 1220 to 1670 plant ha^{-1}, 26.3 to 44.94 m^2ha^{-1}, however in reserve forest ranged 480 to 910 plant ha^{-1}, 43.43 to 44.80 m^2ha^{-1}, respectively in different altitudes. The community forest showed more density than reserve forest site in tree layer.

The biomass was computed through circumference (cm) of different girth classes i.e. 0-30, 30.1-60, 60.1-90, 90.1-120, 120-150 and >150 cm measured from above ground level at breast height 1.37 m. The *Quercus floribunda* was dominant tree species and it shared more biomass, carbon content in hill top sub site than other two sub-sites, however in reserve forest site *Cupressus torulosa, Q. leucotrichophra* and *Pinus roxburghii* accounts more

Table 1. Physico-chemical properties of soil at studied forest sites

Forest site	Bulk density (gcm^{-3})		Soil moisture (%)		Soil porosity (%)		WHC (%)		Texture (%)			pH	
Community forest													
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	Sand	Silt	Clay	0-15	15-30
Hill top	0.92 ±1.24	1.74 ±0.03	4.85 ±1.30	15.33 ±3.32	65.3 ±2.37	34.3 ±1.21	25.1 ±1.01	39.4 ±1.33	65.7 ±1.02	20.9 ±0.0	13.5 ±0.09	6.3 ±4.91	6.2 ±3.53
Hill slope	0.91 ±1.00	1.69 ±0.09	9.0 ±0.98	14.96 ±1.51	68.16 ±2.35	28.75 ±1.59	27.9 ±1.11	32.7 ±1.01	57.2 ±1.60	26.6 ±1.14	16.2 ±0.31	6.6 ±3.80	6.5 ±3.65
Hill base	0.91 ±1.00	2.01 ±1.03	5.0 ±0.26	8.3 ±1.36	65.66 ±1.97	24.19 ±1.74	29.7 ±1.12	31.9 ±1.06	61.9 ±1.77	19.7 ±1.09	18.4 ±0.72	6.5 ±3.67	6.4 ±2.91
Reserve forest													
Hill top	0.83 ±1.79	1.24 ±0.91	19.19 ±1.36	33.13 ±2.10	68.8 ±2.46	53.1 ±4.67	22.3 ±0.95	32.8 ±0.11	41.5 ±1.32	33.2 ±0.56	25.3 ±1.59	6.7 ±2.70	6.7 ±1.61
Hill slope	0.7 ±1.45	1.09 ±0.97	19.62 ±1.21	25.62 ±2.22	46.79 ±1.00	41.02 ±4.01	37.8 ±0.96	33.7 ±0.26	47.5 ±1.39	27.5 ±0.57	25.6 ±1.05	6.6 ±3.49	6.6 ±2.71
Hill base	0.91 ±1.36	1.40 ±1.09	11.52 ±1.07	20.29 ±1.23	34.48 ±1.97	52.81 ±3.78	42.3 ±0.35	43.4 ±0.37	39.0 ±1.32	35.8 ±0.79	25.2 ±2.63	7.0 ±3.06	7.1 ±1.11

Forest site	Carbon (%)		Phosphorus ($kg\,ha^{-1}$)		Nitrogen (%)		Potassium ($kg\,ha^{-1}$)		Soil organic carbon (%)		C:N ratio	
Community forest												
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Hill top	1.230 ±0.011	0.943 ±0.002	20.688 ±0.040	23.133 ±0.120	0.420 ±0.00	0.270 ±0.004	155.21 ±0.456	85.948 ±0.917	2.120 ±0.01	1.625 ± 0.00	2.93 ±0.023	3.49 ±0.01
Hill slope	1.215 ±0.027	0.915 ±0.013	20.785 ±0.247	22.37 ±0.243	0.417 ±0.005	0.273 ±0.006	153.77 ±0.71	85.875 ±0.986	2.095 ±0.02	1.577 ±0.01	2.91 ±.06	3.35 ±0.05
Hill base	1.010 ±0.011	0.890 ±0.004	18.973 ±0.292	23.418 ±0.425	0.458 ±0.009	0.280 ±0.004	175.04 ±1.030	73.290 ±1.123	1.741 ±0.01	1.534 ±0.00	2.205 ±0.03	3.18 ±0.04
Reserve forest												
Hill top	1.018 ±0.003	0.948 ±0.017	13.278 ±0.181	21.278 ±0.039	0.270 ±0.000	0.210 ±0.000	201.850 ±3.566	123.958 ±2.099	1.75 ±0.003	1.63 ±0.03	3.77 ±0.01	4.51 ±0.02
Hill slope	1.112 ±0.045	1.01 ±0.018	18.267 ±0.0664	21.780 ±0.816	0.297 ±0.025	0.212 ±0.008	203.25 ±3.338	128.96 ±1.698	1.92 ±0.05	1.74 ±0.04	5.24 ±0.02	4.76 ±0.00
Hill base	1.068 ±0.013	1.008 ±0.005	14.913 ±0.157	16.550 ±0.280	0.230 ±0.000	0.180 ±0.000	241.985 ±3.037	66.830 ±0.221	1.84 ±0.00	1.74 ±0.00	4.64 ±0.01	5.6 ±0.03

Table 2. Trees biomass (t ha^{-1}) and carbon (t $ha^{-1}yr^{-1}$) with shrub and herbs productivity in two forest sub-sites

Forest sites		Hill top sub-site		Hill slope sub-site		Hill base sub-site	
		Biomass	Carbon	Biomass	Carbon	Biomass	Carbon
Community	AG	36.57±29.47	17.37±14.00	20.19±7.63	9.59 ±3.63	13.25 ±4.84	6.29±2.30
(Mean)	BG	10.15±7.65	4.82±3.63	7.38±2.93	3.50 ±1.39	4.72 ±2.00	2.24±0.95
Total		887.51±14.46	421.55±6.87	529.42±4.03	248.8±1.92	341.41 ±2.57	162.16 1.22
Shrub *		1.45±0.09	0.82±0.04	2.01±0.08	0.94±0.04	1.84 ±0.07	0.87±0.03
Herbs*		40.05±15.7	19.03±7.9	43.77±17.3	20.79±8.6	38.17 ± 17.9	18.13±7.0
Reserve	AG	22.21±16.08	10.55±7.64	29.80±16.84	14.15 ±8.00	16.86 ±10.52	8.01±5.00
(Mean)	BG	5.29±3.25	2.51±1.54	6.81±3.96	3.24 ±1.88	3.92 ±2.18	1.86±1.04
Total		467.55±7.60	222.08±3.61	622.37±8.51	295.6±4.04	353.27 ±5.02	167.8±2.38
Shrub*		0.97±0.08	0.46±0.04	0.95±0.05	0.45±0.02	1.70 ±0.09	0.82±0.04
Herbs*		33.84±8.00	16.07± 4.02	36.03±4.10	17.12±2.05	39.29 ±3.9	14.39±1.96

* Shrub ($tha^{-1}yr^{-1}$) and herbs (gm^{-2}) productivity is shown in this table with tree biomass.
AG (Above ground) and BG (Below ground) biomass

biomass and carbon content in hill top, hill slopeand hill base forest sub-sites, respectively (Table 2). In community forest, community people contributedmore in management and conservation ofbroad leaf tree species (Oak) and in reserve forest site more conifer species in the forests and forest department also conserve them. In community forests the young tree girth classes accounted more carbon content in the forest site whilein reserve forest site old trees (>90 cm, Cbh) shared more carbon content.

Productivity, carbon sequestration and mitigation: The productivity, carbon sequestration rate and carbon mitigation was highest in community forest than reserve forest. The net primary productivity of the community and reserve forest ranged 13.8-25.1 $tha^{-1}yr^{-1}$, 7.9-17.7 $tha^{-1}yr^{-1}$, respectively. The carbon sequestration rate in community and reserve forest ranged 6.5-11.8 $tCha^{-1}yr^{-1}$, 3.7-7.4 $tCha^{-1}yr^{-1}$, respectively (Figs. 2a, 2b). Hill top forest sub-site showed more carbon sequestration rate as compared to other two sub- sites in community forest because of the young trees (<30 cm, Cbh) density was much higher than the other two sub- sites. In reserve forest site the hill slope forest site contributed more in carbon sequestration rate and mitigation because *Q. leucotrichophora* density was highest in the hill slope forest site, local people illegally exploited more conifer species than broad leaves plant species. The reason of the concerned broad leaves plant species in forest sites that community people aware about the significance of broad leaf tree species. Shrub and herbs productivity was also higher in community forest (Table 2). Incommunity forest hill top sub-site contribute highest (50%) biomass followed by hill slope and hill base sub-site, however in reserve forests hill slope region of forest accounted maximum (43%) biomass followed by hill slope and hill base sub site. The evaluated value of soil has positive effects on the vegetation. The soil organic carbon, nitrogen availability on the forest sites promoted vegetation growth, the density and basal area of the forest sites were highest in present studied sites, where's earlier studied soil organic carbonand nitrogen availability on the reducing trends in Oak-Pine forests with altitudes might be due to reducing density and total basal cover of the trees with altitudes (Singh *et al.,* 2009).Oak forest is rich in nutrients than pine forest. Thus, oak forest should be preferred to protect, enhance their nutrients level for enhancing the forest ecosystem services (Shiekh and Kumar, 2010). The climate of the forest sites was cold, had a few months of summer and heavy rainfall in sites. Thus the climate and soil properties were suitable for enhancethe vegetation growth.

The evaluated carbon stock and sequestration rate in the forest site was high as compared to the pervious reported values. Present study revealed that the *Quercus floribunda*, *Myrica esculenta*, *Rhododendron arboreum*, *Pinus roxburghii*, *Cupressus torulosa* and other sub species contributes as carbon sink. The studied results evaluated that community forest was a rich source of the carbon sink. Carbon stock was found high in Pine forest as compared to Oak forest (Negi *et al.,* 2003), in pine forest of Aali community forest due to absence of ground vegetation there was no grazing and low dependency of villagers for their basic requirement (fuel, fodder, timber etc), however, in oak forest of Gwar community forest the dependency of the villagers were high due to proximity of forest (Gorte, 2009; Vikrant and Chauhan, 2014). Carbon sequestration rate in community forestswas even higher in banj oak than chir pine (conifer) forest (Vikrant and Chauhan, 2014). The mean carbon sequestration rate of the community and reserve forest was 9 tC $ha^{-1}yr^{-1}$, 6 $tCha^{-1}yr^{-1}$, respectively. The values on higher side as compared to previously reported 3.41-3.88 $tCha^{-1}yr^{-1}$ for community forest by Rawat in 2013, 0.60-4.38 $tCha^{-1}yr^{-1}$ for oak forest in Kumaun Himalaya by Pant and Tiwari (2014).

The mean carbon stock in community and reserve forest was 277 and 228 $tCha^{-1}$ worth US$1385, US$ 1140 annually at the rate of US$ 5 per ton. The participatory monitoring has proved to be flourishing, reliable and cheap, and improved the condition of community forest, community work more effectively. The present study reveals the efficient conservation and management of community forests and reserve forest. Inclusion of the local community for the forest management can prove more fruitful.

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Potential of Improved Perennial Grasses for Sustainable Fodder Production under Rainfed Conditions of Rajouri District, Jammu and Kashmir

Punit Choudhary, Rakesh Sharma, Sanjay Khar, Vikas Tandon and A. K. Isher

Krishi Vigyan Kendra Jammu
Sher-e-kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India
E-mail:pmd.choudhary@gmail.com

Abstract: Napier hybrid (NB-21) and *Setaria* (PSS-1) transplanted at 3m [illegible] farm bunds. [illegible] harvest green grasses from the available local pastures/lands, but now [illegible] perennial grasses on the bunds.

Key Words: Forage availability, Napier hybrid, Perennial grasses, Setaria

Grazing and harvested grasses form the local grasslands, common land and pastures are the chief fodder source for animal of hilly areas that are browsed, grazed or lopped from standing shrubs and trees. The three major sources of fodder supply are crop residues, cultivated fodder and fodder from common property resources like forests, permanent pastures and grazing lands. Based on 10th Five Year Plan Document, Government of India, the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% feeds. With availability of 400.6 million tonnes of green fodder against the demand of 1,097 million tonnes, still there is deficit of 63.5% green fodder. In Jammu and Kashmir, the demand-supply scenario of the fodder revealed 7,459 thousand metric tonnes of fodder availability over the estimated requirement of 12,563 thousand metric tonnes with 40% deficit.

Agri-silvi-pastoral and silvi-pastoral systems are mostly on the marginal and wastelands in the Rajouri district (Jammu Region) and fodders trees are primarily grown for fuelwood and small timber however, their value for feeding ruminants necessitates the planting of multipurpose fodder trees and grasses on the farm bunds, boundaries and sometimes grown scattered in the fields commonly known as *Gassnies* (Choudhary *et al.*, 2012). Majority of the fields of the district are situated across the slopes of the hills. The mean maximum summer and mean minimum winter temperatures are 36.5^0 C and 2.5^0 C, respectively. The annual rainfall of the district is about 1200mm. The climatic conditions of the Rajouri favours growth of perennial grasses on the farm bunds, boundaries under silvipastoral system. The cropping intensity of the distinct is 185 per cent. The total livestock population of the district is 11.811 lakh. About 94.3% of the population of this hilly district is rural and subsistent (Khar *et al.*, 2012).

Fodder production and its utilization depend on the cropping pattern, climate, socioeconomic conditions and type of livestock. The cattle and buffaloes are normally fed on the fodder available from cultivated areas, supplemented to a small extent by harvested grasses and top feeds. Rainfed areas are characterized by cut and carry system of fodder production with storage in the form of hay as insurance for the dry periods. Perennial grasses namely Hybrid Napier (*Pennisetum typhoides* x *P. purpureum*) and *Setaria* grasses with the advantage of faster growth and more production of herbage with ability to grow on variety of soil provided an opportunity to the farmers of rainfed hilly regions of the Rajouri district of J&K with an alternative cut and carry system of fodder production from their farmlands as per the requirements. In order to achieve the above objective the present study was designed to promote and offer an additional silvipastoral system by the way of cultivation of perennial grasses on the farm bunds in order to overcome the effects of the seasonal shortages of fodder and to insure fodder availability against risks of drought in Rajouri district.

MATERIAL AND METHODS

The study site falls in north-west of Himalayas and lies between 72^0 16' and 72^0 30'' east longitude and

Effect of Different Tree Species on Soil Properties under Agroforestry System

Amandeep Singh, Rajni Sharma*, S. K. Chauhan and Sandeep Sharma**

Department of Forestry & NR, *Department of Botany, **Department of Soil Science
Punjab Agricultural University, Ludhiana-141 004, India
E-mail: amandeepmehal24@gmail.com

Abstract: To assess the effect of turmeric (*Curcuma longa*) based agro-forestry model on soil properties, a experiment was conducted at University Seed Farm, Ladhowal, Ludhiana with four treatments i.e., three fast growing but phenologically different tree species (*Ailanthus excelsa*, *Gmelina arborea* and *Eucalyptus tereticornis*) and a control at 3m [illegible] replications. The soil properties pH, EC, bulk density and organic carbon were estimated at different depths i.e., 0-15, 15-30, 30-60 and 60-90cm. [illegible] recorded more under plantations than control i.e., *Gmelina arborea* (20.45tha^{-1}), *Ailanthus excelsa* (16.92tha^{-1}) and *Eucalyptus tereticornis* (14.75tha^{-1}). Results prove superiority of agroforestry system in improving the soil properties and enhanced carbon storage potential in biomass and soil.

Key Words: *Ailanthus excelsa,* Biomass carbon, *Eucalyptus tereticornis*, *Gmelina arborea,* Soil properties, Turmeric

Agroforestry, one of the important alternatives for diversification is gaining importance in irrigated agro-ecosystem for production and economic upliftment of the farmers. Moreover, it is a natural resource conserving system and comparatively less resource depleting system than intensive agriculture. The tree based farming system can help in diversification of agriculture for efficient and judicious use of depleting natural resources. Tree plantations influence the soil physical, chemical and biological properties through litter fall addition and root turnover. Tree roots explore a large soil volume for water, nutrient, microbial population, increased soil porosity, reduced runoff, etc. Increased soil cover lead to higher water infiltration and reduction in soil profile and diversify the livelihood activities to buffer against income risk during adverse conditions (Ekpo and Asuquo, 2012). Moreover, tree-crop combinations have been found to give better economic returns than tree or annual crops alone (Dogra *et al.*, 2007; Ram *et al.*, 2011).

Selection of suitable tree species with appropriate canopy and crops with partial shade tolerance and better yield potential are important aspects in agroforestry system, which are traditionally been followed. The outstanding example being the association of *Acacia albida*, *Prosopis cineraria*, *Aegle marmelos*, *Zizyphus*, etc on dry land with grain crops, where the yield of intercrops were higher due to microclimate benefits and peculiar reverse phenology of trees, thus accommodating itself to the requirements of crop cultivation. *Ailanthus excelsa* is a summer deciduous, low water requiring and fast growing tree, which is raised in agroforestry. Rajalingam *et al.* (2013) developed a *Ailanthus excelsa* based silvi-horticultural system in which tomato, brinjal, bhindi, cluster bean and cowpea were successfully intercropped. Eucalyptus is another tree, which is used in agroforestry. It is a major source of pollen and nectar for honey bee, fuel wood, good quality pulp for paper production, etc. Timber is used for poles, stakes, boxwoods, bridge timber and the bark and leaves are source of oil of medicinal uses. *Gmelina arborea* has been successfully been tested for agroforestry/plantation in central India for enhanced productivity and environmental benefits (Swamy *et al.*, 2003; Swamy and Puri, 2005). It is one moderately fast growing indigenous tree used for timber, fuel and pulp production. The suitability of this species as an agroforestry tree has increased its planting in agricultural fields in different parts of the country.

Soil fertility under trees get improved, which enhance the crop yield grown under tree canopy. Bayala *et al.* (2013) observed higher soil fertility under trees and the occurrence of hydraulic redistribution in agroforestry parkland ecosystem, which suggested that trees facilitate the under-storey associated crops by increasing nutrients, water availability and reduced evapo-transpiration.

MATERIAL AND METHODS

The study was carried out at Punjab Agricultural University, Seed Farm, Ladhowal, Ludhiana during the year

$34^{0}34'$and $39^{0}30'$ north latitude. To carry out this investigation, seven blocks namely Rajouri, Darhal, Manjakote, Sunderbani, Kalakote, Doongi and Nowshera were selected with altitude ranging between 550–1250 masl. Root-slips of Napier hybrid NB-21 *(Pennisetum typhoides* x *P. purpureum)* and *Setaria* anceps (PSS-1) grasses raised in the previous year were transplanted on the farmers field at seven location during the last fortnight of July each year for consecutive three years (2012, 2013 and 2014) for estimation of performance of perennial grasses under rainfed conditions. The root-slips were transplanted on the onset of monsoon on the farm bunds of the farmer's field at 3 meters apart. Two grasses were evaluated with respect to the survival percentage after three months and total herbage production under rainfed conditions separately for each year. An observation on availability of green herbage was also recorded separately for each grass. A separate row of each perennial grass was maintained for recording the observation.

RESULTS AND DISCUSSION

Analysis of variance depicted significant differences among survival percentage and the production (q ha^{-1}) for both the grasses at among seven locations under study. The maximum survival percentage of 82.78 per cent of Napier hybrid-NB 21 was recorded at Sunderbani statistically followed by 80.78 and 80.56 per cent at Manjakote and Darhal, respectively, whereas Napier hybrid planted at Kalakote recorded minimum survival percentage (73.33 %) (Table 1). Napier Hybrid *recorded* maximum production (245.0 q ha^{-1}) at Sunderbani followed by Nowshera that recorded green herbage yield of 240.11 q ha^{-1}, whereas, Kalakote recorded the minimum production of green herbage (232.66 q ha^{-1}). Locations Doongi, Manjakote, Rajouri and Darhal were found to be statistically at par with each other. On the basis of pooled data Sunderbani recorded maximum *Setaria* (PSS-1) survival percentage (80.11 %) as well as herbage production (169.55q ha^{-1}) that was at par with herbage production at Rajouri (167.33 q ha^{-1}). Lowest survival percentage (66.89%) and green herbage production (159.11 q ha^{-1}) of *Setaria* grass was recorded at Kalakote (Table 3). Low survival percentage and low green herbage production at Kalakote may be attributed to the fact that Kalakote had became more drier due to constant coal mining and receive less rainfall as compared to the other locations of the Rajouri district. However, high survival per cent may be

Table 1. Performance of Napier Hybrid *(Pennisetum typhoides* x *P. purpureum)*-NB 21 under rainfed condition in Rajouri district of J&K

Locations	Survival percentage (%)			Pooled data	Production (q ha^{-1})			Pooled data
	2011	2012	2013		2011	2012	2013	
Nowshera	81.67	73.33	74.0	76.33	253.0	245.67	221.67	240.11
Doongi	76.67	71.67	73.33	73.89	246.67	238.33	216.0	233.66
Sunderbani	80.0	83.33	85.0	82.78	260.33	253.67	221.0	245.0
Manjakote	80.0	81.67	80.67	80.78	248.0	241.33	212.33	233.88
Rajouri	71.67	80.0	83.33	78.33	247.67	238.67	219.67	235.33
Darhal	82.67	78.33	81.67	80.56	244.67	241.0	217.67	234.44
Kalakote	73.33	71.67	75.0	73.33	247.0	235.67	215.33	232.66
CD (p=0.05)	5.8	5.32	4.71	5.61	12.4	7.08	8.44	4.37

Table 2. Performance of *Setaria anceps* (PSS-1) under rainfed condition in Rajouri district of J&K

Locations	Survival percentage (%)			Pooled data	Production (q ha^{-1})			Pooled data
	2011	2012	2013		2011	2012	2013	
Nowshera	73.67	73.33	76.67	74.55	172.67	164.33	154.33	163.77
Doongi	73.0	77.67	82.0	77.55	174.67	168.0	155.0	165.89
Sunderbani	78.0	81.33	81.0	80.11	168.67	169.33	162.33	169.55
Manjakote	77.0	80.33	80.33	79.22	165.67	164.0	157.33	163.33
Rajouri	75.0	76.33	78.67	76.66	173.67	170.0	158.33	167.33
Darhal	67.67	68.33	70.33	68.77	164.67	162.67	156.0	161.44
Kalakote	66.0	67.0	67.67	66.89	177	161.67	151.0	159.11
CD (p=0.05)	3.59	3.82	4.01	2.3	5.92	5.16	5.12	3.28

Table 3. Observation on extent of availability of green forage of perennial grasses under rainfed condition in Rajouri district of J&K

Locations	Extent of availability of green forage	
	Napier Hybrid NB-21 *(Pennisetum typhoides* x *P. purpureum)*	*Setaria anceps* PSS-1
Nowshera	2nd week of November	1st week of November
Doongi	1st week of November	3rd week of October
Sunderbani	3rd week of November	1st week of November
Manjakote	1st week of November	Last week of October
Rajouri	1st week of November	Last week of October
Darhal	Last week of October	2nd week of October
Kalakote	2nd week of November	1st week of November

attributed to the more rains received in the month of July-August, whereas low production was due flood like situations in 2014.

Observation regarding the extent of availability of green forage revealed that Napier hybid (NB-21) was able to provide green forage up to the ending November in low altitude locations namely Sunderbani, upto 2nd week of November at Nowshera and Kalakote, till 1st week of November on midhills like Rajouri, Manjakote and Doongi whereas was farmers were able to harvest green forage till ending October at darhal. On the contrary farmers were able to harvest *Steria anceps* (PSS-1) green forage till 1st week of November at Sunderbani, kalakote and Nowshera locations, up to last week of October at Rajouri and Manjakote having similar clinal variation pattern and till 2nd week of October at Darhal being located at the higher altitude. The prolonged availability of green herbage will provide an opportunity to the fodder deficient farmer a alternative cut and carry system of fodder production as per their requirement from available resources as compared to locally available grass (*Dicantium* spp) that was providing green herbage up to the last week of September. The of extent of availability of green forage was considered to be highly dependent upon the clinal variation with growing season culminating as early as in 2nd week of October at higher altitudes i.e. in Darhal as compared to the locations at lower altitudinal ranges viz., Sunderbani, Nowshera and Kalakote.

The area under permanent pastures and cultivable wastelands is approximately 13 and 15 million hectares respectively. Likewise, the total area under forests is 2.51 crore hectares and that open to grazing is 2.1 crore hectares. All these resources are able to meet the forage requirements of the grazing animals only during the monsoon season only as a result the potential of integrating fodder grasses and livestock in hills is pressing due to increasing paucity of grazing lands because of desertification. Perennial fodder grasses and tree legume forage provide an appropriate mixed diet for ruminants, especially during the dry season when green forages from crops are in short supply (Seresinhe and Pathirana, 2000; Chauhan *et al.,* 2014). Silvopastoral system, which is a mixed land use system for forage, livestock and wood production is gaining importance in hills with grasses having high productive, good quality and longer duration forage with high palatability. Such system of fodder production through improved perennial grasses has been advocated by Gupta *et al*. (2014). For augmenting fodder availability emphasis needs to be given to cultivated fodder crops and grasses on larger area especially on unutilized interspaces. However the management system varies greatly depending upon climatic factors (particularly rainfall), soil type, and the farmer's skill (Nair, 1993; Mishra *et al*., 2011).

Napier hybrid (NB-21) provided more green forage ha^{-1} with prolonged production till the end of November and better survival rate every year as compared to Setaria (PSS-1), which remained green till the ending October in most of the locations under study. The perennial grasses viz. Napier hybrid and Setaria should be allowed to grow on farm bunds and harvested till ending October-November for utilization under cut and carry system and by integrating high yielding perennial grasses in intensive production systems like silvopastoral system, the year round supply of green fodder can be ensured thereby reducing fodder scarcity under rainfed conditions in Rajouri district of J&K.

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2014-2015. The experimental site, comes under the central agro-climatic zone of the Punjab, is located at an elevation of 731ft above mean sea level and lies at $30^0 58'$ latitude and $75^0 45'$ longitude. The on-farm trial on three phenologically diverse tree species [i.e. *Ailanthus excelsa* (summer deciduous), *Gmelina arborea* (winter deciduous) and *Eucalyptus tereticornis*–clone 288 (evergreen)] planted in August 2005 was conducted in completely randomized design with three replications. Turmeric crop (Punjab haldi 1) was sown (30×20cm spacing) under plantations of three trees species and in control in the month of May 2014 and crop was harvested in February 2015. After the harvesting of turmeric crop, the data related to soil physio-chemical properties i.e. pH, EC, bulk density and organic carbon was recorded. The equilibrium pH and electrical conductivity (dSm^{-1}) of 1:2 soils: water suspension was determined with Elicho L1-10 and using sol bridge, respectively. For the determination of bulk density (Mgm^{-3}), fresh weight of each soil sample collected by soil core sampler was taken from each depth. The undisturbed soil cores were taken out at all the depths with the help of cylindrical iron ring and dried in an oven at $105^{\circ}C$ or till the weight of the soil become constant. The ratio of dry soil mass of core and internal volume of the cylindrical ring (equivalent to bulk soil volume) is expressed as bulk density [mass of dry soil (Mg)/total volume of soil (m^3)] of soil in Mgm^{-3} (Blake and Hartage 1986).

Total organic carbon (%) was estimated by Walkley and Black (1934) rapid titration method. 2g soil sample was treated with 10ml of 1N $K_2Cr_2O_7$, 20ml of concentrated H_2SO_4, 5g of sodium fluoride and 100ml of distilled water. 10 drops of diphenylamine indicator were added and it was treated with N/2 ferrous ammonium sulphate till the colour of the solution changed from violet to bright green. The organic carbon was calculated from the amount of ferrous ammonium sulphate consumed in the titration.

RESULTS AND DISCUSSION

pH: Tree species had significant impact on soil pH, which ranged from 8.58 to 8.71 (Table 1). The tree-less plot had numerically highest value (8.71), which was statistically at par with two other species *i.e.*, *Eucalyptus tereticornis* (8.68) and *Ailanthus excelsa* (8.70) but higher than *Gmelina arborea*. It is evident from the data presented in table 1 that depths had significant impact on soil pH, which ranged from 8.56 to 8.78. The data continuously decreased up to 60cm than increased. The effect of interaction between tree species and soil depth on soil pH was similar in all treatments except *Eucalyptus tereticornis i.e.* first increased then decreased with increased depth. pH irrespective of tree species was lower at 15-30cm and 30-60cm depth than top layer but higher at 60-90cm layer. Rekha *et al*. (2007) have reviewed the changes in soil under agroforestry systems, which highlights the decrease in pH and bulk density but increase in SOC. Takimoto *et al.* (2008) also recorded decrease in pH with depth in five land use systems.

EC: The estimated values of EC of soils presented in table 1 showed that there were not much numerical variation in EC due to tree species still differences were significant at 5% level of significance. Variables were higher among all the three species in comparison to tree-less area. Values ranged from 0.24 to $0.26dSm^{-1}$. It was maximum under *A. excelsa* ($0.26dSm^{-1}$) than *E. tereticornis* ($0.25dSm^{-1}$) and *G. arborea* ($0.24dSm^{-1}$). Variation of EC among trees may be due to the differential litter fall addition (quality and quantity) and different efficiency of absorption and translocation of sodium and its salts. The surface soil had higher EC values as compared to sub-surface soils. Interaction between tree species and soil depth showed inconsistent trend. It decreased with increase in soil depth up to 30 cm, later increased in 30-60cm layer only, which may be possibly due to the movement of salts of various ions in lower soil profile.

Table 1. Combined effect of tree and turmeric on soil parameters

Treatment	Soil properties			
	pH	EC (dSm^{-1})	BD (Mgm^{-3})	OC (%)
Ailanthus excelsa	8.70	0.26	1.36	0.71
Gmelina arborea	8.58	0.24	1.44	0.70
Eucalyptus tereticornis	8.68	0.25	1.31	0.55
Control	8.71	0.24	1.40	0.36
CD (p=0.05)	0.03	0.004	0.012	0.07
0-15 cm	8.71	0.27	1.33	0.85
15-30 cm	8.63	0.25	1.37	0.68
30-60 cm	8.56	0.25	1.41	0.56
60-90 cm	8.78	0.22	1.39	0.24
CD (p=0.05)	0.03	0.004	0.01	0.07

The site was only 1.0km from Satluj river and river bed soils are variable at different layers and the differences at lower depths may be influenced by root absorption or exudation. Results are in line with the findings of Sen (2014) and Singh (2014) conducted at the same site and adjoining sites.

Bulk density: Under plantations, bulk density ranged from 1.31 to 1.44Mgm^{-3}. Maximum value was noticed in *G. arborea* followed by *A. excelsa* and *E. tereticornis* (Table 1). There were significant differences in bulk density of soil at different depths and values ranged from 1.33 to 1.41Mgm^{-3}. Maximum value was noticed in 30-60cm soil depth, followed by 15-30cm and 60-90cm. However, 15-30cm and 60-90cm were statistically at par. Lower surface layers had high values of bulk density due to the low content of organic matter and compaction caused by overlying layers. The bulk density has been observed to be inversely related to tillage intensity by Halvorson *et al.* (2002). Similar observations were also reported by Sen (2014). Bolton *et al.* (1993) and Stockfisch *et al.* (1999) that bulk density increased with depth due to compaction. Table 2 shows that interaction between tree species and soil depth on soil bulk density was significant. In all treatments, BD increased with depth up to 60cm with slight reduction beyond 60cm.

Organic carbon: Soil organic carbon (%) is determined by the content and quality of litter, the rate of decomposition/oxidation in the soil thus affects the potential soil productivity. The quantity and quality of litter influence the SOC and it may vary with time, species, age, geometry of planting, management, etc. The soil organic carbon under *Ailanthus excelsa* was higher (0.71) than *G. arborea* (0.70), *E. tereticornis* (0.55) and control (0.36). The per cent OC at 0-15cm soil depth was maximum (0.85) as compared to the other soil depths (Table 1). SOC decreased as the soil depth increased, probably due to the decrease in addition of organic matter with soil depth. Biomass litter is added on the top and which may get mixed up to top 30cm through ploughing and at lower layers, only the decomposition of roots influence the SOC. Singh and Sharma (2007) studied that recycling of organic matter and reported enhanced organic carbon percentage in the soil under plantations. The higher amount of organic carbon under agroforestry system may be due to addition of litter. In agroforestry, trees act as a resource of soil organic carbon by continuously adding the litter, due to which surface layer has higher SOC than lower depths. Negi and Gupta (2013); Sen (2014); Singh (2014) have recorded substantial increase in SOC under different tree species. Yasmila-Ulman and Avudainayagam (2012) recorded 0.46 per cent increase in SOC in *Ailanthus excelsa* in three years. The vertical variation in soil organic carbon is influenced by the root distribution and crop residue. Large quantity of root excretion, dead roots and microbial conversion also supply abundant carbon to soil. Carbon in

Table 2. Interaction effect of tree species and soil depth on soil pH, EC, bulk density and organic carbon

Soil depth	pH				CD (0.05)
	A. excelsa	*G. arborea*	*E. teretircornis*	Control	
0-15 cm	8.83	8.55	8.65	8.80	
15-30 cm	8.41	8.54	8.74	8.81	0.07
30-60 cm	8.68	8.57	8.63	8.35	
60-90 cm	8.88	8.65	8.71	8.86	
	EC				
0-15 cm	0.31	0.30	0.26	0.21	
15-30 cm	0.29	0.20	0.23	0.26	0.007
30-60 cm	0.21	0.21	0.29	0.28	
60-90 cm	0.23	0.23	0.22	0.21	
	Bulk density				
0-15 cm	1.34	1.40	1.28	1.30	
15-30 cm	1.36	1.42	1.32	1.36	0.02
30-60 cm	1.42	1.42	1.32	1.49	
60-90 cm	1.31	1.51	1.31	1.43	
	Organic carbon				
0-15 cm	0.97	0.93	0.94	0.57	
15-30 cm	0.86	0.88	0.62	0.38	0.02
30-60 cm	0.70	0.74	0.45	0.34	
60-90 cm	0.32	0.26	0.20	0.16	

the deeper layers is also influenced by leaching down of dissolved soil organic carbon from upper layer, soil texture, rainfall pattern, etc. (Schwendenmann and Veldkamp, 2005).

Similarly, in interaction of tree species and soil depth, SOC decreased with increase in depth in all treatments. SOC was higher under tree species than control but no consistent pattern was observed under any species at different depths. At top and lowest layer, maximum SOC was observed in *Ailanthus excelsa* but in middle layers, maximum SOC was observed in *G. arborea*. Chauhan *et al.* (2010) recorded higher OC on top layers, which reduced gradually with depth. Nair *et al.* (2009) have ranked different land use systems for SOC content in the order of forests>agroforests>tree plantations>arable crops. The tree biomass also contributed substantially to the total carbon storage. The biomass carbon plus soil organic carbon (SOC) was recorded more under plantations than control. Total carbon storage under nine year old plantation of *Gmelina arborea, Ailanthus excelsa* and *Eucalyptus tereticornis* was 20.45tha^{-1}, 16.92tha^{-1} and 14.75tha^{-1}, respectively, which managed sustainably could make substantial sequestration in the agroforestry system, however, as Sharma *et al.* (2015) have reported some issues for consideration for practical applicability of carbon projects in agroforestrry.

CONCLUSION

Soil properties improved under plantation than tree-less area. However, no consistent pattern was observed excepting improved OC in the top layer (0-30cm) and decrease thereafter. As clearly indicated, tree-crop combination improved the soil properties as compared to grow only crop and ameliorated environment through carbon storage in biomass and soil in the system.

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Potential of Improved Perennial Grasses for Sustainable Fodder Production under Rainfed Conditions of Rajouri District, Jammu and Kashmir

Punit Choudhary, Rakesh Sharma, Sanjay Khar, Vikas Tandon and A. K. Isher

Krishi Vigyan Kendra Jammu
Sher-e-kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India
E-mail:pmd.choudhary@gmail.com

***Abstract*:** Napier hybrid (NB-21) and *Setaria* (PSS 1) transplanted at 3 m apart on farm bunds revealed maximum survival percentage of 82.78 % and 80.11 % respectively at Sunderbani. Pooled results over three consecutive years also revealed that Napier hybrid (NB-21) and **Setaria (**PSS 1) grasses recorded an average green fodder production of 245.0 q/ha and 169.55 q/ha respectively under rainfed condition. Availability of green fodder was enhanced up to last week of November and ending October with Napier hybrid and *Setaria* respectively as compared to locally available grass (*Dicantium* spp) that was providing green herbage up to the last week of September only every year. Farmers use to harvest green grasses from the available local pastures lands but now they can take multi-cut from available perennial grasses on the bunds.

Kew Words: Forage availability, Napier hybrid, Perennial grasses, Setaria

Grazing and harvested grasses form the local grasslands, common land and pastures are the chief fodder source for animal of hilly areas that are browsed, grazed or lopped from standing shrubs and trees. The three major sources of fodder supply are crop residues, cultivated fodder and fodder from common property resources like forests, permanent pastures and grazing lands. Based on 10th Five Year Plan Document, Government of India, the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% feeds. With availability of 400.6 million tonnes of green fodder against the demand of 1,097 million tonnes, still there is deficit of 63.5% green fodder. In Jammu and Kashmir the demand-supply scenario of the fodder revealed 7,459 thousand metric tonnes of fodder availability over the estimated requirement of 12,563 thousand metric tonnes with 40% deficit.

Agri-silvi-pastoral and silvi-pastoral systems are mostly on the marginal and wastelands in the Rajouri district (Jammu Region) and fodders trees are primarily grown for fuelwood and small timber, however, their value for feeding ruminants necessitates the planting of multipurpose fodder trees and grasses on the farm bunds, boundaries and sometimes grown scattered in the fields commonly known as *Gassnies* (Choudhary *et al.,* 2012). Majority of the fields of the district are situated across the slopes of the hills. The mean maximum summer and mean minimum winter temperatures are 36.5^{0} C and 2.5^{0} C, respectively. The annual rainfall of the district is about 1200mm. The climatic conditions of the Rajouri favour growth of perennial grasses on the farm bunds, boundaries under silvipastoral system. The cropping intensity of the distinct is 185 per cent. The total livestock population of the district is 11.811 lakh. About 94.3% of the population of this hilly district is rural and subsistent (Khar *et al.,* 2012).

Fodder production and its utilization depend on the cropping pattern, climate, socioeconomic conditions and type of livestock. The cattle and buffaloes are normally fed on the fodder available from cultivated areas, supplemented to a small extent by harvested grasses and top feeds. Rainfed areas are characterized by cut and carry system of fodder production with storage in the form of hay as insurance for the dry periods. Perennial grasses namely Hybrid Napier *(Pennisetum typhoides* x *P. purpureum)* and *Setaria anceps,* with the advantage of faster growth and more production of herbage with ability to grow on variety of soil provided an opportunity to the farmers of rainfed hilly regions of the Rajouri district of J&K with an alternative cut and carry system of fodder production from their farmlands as per the requirements In order to achieve the above objective the present study was designed to promote and offer an additional silvipastoral system by the way of cultivation of perennial grasses on the farm bunds in order to overcome the effects of the seasonal shortages of fodder and to insure fodder availability against risks of drought in Rajouri district.

MATERIAL AND METHODS

The study site falls in north-west of Himalayas and lies between 72^{0}16' and 72^{0}30" east longitude and

$34^{0}34'$and $39^{0}30'$ north latitude. To carry out this investigation, seven blocks namely Rajouri, Darhal, Manjakote, Sunderbani, Kalakote, Doongi and Nowshera were selected with altitude ranging between 550–1250 masl. Root-slips of Napier hybrid NB-21 *(Pennisetum typhoides* x *P. purpureum)* and *Setaria* anceps (PSS-1) grasses raised in the previous year were transplanted on the farmers field at seven location during the last fortnight of July each year for consecutive three years (2012, 2013 and 2014) for estimation of performance of perennial grasses under rainfed conditions. The root-slips were transplanted on the onset of monsoon on the farm bunds of the farmer's field at 3 meters apart. Two grasses were evaluated with respect to the survival percentage after three months and total herbage production under rainfed conditions separately for each year. An observation on availability of green herbage was also recorded separately for each grass. A separate row of each perennial grass was maintained for recording the observation.

RESULTS AND DISCUSSION

Analysis of variance depicted significant differences among survival percentage and the production (q ha^{-1}) for both the grasses at among seven locations under study. The maximum survival percentage of 82.78 per cent of Napier hybrid-NB 21 was recorded at Sunderbani statistically followed by 80.78 and 80.56 per cent at Manjakote and Darhal, respectively, whereas Napier hybrid planted at Kalakote recorded minimum survival percentage (73.33 %) (Table 1). Napier Hybrid *recorded* maximum production (245.0 q ha^{-1}) at Sunderbani followed by Nowshera that recorded green herbage yield of 240.11 q ha^{-1}, whereas, Kalakote recorded the minimum production of green herbage (232.66 q ha^{-1}). Locations Doongi, Manjakote, Rajouri and Darhal were found to be statistically at par with each other. On the basis of pooled data Sunderbani recorded maximum *Setaria* (PSS-1) survival percentage (80.11 %) as well as herbage production (169.55q ha^{-1}) that was at par with herbage production at Rajouri (167.33 q ha^{-1}). Lowest survival percentage (66.89%) and green herbage production (159.11 q ha^{-1}) of *Setaria* grass was recorded at Kalakote (Table 3). Low survival percentage and low green herbage production at Kalakote may be attributed to the fact that Kalakote had became more drier due to constant coal mining and receive less rainfall as compared to the other locations of the Rajouri district. However, high survival per cent may be

Table 1. Performance of Napier Hybrid *(Pennisetum typhoides* x *P. purpureum)*-NB 21 under rainfed condition in Rajouri district of J&K

Locations	Survival percentage (%)			Pooled data	Production (q ha^{-1})			Pooled data
	2011	2012	2013		2011	2012	2013	
Nowshera	81.67	73.33	74.0	76.33	253.0	245.67	221.67	240.11
Doongi	76.67	71.67	73.33	73.89	246.67	238.33	216.0	233.66
Sunderbani	80.0	83.33	85.0	82.78	260.33	253.67	221.0	245.0
Manjakote	80.0	81.67	80.67	80.78	248.0	241.33	212.33	233.88
Rajouri	71.67	80.0	83.33	78.33	247.67	238.67	219.67	235.33
Darhal	82.67	78.33	81.67	80.56	244.67	241.0	217.67	234.44
Kalakote	73.33	71.67	75.0	73.33	247.0	235.67	215.33	232.66
CD (p=0.05)	5.8	5.32	4.71	5.61	12.4	7.08	8.44	4.37

Table 2. Performance of *Setaria anceps* (PSS-1) under rainfed condition in Rajouri district of J&K

Locations	Survival percentage (%)			Pooled data	Production (q ha^{-1})			Pooled data
	2011	2012	2013		2011	2012	2013	
Nowshera	73.67	73.33	76.67	74.55	172.67	164.33	154.33	163.77
Doongi	73.0	77.67	82.0	77.55	174.67	168.0	155.0	165.89
Sunderbani	78.0	81.33	81.0	80.11	168.67	169.33	162.33	169.55
Manjakote	77.0	80.33	80.33	79.22	165.67	164.0	157.33	163.33
Rajouri	75.0	76.33	78.67	76.66	173.67	170.0	158.33	167.33
Darhal	67.67	68.33	70.33	68.77	164.67	162.67	156.0	161.44
Kalakote	66.0	67.0	67.67	66.89	177	161.67	151.0	159.11
CD (p=0.05)	3.59	3.82	4.01	2.3	5.92	5.16	5.12	3.28

Table 3. Observation on extent of availability of green forage of perennial grasses under rainfed condition in Rajouri district of J&K

Locations	Extent of availability of green forage	
	Napier Hybrid NB-21 *(Pennisetum typhoides* x *P. purpureum)*	*Setaria anceps* PSS-1
Nowshera	2nd week of November	1st week of November
Doongi	1st week of November	3rd week of October
Sunderbani	3rd week of November	1st week of November
Manjakote	1st week of November	Last week of October
Rajouri	1st week of November	Last week of October
Darhal	Last week of October	2nd week of October
Kalakote	2nd week of November	1st week of November

attributed to the more rains received in the month of July-August, whereas low production was due flood like situations in 2014.

Observation regarding the extent of availability of green forage revealed that Napier hybid (NB-21) was able to provide green forage up to the ending November in low altitude locations namely Sunderbani, upto 2nd week of November at Nowshera and Kalakote, till 1st week of November on midhills like Rajouri, Manjakote and Doongi whereas was farmers were able to harvest green forage till ending October at darhal. On the contrary farmers were able to harvest *Steria anceps* (PSS-1) green forage till 1st week of November at Sunderbani, kalakote and Nowshera locations, up to last week of October at Rajouri and Manjakote having similar clinal variation pattern and till 2nd week of October at Darhal being located at the higher altitude. The prolonged availability of green herbage will provide an opportunity to the fodder deficient farmer a alternative cut and carry system of fodder production as per their requirement from available resources as compared to locally available grass (*Dicantium* spp) that was providing green herbage up to the last week of September. The of extent of availability of green forage was considered to be highly dependent upon the clinal variation with growing season culminating as early as in 2nd week of October at higher altitudes i.e. in Darhal as compared to the locations at lower altitudinal ranges viz., Sunderbani, Nowshera and Kalakote.

The area under permanent pastures and cultivable wastelands is approximately 13 and 15 million hectares respectively. Likewise, the total area under forests is 2.51 crore hectares and that open to grazing is 2.1 crore hectares. All these resources are able to meet the forage requirements of the grazing animals only during the monsoon season only as a result the potential of integrating fodder grasses and livestock in hills is pressing due to increasing paucity of grazing lands because of desertification. Perennial fodder grasses and tree legume forage provide an appropriate mixed diet for ruminants, especially during the dry season when green forages from crops are in short supply (Seresinhe and Pathirana, 2000; Chauhan *et al.,* 2014). Silvopastoral system, which is a mixed land use system for forage, livestock and wood production is gaining importance in hills with grasses having high productive, good quality and longer duration forage with high palatability. Such system of fodder production through improved perennial grasses has been advocated by Gupta *et al*. (2014). For augmenting fodder availability emphasis needs to be given to cultivated fodder crops and grasses on larger area especially on unutilized interspaces. However the management system varies greatly depending upon climatic factors (particularly rainfall), soil type, and the farmer's skill (Nair, 1993; Mishra *et al*., 2011).

Napier hybrid (NB-21) provided more green forage ha^{-1} with prolonged production till the end of November and better survival rate every year as compared to Setaria (PSS-1), which remained green till the ending October in most of the locations under study. The perennial grasses viz. Napier hybrid and Setaria should be allowed to grow on farm bunds and harvested till ending October-November for utilization under cut and carry system and by integrating high yielding perennial grasses in intensive production systems like silvopastoral system, the year round supply of green fodder can be ensured thereby reducing fodder scarcity under rainfed conditions in Rajouri district of J&K.

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Effect of Planting Seasons, Age of Planting Stocks and Hydrogel on Survival and Growth of *Populus deltoides* Under Degraded Sites of North Western Himalayas

Tahir Mushtaq and Rakesh Banyal

Faculty of Forestry, Benhama, Ganderbal, Sher-e-Kashmir university of Agricultural and Technology, Kashmir-191 201, India.
E-mail: tahirmushtaq333@gmail.com

Abstract: The plantation of *Populus deltoides* using different plantation and moisture conservation techniques was done on three types of land namely: degraded underutilized (scrub dominated), degraded pastures/grazing lands, barren rocky/stony waste. The experimental site falls in a mid to high altitude characterized by hot summers and very cold winters. Two planting seasons, two planting stocks and five hydrogel levels (20 treatment combinations) for moisture conservation were analyzed for survival and growth of plantation. Results showed that out of two planting seasons studied, autumn planting was better compared to spring planting. Among two planting stocks, two year old plantss were observed to perform better on the experimental site. Survival and growth parameters were recorded higher in liquid application 3 g plant^{-1} compared to control, solid application 3 g plant^{-1}, liquid application 1.5 g plant^{-1} and 4.5 g plant^{-1}.

Key Words: Degraded site, Growth, Hydrogel, Plantation, Survival, Stock

Land is one of the most important resource on which human beings depend and rate of soil degradation is continuously increasing with the advancement of science and technology, industrial expansion, urbanization and population explosion. The most important cause of land degradation is destruction of forests and other vegetation from sloping lands, river sides and other areas sensitive to damage (Pramod and Mohapatra, 2012). Anthropogenic activities like over grazing, wood cutting and burning have intensified land degradation results in soil deterioration all over the world (Jin, 2002). Vegetation acts as a protective cover against the forces of wind and water, protecting the soil from being washed or blown away and preserving the physical and hydrographic balance of nature (Jain and Singh, 1998). Plantations can conserve soil on degraded lands by reducing nutrient loss, increasing soil organic matter and improving the soil texture (Thapa, 2003). The forestry is ecologically as well as economically more viable option then traditional forestry and technology of fast growing species mainly poplar and eucalyptus have been taken up by farmers and institutions to boost wood production in the world. Tree plantations present an economically attractive alternative to natural forests and might also be a practical option for production on degraded lands and contribute considerably in terms of carbon sequestration, increased soil organic carbon and conservation of biodiversity (Bremer and Farley, 2010).

In temperate regions particularly in Kashmir valley, farmers possess small land holding which is mostly under the cultivation of agricultural crops. Therefore, farmers are left with only option to plant trees on degraded lands. As the availability of land for tree plantation is insufficient, people have to grow short rotation crops and are seen viable option to produce better income and biomass in a short time and in a sustainable way (Bentsen and Felby, 2012). The most important exotic species used for this purpose in the region is *Populus deltoids* and is most common in community and household woodlots. In an environment suffering from land degradation and deterioration, fast growing and resilient *Populus deltoides* perform better than most indigenous tree species. Small holders show a clear preference for this poplar. which is multiple in use (Jagger and Pender, 2003). Therefore, an attempt was made to utilize degraded lands for plantation of poplar to address the problem of land degradation with social commitment.

MATERIAL AND METHODS

The plantation of *Populus deltoides* was done on degraded land of the Faculty of Forestry, SKUAST-Kashmir, Benihama Campus, Ganderbal, Jammu and Kashmir at an altitude of 5850 feet above mean sea level. The existing land of the experimental site was pertaining to three types of land problems namely: degraded underutilized (scrub dominated), degraded pastures/grazing lands, barren rocky/stony waste. The experimental site falls in a mid to high altitude characterized by hot summers and very cold winters. The average precipitation is 690 mm most of which was received from December to April in the form of snow and rains. The metrological data for the plantation season was obtained from the meteorological observatory Ganderbal. The total rainfall (mm) during the experimentation period was

281.2 and 418.80 during 2013 and 2014, respectively. The minimum temperature (°c) ranged from -1 to -6 and 3.4 to 14.1, and temperature from 17.7 to 24.4 and 21.7 to 32.5 and the average maximum relative humidity (%) from 74.5 to 95.1 and 70.4 to 90.8, whereas, mean minimum from 43.1 to 78.7 and 37.1 to 80.1% during the plantation season of autumn 2013 and spring 2014, respectively.

Plantation details: The ETPs of *Populus deltoides* were planted to evaluate the effect of planting season, age of planting stock and different levels of hydrogel on growth and establishment of the species. Two planting seasons viz. autumn planting and spring planting were compared to evaluate the best planting season for the species, plantss of two different ages were tried viz. one year old (A_1) and two year old (A_2) to evaluate the most appropriate age of plantss of *Populus deltoides* for best growth in both the planting seasons. Five levels of hydrogel viz. H_0 (control), H_1 (solid application 3 g plant^{-1}), H_2 (liquid application 1.5 g plant^{-1}), H_3 (liquid application 3 g plant^{-1}) and H_4 (liquid application 4.5 g plant^{-1}) were tried to elucidate best level for *Populus deltoides* on problematic sites in both the season

The experiment was raised in factorial randomized block design with 20 treatment combinations in three replications with two plants per replication. One and two year old plants of *Populus deltoides* were uprooted from the nursery beds and ETPs were planted at a spacing of 2 m by line planting in the experimental field.

RESULTS AND DISCUSSION

There were significant variations for survival percentage between two seasons. Autumn planting recorded highest survival (70.99%) followed by spring planting (69.99%). The age of planting stock in both the seasons significantly affected plant survival. Highest survival was for second year plants due to long tap root system of two year old plants, which helps in better moisture absorption. The hydrogel application to the plantation significantly affected survival percentage of plants. Highest survival percentage was recorded for liquid application 3 g plant liquid application, followed by liquid application 1.5 g plant liquid application, 4.5 g plant liquid application, solid application 3 g plant liquid application and control in both the seasons.

The present investigation reveals that plant height increment is significantly influenced by planting season, age of planting stock and different levels of hydrogel application. Maximum plant height increment (26.99 cm) was recorded for autumn planting and minimum (26.31 cm) for spring planting. The reason might be availability of abundant moisture in autumn, which was responsible for early plant establishment compared to spring planting. The irrigation requirement in autumn planting is far less than spring planting. The table that age of planting stock significantly affected plant height increment. Maximum height increment was recorded for second year planting stock compared to first year planting stock in both the seasons. The hydrogel application to the plantation significantly affected plant height increment in both the seasons. Maximum plant height increment was observed in liquid application 3 g plant liquid application, followed by liquid application 1.5 g plant liquid application, 4.5 g plant liquid application, solid application 3 g plant liquid application and control.

Collar diameter increment was influenced by planting season, age of planting stock and different hydrogel levels. Both the planting seasons significantly affected the collar diameter increment. Highest collar diameter increment (5.34 mm) was for autumn planting and lowest for spring planting. The age of planting stock significantly affected collar diameter increment. The hydrogel application to the plantation significantly affected collar diameter increment. Maximum collar diameter increment was observed in liquid application 3 g plant liquid application, followed by liquid application 1.5 g plant liquid application, 4.5 g plant liquid application, solid application 3 g plant liquid application and control.

The leaf area of *Populus deltoides* was significantly affected by planting season, age of planting stock and different hydrogel levels. Highest leaf area growth (888.91 cm^2) was recorded for autumn planting and minimum (887.11 cm^2) for spring planting. The leaf area growth was affected by age of planting stock and highest leaf area growth was recorded for second year planting stock (A_2) and minimum for first planting stock (A_1) in both the planting seasons. Second year planting stock possess greater number of branches because of more shoot length, so greater leaf area. Different hydrogel levels applied to the *Populus deltoides* plantation significantly affected leaf area growth in both the seasons. Leaf area of plants increased with increase in hydrogel concentration upto certain limit and then decreases. The liquid hydrogel application was found more effective than solid application and reason for this might be easy expansion of rootlets, which otherwise is somewhat difficult in solid application.

The current study suggested that out of two planting seasons, survival and growth parameters was better in autumn planting compared to spring planting. Second year planting stock recorded better survival and growth compared to first year planting stock. Among the hydrogel levels applied, liquid application 3 g plant liquid application was quite effective.

Table 1. Effect of planting season, age of planting stock and hydrogel on *Populus deltoides*

Age	Autumn planting		Mean	Spring planting		Mean	Factor means					
Hydrogel	A_1	A_2		A_1	A_2		Hydrogel		Age		Planting season	
Survival (%)												
H_0	50.00	66.66	58.33	50.00	50.00	50.00	H_0	54.16	A_1	69.99	S_1	79.99
H_1	66.66	83.33	74.99	50.00	66.66	58.33	H_1	66.66	A_2	79.99	S_2	69.99
H_2	83.33	83.33	83.33	66.66	83.33	74.99	H_2	79.16				
H_3	100	100	100	83.33	100	91.66	H_3	95.83				
H_4	83.33	83.33	83.33	66.66	83.33	74.99	H_4	79.16				
Mean	76.66	83.33	79.99	63.33	76.66	69.99						
CD (p = 0.05)	H=1.48,	S =2.43,	A=3.54,	H×S =2.58,	H×A= 3.68,	S×A=3.11,	H×A×S=NS					
Plant height increment (cm)												
H_0	26.11	26.20	26.16	26.00	26.05	26.03	H_0	26.09	A_1	26.59	S_1	26.99
H_1	26.33	26.54	26.44	26.16	26.25	26.21	H_1	26.32	A_2	26.71	S_2	26.31
H_2	26.88	27.00	26.94	26.31	26.39	26.35	H_2	26.65				
H_3	28.27	28.39	28.33	26.66	26.92	26.79	H_3	27.56				
H_4	27.01	27.13	27.07	26.12	26.26	26.19	H_4	26.63				
Mean	26.92	27.05	26.99	26.25	26.37	26.31						
CD (p = 0.05)	H= 0.08,	S =0.11,	A= 0.13,	H×S = 0.12,	H×A= 0.11,	S×A= 0.12,	H×A×S= 0.13					
Collar diameter increment (mm)												
H_0	5.08	5.21	5.14	5.00	5.07	5.04	H_0	5.09	A_1	5.31	S_1	5.34
H_1	5.30	5.38	5.34	5.18	5.24	5.21	H_1	5.27	A_2	5.34	S_2	5.32
H_2	5.40	5.42	5.41	5.32	5.40	5.36	H_2	5.38				
H_3	5.50	5.55	5.52	5.77	6.00	5.89	H_3	5.70				
H_4	5.28	5.37	5.32	5.05	5.13	5.09	H_4	5.20				
Mean	5.31	5.38	5.34	5.26	5.37	5.32						
CD (p = 0.05)	H= 0.09,	S =0.10,	A= 0.12,	H×S =0.11,	H×A=0.10,	S×A= 0.12,	H×A×S=0.13					
Leaf area (cm^{-2})												
H_0	886.60	887.10	886.85	885.13	885.98	885.56	H_0	886.20	A_1	887.71	S_1	888.91
H_1	888.33	888.98	888.66	886.09	886.42	886.26	H_1	887.46	A_2	888.31	S_2	887.11
H_2	889.42	889.67	889.55	887.33	887.91	887.62	H_2	888.58				
H_3	890.54	891.80	891.17	888.10	888.94	888.52	H_3	889.85				
H_4	888.10	888.52	888.31	887.42	887.78	887.60	H_4	887.96				
Mean	888.60	889.21	888.91	886.81	887.41	887.11						
CD (p ≤0.05):	H=1.01,	S = 0.28,	A= 1.00,	H×S = 1.23,	H×A= 1.38,	S×A= 1.21,	H×A×S= 1.					

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Anticipated Performance Index of Plant Species Growing alongside the National Highway 21 of Himachal Pradesh, India

Tanvi Kapoor, S. K. Bhardwaj, S. S. Sharma, P. K. Mahajan and N. K. Gupta
College of Forestry, Dr. Y S Parmar University of Horticulture and Forestry, Solan-173 230, India
E-mail: tanvikapoor.evs@gmail.com

Abstract: Field study was conducted to assess the anticipated performance index (API) of plants growing alongside the National Highway 21. To undertake the study a stretch from Bilaspur to Mandi on the National Highway was selected . A complete survey of the study area was done and four commonly growing species namely *Ficus carica*, *Morus alba, Toona ciliata* and *Melia azedarach* were selected to calculate air pollution tolerance index (APTI). The APTI of commonly growing species was in the order of *T. ciliata* > *M. azederach* > *F. carica* > *M. alba*. According to anticipated performance index (API), the species were found to be in the range of 'very poor' to 'very good'. The order of API in selected plant species was *T. ciliata* > *F. carica* = *M. alba* > *M. azederach*. The study indicated that *T. ciliate* should be considered for plantation alongside the National Highway 21 in Bilaspur to Mandi stretch because of its highest tolerance capacity to pollution and very good anticipated performance index among the commonly growing species.

***Key Words*:** APTI, Biochemical parameters, *F. carica , M. azedarach, M. alba , T. ciliata*

In the present time, high rate of urbanization, increasing vehicular density and exponential population growth has led to atmospheric pollution. Air pollution is the most dangerous of its kind as its control is more complex than any other type of environmental problems. Moreover, the amelioration of this pollution is not feasible by physical and chemical methods. However, plantations with suitable species have been considered as one of the suitable abatement techniques for its control. Plants being the initial receptors of pollutants provide an enormous area for their impingement and helps in monitoring and controlling air pollution. Plants help in bio filtering of toxic waste besides maintaining the ecological balance and providing other economic benefits in the ecosystem (Escobedo *et al*.,2008). Since the plants vary in their sensitivity and tolerance to various kinds of toxins and hence their characterization help in screening them to use as an indicator and as sink for pollutants. In the presence of pollution, plants undergo many physiological and biochemical changes before any visible or change in morphology. Consequently based on such changes their level of tolerance can be calculated. In order to screen the plants for green belt plantations, air pollution tolerance index is generally used (Singh and Rao,1983). However, to select plants with better tolerance capacity to pollution and considering its socio-economic and other benefits the anticipated performance index (API) is being advocated. This index provides an improvement over APTI as it uses biological and socio-economic along the biochemical parameters to evaluate the overall performance of the plant species. The evaluation of API helps to assess the capability of the plant species to reduce the atmospheric pollution and indicate their socio-economic benefits. In the region since no such studies have been done so far, therefore, the present investigation to categorize the plants growing on the National Highway on the basis of their tolerance levels and socioeconomic aspect has been undertaken.

MATERIAL AND METHODS

The study was conducted on the National Highway 21 situated in Shivalik range North Western Himalayas. This highway by covering a distance of about 323 kms connects Chandigarh with Manali in Himachal Pradesh by passing through many towns and villages. In order to conduct the study, a stretch of National highway from Bilapsur to Mandi falling in subtropical type of climate was selected for the study. This stretch of national highway is having fragile strata and passes through a major cement plant of the state. Further, this highway is leading to Kullu-Manali, one of the main tourist place of the country and has high vehicular density.

A detailed survey was conducted on the Bilaspur to Mandi stretch to study the distribution of plants. During the survey, an account of plant species growing alongside the national highway was made and commonly occurring species were identified. In order to identify the tolerance levels of plants four commonly occurring species (two each of Moraceae and Meliaceae families) namely *Ficus carica* (Moraceae), *Morus alba* (Moraceae), *Toona ciliata* (Meliaceae) and *Melia azedarach* (Meliaceae) were selected in order to assess the degree of impact of vehicular pollution on the plants were selected at three horizontal distances namely 0-15, 15-30 and >30m. To compare the effect of horizontal distance the location falling at >30m was considered as control. Leaf biochemical parameters namely leaf ascorbic acid, total chlorophyll, leaf extract pH and relative water content were measured by taking fully matured leaves of selected species (collected in the morning hours) of same diameter. The fresh leaf samples were analysed for total chlorophyll (Hiscox and Istaelstam, 1979), ascorbic acid (AOAC,1980), leaf extract pH (Barrs and Weatherly, 1962) and relative water (Singh, 1977) content using standard procedures.

Air pollution tolerance index (APTI): The leaf biochemical parameters based air pollution tolerance index of the selected species was calculated using the following formula given by Singh and Rao (1983).

$$APTI = \frac{[A(T+P)] + R}{10}$$

Where, A- ascorbic acid (mg g^{-1} FW) , T- total chlorophyll (mg g^{-1} FW) ,P- leaf extract pH

R- relative water content (%) of the leaves

Anticipated performance index: By combining the resultant APTI values with some relevant biological and socio-economic characters (plant habit, canopy structure, type of plant, laminar structure & economic values), the API was calculated for different species. Based on these characters, different grades (+ or -) are allotted to plants. Different plants are scored according to their grades as per the procedure outlined by Mondal *et al*. (2011) and presented in table 1 and 2.

Biological parameters: The tree height was measured using relascope. The trees were classified as small, medium and large based upon their height. The trees of height < 10m were taken as small, between 10-20m as medium and in the range 20-30m as large. The leaf size was calculated by measuring the leaf area. The leaves in the range of 30-50cm^2 were considered small, between 50-100cm^2 as medium and of size >100cm^2 as large.

The data generated were statistically analyzed and interpreted by using Statistical Package Software version 21.

Table 1. Anticipated performance index (API) of plant species

Grade	score	Assessment category
0	Up to 30	Not recommendation for plantation
1	31-40	Very poor
2	41-50	Poor
3	51-60	Moderate
4	61-70	Good
5	71-80	Very good
6	81-90	Excellent
7	91-100	Best

Table 2. Gradation of plant species on the basis of air pollution tolerance index (APTI) and other biological and socio-economic characters

Grading character	Pattern of assessment	Grade allotted*
Air pollution tolerance index (APTI)	8.5 – 9.0	+
	9.1 – 9.5	++
	9.6 – 10.0	+++
	10.1– 10.5	++++
	10.6 – 11.0	+++++
(b) Tree habit	Small	-
	Medium	+
	Large	++
(c) Canopy structure	Sparse/Irregular/Globular	-
	Spreading	+
	crown/open/semi dense	++
	Spreading dense	
(d) Type of tree	Deciduous	-
	Evergreen	+
(e) Laminar Characters	Small	-
(i) Size	Medium	+
	Large	++
(ii) Texture	Smooth	-
	Coriaceous	+
(f) Hardiness	Hardy	+
	Delineate	-
(g) Economic value	Less than three uses	-
	Three of four used	+
	Five or more used	++

*maximum grades are 16

RESULTS AND DISCUSSION

Biochemical parameters: The selected trees alongside the National Highway 21 vaiedy in their biochemical characteristics. The leaf ascorbic acid ranged from 1.98 to 2.53mg g^{-1}. The higher ascorbic acid content of 2.53mg g^{-1} was recorded in *Toona ciliata,* followed by *Ficus carica* (2.19 mg g^{-1}), *Morus alba* (1.99mg g^{-1}) and the lowest (1.98mg g^{-1}) content was found in *Melia azedarach.* As ascorbic acid is an antioxidant, that influences resistance of the plant to any kind of adverse environmental conditions. Thus, in *Toona ciliata* the highest amount of ascorbic acid may be due to its higher tolerance to pollution. The results are in line with the findings of (Hippeli and Elstner, 1996). The total chlorophyll content in the leaves of the selected plant species was maximum (3.04mg g^{-1}) in *Morus alba* and minimum (1.12 mg g^{-1}) in *Ficus carica*. The higher chlorophyll content in the plants may be due to increased tolerance of plant to pollution (Joshi *et al.,* 1993). The value of relative water content also found the same trend. The highest value of relative water content in

Table 3. Variations in the biochemical parameters and APTI values of selected plant species

Plant Species	Biochemical parameters				
	Ascorbic acid	Total chlorophyll	Leaf extract pH	Relative water content	APTI
F. carica	2.19 mg g^{-1}	1.12 mg g^{-1}	5.80	81.65%	9.68
M. alba	1.99 mg g^{-1}	3.04 mg g^{-1}	5.90	74.84%	9.26
M.azedarach	1.98 mg g^{-1}	2.14 mg g^{-1}	5.97	85.23%	10.13
T. ciliate	2.53 mg g^{-1}	2.47 mg g^{-1}	5.83	88.36%	10.94

Table 4. Evaluation of plant species on the basis of APTI value and some biological and socio-economic characteristics

Common name	Scientific name	Assessment parameters				laminar stucture				grade alloted		
		APTI	Tree habit	Canopy stucture	Tree type	Size	Texture	Hardiness	Economic importance	Total plus	% scoring	API grade
Fig	*F. carica*	+++	-	+	-	+	+	-	++	8	50.00	2
Mulberry	*M. alba*	++	+	+	-	-	+	-	+	6	37.5	1
Drek	*M. azederach*	++++	+	+	-	-	-	-	++	8	50.00	2
Toon	*T. ciliata*	+++++	++	+	-	++	+	-	+	12	75.00	5

Table 5. Anticipated performance index (API) of selected plant species

Local Name	Scientific name	Total grade allotted	%	API Grade	Assessment
Fig	*F. carica*	9	56.25	3	Moderate
Mulberry	*M. alba*	7	43.75	2	Poor
Drek	*M.azederach*	9	56.25	3	Moderate
Toon	*T. ciliata*	13	81.25	6	Excellent

Toona cilata may be ascribed due to its higher resistant capacity to stress conditions. The leaf extract pH varied from 5.8- 5.97 (Table 3).

Air pollution tolerance index: The plants respond in different ways to various air pollutants. The variation the various physiological and biochemical aspects *viz* ascorbic acid, total chlorophyll content , relative water content and leaf extract pH, resulted in the variation in APTI values. Thus, it can be attributed that biochemical parameters play an important role in determining the tolerance level of plants to pollution. The highest value (10.94) of APTI was in *Toona ciliata* indicating its higher tolerance among the selected species. It was followed by *Melia azedarach* (10.13) and *Ficus carica* (9.68). The lowest value (9.26) was found in *Morus alba* indicating its sensitivity to the pollution. The species having APTI value <10 is considered as 'sensitive'; value within 10-16 is considered as 'intermediate' and >17 is 'tolerant' (Chaudhary and Banerjee, 2009). In the present study *Toona ciliata* and *Melia azedarach* can be used in the green belt development as both come in the range of intermediately sensitive and tolerant species.

Anticipated performance index: The comparison of the grading parameters by their summation for the API showed a variation in the plant species from a very poor to very good scale (Table 4). Among the selected plant species *Toona ciliata* with highest API was in the very good category of plants followed by *Ficus carica* and *Melia azedarach* in the poor category and *Morus alba* in the very poor category. The highest value of API of *Toona ciliata* may be due to the high value of APTI and better laminar characteristics. Dust interception capacity of plants depends on their surface geometry, phyllotaxy, leaf external characteristics (such as hairs, cuticle, etc.), and height and canopy of trees (Nowak, 1994; Singh, 2000). Among the four plant species *Toona ciliata* was the most tolerant species and also this species has the high economic and aesthetic value. Hence it can be recommended for the plantation in the polluted areas. From the present investigation it can be concluded that all the biochemical, physiological, biological as well as socio-economic parameters of the plant species play an important role in determining the sensitivity and tolerance of plants to air pollution with reference to their tolerance and performance index. The study indicated that *T. ciliata* should be considered for plantation alongside the National Highway 21 in Bilaspur to Mandi stretch because of its highest tolerance capacity to pollution and very good anticipated performance index among the commonly growing species.

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Plus Tree Selection and Progeny Testing of Burma Dek (*Melia composita* Willd.)

Vishal Johar, Kavita Bhambani Sharma, Rachana[1] and Praveen Kumar

Department of Forestry, CCS Haryana Agricultural University, Hisar-125 004, India
[1]Department of Botany, Kurukshetra University, Kurukshetra-136 119, India
E-mail: vishaljohar89@gmail.com

Abstract: Twenty four candidate plus trees (CPTs) of Burma dek were selected through intensive survey from Haryana and bordering states. Selection was based on the characters of economic interest viz. straightness, self pruning ability, clear bole height, low branching habit, disease resistance. The maximum plant height was in accession MCP1 from Punjab (17.5 m), while accession MPN1 from Pantnagar was recorded to have maximum clear bole height (10.2 m). Highly significant and positive correlation (r = 0.522) was obtained between age and other morphological character viz. height, clear bole height and GBH. Progenies of CPTs were also assessed for field emergence (%), seedling height, basal diameter, clear stem height, number of branches per seedling and root shoot ratio and significant variation was obtained among the species within the character. The progeny performance of MCPN1 from Uttrakhand was found extraordinarily well having superior values for most of the characters. Progeny performance of plus trees MCPAU1, MCP1, MCPAU3, MCPAU5 and MCK1 were also equally good obtaining good rank in all the observations. The findings of the present study may be helpful in identifying candidate plus trees in a scientific manner.

***Key Words*:** Burma dek, Candidate plus tree, Progeny, Substantial variability

Currently tree improvement programs are the imperative need to meet the growing demands of wood and wood products i.e. 13.2 million tonnes by 2020 in India (Palsaniya *et al*., 2009). Plus tree selection is the first step of any tree improvement programe as superior genotypes generally give quality performance. However, phenotype is the joint result of genotype and environment, therefore, it is not easy to assess genetic worth by external appearance of the tree and progeny testing must follow plus tree selection (Dogra *et al.,* 2005). Several researchers followed the same strategy for various tree species (Hooda *et al*., 2009; Kaushik *et al*., 2011; Kumar, 2012; Kala and Kumaran, 2012).

Melia composita Willd. is a deciduous tree, native to Indian sub-continent but now has spread in many Asian countries and also in different regions of the globe (Chauhan *et al.,* 2008; Murugesan *et al.,* 2013). The species has a wide range of adaptability and thrives well in areas within mean annual temperature of 23-27°C, on an altitude upto 1800 m with a mean annual rainfall range of 350-2000 mm. It grows on variety of soils, however, deep fertile sandy loam soils shows good growth (Orwa *et al.,* 2009). *M. composita* is valued for its good quality fodder and high-quality termite and fungus resistant timber (Swaminathan *et al.,* 2012) as *Eucalyptus* and Casuarinas spp. are prone to attack by pests and diseases (Anand *et al.,* 2012). Inspite of it's such a high value required efforts have not been made for its genetic improvement. Therefore, present study was conducted to select the plus tree and progeny testing of *M. composita* Willd.

MATERIAL AND METHODS

Intensive survey was conducted in different agroclimatic regions of Haryana, Punjab, Uttrakhand and Himachal Pradesh to select the plus trees of Burma dek during Feb.-March. The selection was made on phenotypic assessment of desirable characters of economic interest such as stem straightness, self-pruning ability; clear bole height, low branching habit, disease resistance, etc. Twenty four morphologically superior trees (plus trees) were selected and different morphological parameters viz. height, clear bole height, girth at breast height (GBH), clear bole: height ratio, height: GBH ratio, height of crown and straightness were also recorded. The sufficient amount of good quality ripened fruits was collected from these trees. The fruits were depulped and seeds were washed thoroughly with tap water and air dried at room temperature for 2-3 days. Before sowing, seeds were kept in cotton cloths bags and stored at room temperature.

For each plus tree progeny, 400 polythene bags (22 x 10 cm size) having equal proportion of FYM: dune sand: clay were arranged randomly in four blocks at CCS Haryana Agricultural University, Hisar. Two seeds were sown in each bag during the 2nd week of March. The polythene bags soon after seed sowing were irrigated with the help of garden sprinkler and thereafter, proper moisture was undertaken as and when considered necessary to keep the seedling free from weeds. The observations on field emergence (%), seedling height, basal diameter, clear stem height, no. of branches per seedling and root shoot ratio were recorded at regular intervals.

Table 1. Morphological characters of selected plus trees of *Melia composita*

Assession code	Latitudes & Longitudes	Age (yrs)	Height (m)	Clear bole height (m)	GBH (cm)	Clear bole: total height ratio	Height: GBH ratio	Height of crown (m)	Straightness (Visual index)
MCS1	30°50' N and 77°11'30" E	3	7.2	3.2	82.2	0.44	0.08	4.0	2
MCPN1	29°N and 79.29°E	7	16.5	10.2	60.3	0.62	0.27	6.2	3
MCBI1	29^{o}33’0” N and 75^{o}56’0” E	3	5.2	2.5	33.1	0.47	0.15	2.7	2
MCBI2	29^{o}33’0” N and 75^{o}56’0” E	3	6.5	3.2	45.2	0.50	0.14	3.2	1
MCBI3	29^{o}33’0” N and 75^{o}56’0” E	3	5.2	3.0	47.4	0.57	0.11	2.2	4
MCBI4	29^{o}33’0” N and 75^{o}56’0” E	3	8.2	2.5	50.3	0.30	0.16	5.7	3
MCBI5	29^{o}33’0” N and 75^{o}56’0” E	3	8.2	4.2	51.4	0.51	0.16	4.0	2
MCK1	29.96° N, 76.83° E	5	8.5	2.7	76.3	0.32	0.11	5.7	2
MCK2	29.96° N, 76.83° E	3	7.5	3.5	46.2	0.46	0.16	4.0	1
MCP1	30^{o}65’N, and 75^{o}69’ E	8	10.0	3.2	90.9	0.40	0.10	6.7	4
MCP3	24°20' N and 72° 44 E	3	8.5	3.5	26.4	0.41	0.32	5.0	1
MCP5	24°20' N and 72° 44 E	5	9.5	3.5	116.1	0.36	0.08	6.0	4
MCP6	21^{o}39’N and 73^{o}43 E	3	7.5	2.5	62.1	0.33	0.12	5.0	2
MCP7	21^{o}39’N and 73^{o}43 E	7	17.5	8.7	185.5	0.49	0.40	8.8	5
MCP10	30^{o}42'N and 75^{o}18' E	4	8.5	3.2	79.2	0.38	0.10	5.2	1
MCP11	30^{o}42'N and 75^{o}18' E	3	10.2	4.2	81.2	0.41	0.12	6.0	2
MCP12	30^{o}42'N and 75^{o}18' E	5	11.7	5.0	131.2	0.42	0.08	6.7	3
MCP14	29^{o}43'N and 76^{o}13' E	3	8.2	6.5	50.4	0.78	0.16	1.7	4
MCP15	29^{o}43'N and 76^{o}13' E	3	7.5	6.2	45.7	0.83	0.16	1.2	5
MCPAU1	30^{o}90’N and 75^{o}81’E	4	12.2	4.7	80.2	0.38	0.15	7.5	4
MCPAU2	30^{o}90’N and 75^{o}81’E	4	11.2	3.2	78.4	0.28	0.14	8.0	3
MCPAU3	30^{o}90’N and 75^{o}81’E	4	12.5	4.5	79.1	0.36	0.15	8.0	4
MCPAU5	30^{o}90’N and 75^{o}81’E	3	7.5	4.5	54.7	0.60	0.13	3.0	3
MCB1	30^{o} 10’ N and 75^{o}09’ E	5	6.2	2.5	95.4	0.40	0.06	3.7	3
Range			5.2–17.5	2.2-10.2	26.4-185.5	0.28-0.83	0.06-0.40	1.2-9.5	1-5
Mean			9.2	4.1	74.8	0.44	0.14	5.1	2.8

*Himachal Pradesh - 1; Uttarakhand - 2; Haryana: 3-9; Punjab: 10-24

RESULTS AND DISCUSSION

The height of trees ranged from 5.2 m (MCBI1 from Bithmera, Haryana) to 17.5 m (MCP1 from Punjab) with an average height of 9.2 m. MCPN1 accession from Pantnagar, Uttrakhand recorded maximum clear bole height (10.2 m) while minimum was for MCS4 accession (Solan, Himachal Pradesh). Selected trees in the present study had fairly good straightness, compact crown and clear bole upto 60 per cent of the total height. Yadav *et al.* (2005); Chauhan *et al.* (2012); Meena *et al.* (2014;2016) also reported that straightness, main stem: total height and clear bole: total height ratios coupled with low value of crown spread are desirable for an ideal agroforestry tree. From the correlation studies, it was observed that the straightness had positive and highly significant association with clear bole height (r = 0.522) of the tree (Table 2). The age of the tree had a highly significant and positive association with the height, clear bole height and GBH of the tree while the height had a highly significant and positive correlation with clear bole height, GBH and height: GBH ratio but had a highly significant but negative correlation with clear bole: total height ratio. Similarly, GBH also shows a highly significant but negative correlation with clear bole height: total height ratio but a significant and positive association with height of crown. Similar results of height, GBH and CBH correlation were reported by Dhillon *et al.* (2003) in *Azadirachta indica*; Dogra *et al.* (2005) in *Dalbergia sissoo*.

Progeny testing of Burma dek at the age of six months in nursery showed significant variation in mean performance (Table 3). The progeny performance of MCPN1 from Uttrakhand was extraordinarily well with higher values for field emergence, total height, clear height and basal diameter and root shoot ratio. All the traits are important from economic point of view in tree breeding. Progeny performance of plus trees MCPAU1, MCP1, MCPAU3, MCPAU5 and MCK1 were also equally good obtaining rank in all the observations. At the age of six months, highly significant variation due to progenies for field emergence, seedling height, basal diameter, clear stem height, number of branches and root: shoot ratio open a way to go ahead for further improvement in the material through selection. Best way for this would be to selected large amount of seed from the superior (through progeny testing) plus trees and raise their progeny for second cycle of selection. The findings of the present study may be helpful in identifying candidate plus trees in a scientific manner by taking into account the objectives as well as subjective assessment of the parameters in a simple and systematic way and easily identify the best individuals or laying out the progeny trails and multi locational clonal trails. This will further help in selection of clones with still higher productivity.

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Table 2. Correlation coefficients among different traits of selected plus trees of *Melia composita*

	Age (yrs)	Height (m)	Clear bole height (m)	GBH (cm)	Clear bole: total height ratio	Height: GBH ratio	Height of crown (m)	Straightness
Age (yrs)		0.445**	0.470**	0.732**	-0.346*	0.054	0.404*	0.338*
Height (m)			0.591**	0.645**	-0.437**	0.668**	0.990**	0.380*
Clear bole height (m)				0.379*	0.246	0.550**	0.471**	0.522**
GBH (cm)					-0.506**	-0.034	0.639**	0.370*
Clear bole: total height ratio						-0.111	-0.521**	0.104
Height: GBH ratio							0.635**	0.152
Height of crown								0.325*

* and **Significant at 5 and 1 per cent level, respectively

Table 3. Mean performance of the plus trees progenies of *Melia composita* for emergence and seeding characters

Accession code	Field emergence (%)	Seedling height (cm)	Basal diameter (mm)	Clear stem height (cm)	No. of branches seedling^{-1}	Root : shoot ratio
MCS1	27.0	56.8	5.3	33.5	2.0	0.3
MCPN1	87.4	105.1	9.8	89.3	1.3	0.5
MCBI1	71.7	82.1	6.5	65.5	2.3	0.4
MCBI2	71.4	86.4	6.7	63.4	3.3	0.2
MCBI3	80.2	78.8	6.4	59.8	2.6	0.3
MCBI4	78.3	82.9	6.6	63.4	3.0	0.4
MCBI5	63.7	75.4	5.0	58.4	1.0	0.3
MCK1	92.6	63.5	5.5	43.9	5.0	0.4
MCK2	89.0	91.2	8.5	64.6	3.6	0.4
MCP1	62.3	94.8	7.0	87.4	6.6	0.3
MCP3	74.1	82.4	6.8	59.4	3.3	0.3
MCP5	55.0	68.8	5.4	54.6	1.0	0.2
MCP6	81.6	77.0	7.3	58.0	2.6	0.4
MCP7	66.3	95.2	8.2	67.2	4.3	0.3
MCP10	71.3	89.6	7.6	58.1	1.6	0.5
MCP11	43.6	75.9	6.7	67.0	4.0	0.4
MCP12	92.6	63.5	5.5	43.9	3.0	0.3
MCP14	68.3	83.5	7.4	53.5	3.6	0.3
MCP15	75.0	84.3	6.9	58.5	4.3	0.2
MCPAU1	68.3	104.9	8.0	86.1	7.3	0.3
MCPAU2	74.0	83.6	7.7	63.2	4.0	0.4
MCPAU3	75.4	71.2	6.9	60.5	3.6	0.4
MCPAU5	82.0	86.8	7.8	64.8	3.3	0.4
MCB1	25.3	65.4	5.7	43.7	2.3	0.4
Mean	62.1	81.2	6.8	61.1	3.2	0.3
CD (p=0.05)	7.6	4.5	0.83	7.4	1.48	0.08

*Himachal Pradesh - 1; Uttarakhand - 2; Haryana: 3-9; Punjab: 10-24

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Growth and Above Ground Biomass Accumulation in *Populus deltoides* Bartr Clones in Sub-Tropics of Jammu, India

S. K. Gupta, Jagdeep Singh, K. K. Sood, S. Sehgal, N. S. Raina and L. M. Gupta

Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Jammu-180 009, India
E-mail: sushilgupta67@rediffmail.com

Abstract: The investigation revealed that growth characteristics viz. plant height, diameter at breast height and mean volume (m^3 $tree^{-1}$) were significantly variable among the clones. The clone S_7C_{15} attained maximum plant height whereas, maximum values for mean volume (m^3 $tree^{-1}$) and DBH was observed in clone WSL-22. Above ground oven dry biomass (kg $tree^{-1}$) and its allocation among tree components revealed that mean tree above ground biomass was maximum in WSL-22. Biomass allocation to different components was of the order; stemwood > branch + twig > leaf in all the clones. Among the different clones, WSL-22 performed best with respect to above ground biomass and growth parameters like DBH and per tree volume production in the sub-tropics of Jammu.

***Key Words*:** Above ground biomass, Clones, *Populus deltoides, S*ub-tropics

Forests, having been continuously exploited to meet the needs of civilization, necessitated the improvement of forests and biomass productivity. Thus, the quantification and improvement of the biomass of natural, manmade forest plantations has been the thrust area. Western Himalayan region in the Indian sub-continent consists of states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand covering an area of 33.85 mha and the soil organic carbon contributes about 14% of carbon stocks of the country (Bhattacharya *et al.,* 2008). Among the various forest types, tropical fast growing species have emerged as the alternate option and dependable source of carbon stock in the region. Poplar (*Populus deltoides* Barter), a short rotation species has been ultimate choice for plantation forestry in the Indo-Gangetic plains of North- Western Himalayas. Bulk of the agroforestry plantations in the region have been established in Western Uttar Pradesh, Uttarakhand, Haryana, Punjab and Jammu & Kashmir due to its deciduous nature, fast growth, short rotation and huge industrial demand. Poplar based agroforestry is prevalent among farmers of irrigated sub-tropical plains in North-West India (Chauhan and Mangat, 2006). It has been estimated that 60,000 hectares equivalent plantations of poplar exists in India (Kishwan and Kumar, 2003), which cater to nearly 45% of wood requirements for paper making. Farmers earn good returns from the nursery as well as plantation activities and higher benefit : cost ratio with poplar based intercropping (Rani *et al*., 2011; Chauhan *et al.,* 2015).

Growth behaviour, biomass and soil carbon accumulation studies under different land uses has revealed that *Populus deltoides* significantly contributed to biomass and soil carbon pool in agroforestry plantations (Chauhan *et al.,* 2007, 2011, 2012; Rizvi *et al.,* 2011; Sharma *et al.,* 2015). Promising clones of *Populus deltoides* in an agri-silviculture system revealed higher biomass production (Swami *et al.,* 2006).

By virtue of the fast growth, good companionship with agricultural and medicinal/cash crops and ease in propagation, demand of wood based industry and agroforestry potential, extensive plantations of *Populus deltoides have been* encouraged. Biomass measurements of individual trees and whole stands have long been of principle interest but the concept of complete tree utilization is of recent approach in Indian Forestry. To provide impetus to genetic improvement, wide variety of improved location specific clones suitable for microclimatic situations have been evolved. Information on above ground biomass storage, carbon accumulation by these superior clones is of utmost importance for research, commercial utilization and valuation purposes. Therefore an investigation was carried to estimate above ground biomass production (AGB), its partitioning and carbon storage potential of improved clones of poplar *(Populus deltoides* Bartr) in the irrigated sub-tropics of Jammu and Kashmir.

MATERIAL AND METHODS

The experiment was carried out in a block plantation comprising of different poplar clones at Chatha, Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu and Kashmir during the year 2011-2012. The study site is located at 32° 40N latitude and 74° 53 E longitude at an elevation of 332 meters above mean sea level (amsl). The climate of the area is sub-tropical with a considerable variation in the seasonal and diurnal temperature and rainfall in the area. June and July are the hottest months, whereas, December and January being the coldest months experience severe frost. The average annual rainfall is 1000 mm, the bulk of which is received during the rainy season from the south-east monsoon (July-September). Maximum temperature rises up to 45°C and minimum temperature falls upto 2°C.

The height and diameter at breast height (dbh) of the sample trees for each clone was determined using altimeter and digital tree calipers. Biomass estimation was carried out using simple random sampling. Only the randomly selected sample trees in all the clones were measured for estimating above ground biomass in the month of October. Stem biomass of the sample trees was calculated using volume of the stem and wood density as:

Biomass (kg) = Volume (m^3) × specific gravity (Rajput *et al.,* 1996)

For *Populus deltoides* Barter, the specific gravity used for calculations was 0.491 g cm^3 (Rana *et al.,* 1989). Branch + twig biomass and leaf biomass per tree (kg) was determined as per the procedure adopted by Chidumaya (1990). The total above ground biomass per tree was calculated as the sum of stem, branch plus twigs and leaf biomass.

RESULTS AND DISCUSSION

The data on growth and above ground biomass production by different clones have been presented in table 1. It is evident from the results that growth characteristics viz. plant height, diameter at breast height and mean volume ($m^3 tree^{-1}$) were significantly variable among different clones (Table 1). The clone S_7C_{15} attained maximum plant height but the clones S_7C_{15} and WSL-22 were statistically at par and also the differences among clones; WSL-32, WSL-39, Udai and Karanti were non-significant. Maximum DBH was observed in clone WSL-22 (41.25 cm) followed by clones WSL-32 (38.46 cm), WSL-39 (38.12 cm), however, these values were statistically non-significant. Minimum growth in DBH was recorded in clone Karanti (29.34 m) which was statistically at par with $S_7C_{15.}$

Similarly mean volume (m^3 $tree^{-1}$) varied significantly amongst the clones with maximum observed in clone WSL-22 (4.126 m^3 $tree^{-1}$) followed by WSL-39 (3.544 m^3 $tree^{-1}$). The mean values in clones WSL-32, WSL-39 and Udai i.e., 3.445, 3.544 and 3.249 m^3 $tree^{-1}$, respectively were statistically similar. Minimum volume per tree was recorded in clone Karanti (1.929 m^3 $tree^{-1}$). The variation in growth among different clones be attributed to superior genetic makeup, better adaptability, and genotype x environment interaction. Similar variation among the clones has also been reported by Rawat and Kapoor (2008).

Data for leaf biomass presented in table 1 revealed that the leaf biomass production varied among the poplar clones. Leaf biomass ranged between 7 to 20 kg $plant^{-1}$. The maximum leaf biomass was recorded in clone WSL-39 (20 kg) followed by clones WSL-22 (19 kg), WSL-32, G-48 (16 kg), Udai (12 kg), S_7C_{15} (8 kg) and Karanti (7 kg). Similarly, branch + twig biomass varied among poplar clones under study. The values ranged between 37 to 15 kg per plant. The maximum branch + twig biomass was recorded in clone WSL-22 (37 kg) followed by clones WSL-39 (34 kg), WSL-32 (28 kg), Udai (26 kg), G-48 (24 kg), S_7C_{15} (16 kg) and Karanti (15 kg). Stemwood biomass ranged between 91.0 kg to 40.7 kg. Higher biomass was recorded in clone WSL-22 (91.0 kg) followed by WSL-39 (90.0 kg), G-48 (86.0 kg), Udai (83.0 kg), WSL-32 (68.3 kg), S_7C_{15} (42.0 kg) and Karanti (40.7 kg). Verma *et al.* (2014) also recorded significant clonal variation in poplar growth and biomass.

Total above ground biomass (stem+ branch+ twig +leaf biomass) and its allocation among tree components revealed that total above ground biomass was maximum in WSL-22 (147.0 kg) closely followed by WSL-39 (144.0 kg). Biomass allocation pattern among different components was of the order; stemwood > branch + twig > leaf in all the clones (Table 1). Maximum contribution by stemwood to total above

Table 1. Growth and biomass of different poplar (*Populus deltoides*) clones in the sub-tropics of Jammu

Clones	Plant height (m)	DBH (cm)	Mean volume ($m^3 tree^{-1}$)	Leaf (kg $tree^{-1}$)	Branch + twig (kg $tree^{-1}$)	Stem wood (kg $tree^{-1}$)	Total above ground biomass (kg $tree^{-1}$)
WSL-22	30.56	41.25	4.126	19.0	37.0	91.0	147.0
WSL-32	29.12	38.46	3.445	16.0	28.0	68.2	112.2
WSL-39	29.87	38.12	3.544	20.0	34.0	90.0	144.0
Karanti	28.12	29.34	1.929	7.0	15.0	40.7	62.7
Udai	28.37	37.80	3.249	12.0	26.0	83.0	121.6
S_7C_{15}	31.12	32.81	2.016	8.0	16.0	42.0	66.0
G48	27.12	36.81	2.973	16.0	24.0	86.0	126.0
CD (p=0.05)	2.13	3.71	0.676	4.76	8.11	3.74	22.21

ground biomass can be ascribed to more accumulation in stemwood with age and diameter growth. The findings of present studies are in accordance with those of Rawat and Kapoor (2008) and Swami *et al*. (2006).

This investigation proves the superiority of the clone WSL-22 with respect to above ground biomass (kg tree^{-1}) and growth parameters like DBH and per tree volume production in the sub-tropics of Jammu.

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Effect of Seed Characters on Germination Parameters of Ban Oak (*Quercus leucotrichophora A. Camus)*

Anuradha Thakur and N. K. Gupta

Department of Siviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan-173 230, India
E-mail: anugogle@gmail.com

Abstract: The maximum values for germination (%) was observed in large sized (43.89%), dark brown colour seeds (39.44%) sown at depth 1cm (47.04%). Maximum value for germination index was obtained in large sized (0.23seed day^{-1}), dark brown colour seeds (0.21seed day^{-1}) sown at depth of 1cm (2.89seed day^{-1}). It was found that effect of interaction for large size, dark brown colour seeds sown 1cm deep significantly excelled over other categories in terms of germination parameters.

Key Words: Ban oak, Individual effect, Interaction effect, Seed germination, Seed size, Seed colour, Sowing depth

Oaks (*Quercus* of Fagaceae family) afford a unique insight into the history of our landscape, flora, vegetation and constitute an important group of forest trees and occupy a sizeable area in the Himalayas. There are 16 species of oaks growing in India, ten in eastern Himalayas and six in the western Himalayas. Oak forests in many parts of the Western Himalayas and in the rest of the world are dwindling due to lack of regeneration, habitat changes and biological invasions. The causes of failure in germination and regeneration include erratic seed production, poor seed viability, defoliation, acorn predation and increased incidences of fire, unfavourable micro-sites and overgrazing by domestic animals. Thus, seed plays a vital role in the process of germination and natural regeneration of tree species. Seed size naturally reflects the comparative nutrient pool and energy of a seed, which affects the further growth and development. Use of good quality seeds is pre-requisite for raising good and vigorous planting stock in nursery and the study the effect of sowing depth and oak seed characters on germination parameters.

The experimental site was located at 3051'N latitude and 7611'E longitude with an altitude of 1250 m above mean sea level. The mature acorns were collected from vigorous, middle aged and good form trees in the month of January. Acorns were sown in polybags in the month of February under nursery conditions. The number of seeds taken for each replication under all treatments was thirty. The categorization of the seed size was done on the basis of average acorn weight (g) i.e. large: >2.58g, medium: 1.82-2.58 (g) and small: <1.82. The seeds were graded in colour class on the basis of their appearance. Two depths of sowing (1cm and 2.5cm), three seed size (large, medium and small) and three seed colour (light brown, dark brown and greenish brown) were evaluated on the basis of germination seed tested. The experiment was in factorial design with three replications. Germination, Germination index (total number of seed germinated at the end of the experiment divided by the time taken for fifty per cent germination) and germination vigor (product of germination per cent and seedling length) were recorded after one month of sowing.

The maximum germination (43.89%) was recorded in large sized, dark brown colour seeds (39.44%) when sown at depth 1cm (47.04%). Individual effect of sowing depth with seed size and seed colour was found statistically significant with the maximum value (58.89%) for large sized seeds when sown at depth 1cm depth , whereas, in case of seed colour maximum value (56.67%) was found for dark brown seeds sown at 1cm deep. For the interaction between seed size and seed colour, maximum germination was found (55%) for large sized - dark brown colour seeds and minimum (16.67%) for small sized seeds of light brown colour. Germination index and germination vigour also showed the same trend.

Among seed size and seed colour categories, germination vigour was recorded maximum (74.34) for the large sized seed followed (60.03) by for medium sized seed, whereas, minimum was recorded (39.44) for small sized seeds. Among seed colour, maximum value (73.82) was recorded for dark brown seeds followed by light brown seeds (56.33) and minimum was recorded quite low for greenish brown seeds (43.64). The significantly highest germination with large and heavy seeds of various tree species has been reported by various other workers (Singh *et al*., 1973; Kandya, 1978; Santon, 1985; Kackar *et al.,* 1986; Chauhan and Verma, 1994). Interaction effect between sowing depth and seed colour was found significant. Shallow sowing depth improved germination and reduced the number of days taken to initiate germination. Similar findings have been reported by

Table 1. Effect of sowing depth, seed colour and seed size on germination (%)

	Depth (D)		Seed colour (C)			
	1cm	2.5cm	Light brown	Dark brown	Greenish brown	Mean
Seed size (S)						
Large	58.89 (50.39)	28.89 (31.99)	45.00 (41.91)	55.00 (48.05)	31.67 (33.60)	43.89 (41.18)
Medium	52.22 (46.26)	13.33 (20.97)	35.00 (34.98)	40.00 (38.05)	23.33 (27.82)	32.78 (33.62)
Small	30.00 (33.06)	8.89 (15.24)	16.67 (19.57)	23.33 (28.17)	18.33 (24.70)	19.44 (24.15)
Mean	47.04 (43.24)	17.41 (22.73)	32.22 (32.15)	39.44 (38.09)	24.44 (28.71)	
Seed colour (C)						
Light brown	48.89 (44.21)	15.56 (20.09)				
Dark brown	56.67 (49.05)	22.22 (27.13)				
Greenish brown	35.56 (36.44)	13.33 (20.97)	CD (p=0.05)			
Mean	47.04 (43.24)	17.41 (22.73)	D=2.58	D*S=4.46	D*S*C=NS	
			S=3.15	D*C=4.46		
			C=3.15	S*C=5.46		

Figures in parentheses indicate the arc sine transformed values

Table 2. Effect of sowing depth, seed colour and seed size on germination index

	Depth (D)		Seed colour (C)			
	1cm	2.5cm	Light brown	Dark brown	Greenish brown	Mean
Seed size (S)						
Large	0.36 (3.37)	0.10 (1.78)	0.25 (2.68)	0.31 (3.05)	0.14 (1.99)	0.23 (2.57)
Medium	0.29 (3.03)	0.05 (1.19)	0.21 (2.35)	0.20 (2.34)	0.10 (1.66)	0.17 (2.11)
Small	0.17 (2.29)	0.03 (0.83)	0.07 (1.18)	0.13 (1.93)	0.08 (1.56)	0.09 (1.59)
Mean	0.27 (2.89)	0.06 (1.27)	0.18 (2.07)	0.21 (2.44)	0.11 (1.74)	
Seed colour (C)						
Light brown	0.31 (3.06)	0.05 (1.07)				
Dark brown	0.34 (3.26)	0.09 (1.62)				
Greenish brown	0.18 (2.37)	0.04 (1.10)	CD (p=0.05)			
Mean	0.27 (2.89)	0.06 (1.27)	D=0.20	D*S=NS	D*S*C=NS	
			S= 0.24	D*C=0.34		
			C=0.24	S*C=0.42		

Figures in parentheses indicate the arc sine transformed values

Table 3. Effect of sowing depth, seed colour and seed size on germination vigour

	Depth (D)		Seed colour (C)			
	1cm	2.5cm	Light brown	Dark brown	Greenish brown	Mean
Size (S)						
Large	91.08	57.60	73.12	90.91	58.98	74.34
Medium	82.79	37.28	59.57	78.37	42.17	60.03
Small	63.93	14.90	36.30	52.17	29.78	39.42
Mean	79.27	36.59	56.33	73.82	43.64	
Seed colour (C)						
Light brown	78.95	33.70	CD (p=0.05)			
Dark brown	101.40	46.23	D=7.11	D*S=NS	D*S*C=NS	
Greenish brown	57.44	29.84	S=8.71	D*C=12.32		
Mean	79.27	36.59	C=8.71	S*C=NS		

Ghosh *et al*., (1976), who ascribed that the seed sowing at 1.0 cm depth resulted into best germination in *Pinus patula, Pinus caribea* and *Pinus elliottii*.

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Variation in Chemical Components and Fibre Length in Wood of High Density Plantation of *Eucalyptus tereticornis* Smith

Shabir Ahmad Rather, Kulwant Rai Sharma, Heena Gupta and Sabeena Nabi[1]

College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan-173 230, India

[1]Faculty of Forestry, SKUAST-Kashmir, Benhama, Ganderbal-191 201, India

[*]E-mail: sshab32@gmail.com

Abstract: The effect of sampling height and spacing on some chemical components and fibre length of wood was investigated in high density plantation of 25 year old *Eucalyptus tereticornis*. Four trees each from three spacings viz. 0.60 × 0.60 m, 0.90 × 0.90 m and 1.20 × 1.20 m were randomly selected and harvested. The observations were recorded by taking sample discs at four different tree heights, ground level, 30, 60 and 90% of total tree height. Klason lignin content decreased significantly with increase in height and the highest value of 31.15% was at ground level. Holocellulose content decreased significantly with increase in height being maximum at 90% of total tree height and minimum at ground level. Fibre length displayed significant decreasing trend with increase in height and was maximum (0.893 mm) at ground level. The interaction of height was non-significant.

Key Words*:* Eucalyptus, Fibre length, Holocellulose, lignin, Spacing, Sampling height,

Forests occupy 30 per cent of the world's terrestrial surface (Anonymous, 2007) and are key terrestrial carbon stores, much of which is from wood. Wood derived from forests is also the basis of renewable energy and industrial production systems for products such as timber and pulp. Wood is the fibrous material in the trunk of trees, which is composed of a complex mixture of polymers. Quantitatively, the most important is cellulose, followed by lignin, hemicelluloses, and then extractives. Cellulosic ?bres are deposited on cell walls along with lignin during the process of wood formation (Walker, 2006). Lignin supports the cellulosic ?bres, provides the hydrophobic surfaces in vessels essential for water conduction and also plays role in defense against wood eaters and pathogens. The primary structural block of wood is the tracheids or fibre cells. These cells vary from 16 - 42 micrometers in diameter and from 870-4000 micrometer long. Fibres are the principal element that is responsible for the strength of the wood. Planted forests comprise an increasing proportion of the world's forests and now provide nearly half of the global wood production (Anonymous, 2007). Short-rotation tree crops such as eucalypt plantations, are the feed stocks not only of the pulp and paper industry (Clarke, 2009), but are also seen as the basis of new industries replacing the use of fossil hydrocarbons for energy and industrial organic chemicals (Bozell, 2010). In India, eucalypt plantations are preferred over indigenous trees primarily for the reason of short-term tangible benefits (timber, fuel, fodder, oil and ash), fast growth rate, more productivity per unit area and least post plantation care (Sangha and Jalota, 2005). While evaluating the potential of the plantations for industrial use, the concern for quality of wood is as important as rate of growth. Wood in general, is a very variable substance, clear understanding of variation patterns with in trees, between trees of same species, and among different species is very important for production and efficient use of wood. The greater the uniformity of wood, the greater will be the efficiency of producing a specific produce with much improved quality of the final product. Therefore, the current study was undertaken to examine the variation in lignin, holocellulose and fibre length in plantation grown *Eucalyptus tereticornis* wood.

The experiment was conducted on high density plantation of 25 year old *Eucalyptus tereticornis*, raised at a spacing of 0.60 × 0.60 m (S_1), 0.90 × 0.90 m (S_2) and 1.20 × 1.20 m (S_3). The plantation area is located at an altitude of 1200 m above mean sea level and lies at $30^0$51N latitude and $76^0$11E longitude (Survey of India Toposheet No. 55 F/1). Chemical investigation was performed on 5 cm long stem sections removed from the main stem at ground level (H_1), 30 (H_2), 60 (H_3) and 10 cm at 90% (H_4) of total tree height in the Department of Forest Products, College of Forestry, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan.

The Klason-lignin and holocellulose contents were determined by employing the method TAPPI T 222 om-11 (2011) and TAPPI T 249 cm-00 (2000), respectively. The experiment was in randomized block design (factorial).

Lignin content: The lignin content decreased significantly with increase in tree height. Maximum value of 31.15 per cent has been recorded at the base and minimum of 25.80 per cent at ninety per cent of the total tree height (Table 1) . The

Table 1. Effect of spacing and sampling height on Klason-lignin, holocellulose and fibre length in wood of *Eucalyptus tereticornis*

Spacing	Klason-lignin				Holocellulose				Fibre length			
Height	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
H_1 (Ground level)	30.81	31.16	31.49	31.15	66.01	66.06	66.33	66.13	0.886	0.895	0.899	0.893
H_2 (30% of total tree height)	29.43	29.37	29.48	29.43	67.29	67.57	68.11	67.66	0.845	0.875	0.874	0.865
H_3 (60% of total tree height)	27.38	26.76	28.22	27.45	69.88	70.31	69.45	69.88	0.829	0.794	0.875	0.832
H_4 (90% of total tree height)	26.50	24.66	26.25	25.80	70.04	71.94	70.64	70.87	0.792	0.743	0.766	0.767
Mean	28.53	27.99	28.86		68.31	68.97	68.63		0.838	0.827	0.853	
	CD (p=0.05)				CD (p=0.05)				CD (p=0.05)			
S	NS				NS				NS			
H	0.999				0.891				0.022			
S × H	NS				NS				NS			

$S_1 = 0.60 \times 0.60$ m, $S_2 = 0.90 \times 0.90$ m, $S_3 = 1.20 \times 1.20$ m

decrease in lignin content from base to top of the tree may be due to its lesser deposition in juvenile tissues as lignin deposition is more in old tissues. It is because of this only that heartwood content is more in older stems. These findings are in agreement with those of Silva *et al*. (2005) in *Eucalyptus grandis.* Lignin content did not observe any significant effect of spacing and its interaction with sampling height. However, among spacings, the maximum value of 28.86 per cent was for 120 × 120 m and minimum 27.99 per cent for 90 × 90 m. These findings lend their support to the findings of Sharma and Sharma (2003) on *Eucalyptus tereticornis*.

Holocellulose content: Holocellulose contents in wood include both celluloses and hemicelluloses. The appraisal of data revealed significant increase in holocellulose content with increase in tree height (Table 1). It was 66.13 per cent at ground level and 70.87 per cent at ninety per cent of the total tree height. It may be due to the varied production of dry matter at different sampling heights. These results are in conformity with the findings of Sharma and Sharma (2003) in *Eucalyptus tereticornis*, Silva *et al*. (2005) in *Eucalyptus grandis* and Sharma and Sharma (2005) in *Robinia pseudoacacia*. The effect of spacings and their interaction with sampling heights was non-significant. However, the maximum value of 71.94 per cent was recorded for $S_2 \times H_4$ and minimum of 66.01 per cent for $S_1 \times H_1$ treatment combination.

Fibre length: The fibre length was non-significant for different spacings. This varied between 0.827 mm (S_2) and 0.853 mm (S_3). The effect of sampling height was statistically significant, higher (0.893 mm) at ground level (H_1) than H_3 but was at par with H_2. The lowest value (0.767 mm) was observed at 90% of the total tree height (H_4). The differences in fibre length associated with increase in height are mainly due to the differences in the juvenile and mature wood proportion in the tree. Since the proportion of juvenile wood increases with an increase in height, the fibre length has shown a decrease from base to top of the tree. The interaction between spacing and different levels of tree heights was found to be non-significant. The combination $S_3 \times H_1$ recorded the highest value of 0.899 mm and $S_2 \times H_4$ the lowest (0.743 mm). The above results are in conformity with the findings of Tavares *et al*. (2011) and Quilho *et al*. (2000) in *Eucalytpus globules* and Susilawati and Marsoem (2006) in *Eucalyptus pellita.*

It is quite evident from the present study that the chemical composition and fibre length of wood was significantly influenced by stem height levels. Spacing had a non-significant effect on lignin, holocellulose and fibre length of wood. Such results are very important to chemical technologists and wood scientists working on pulp wood quality parameters in hardwoods.

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Influence of Growing Media and Container Size on Germination and Plant Survival of *Ailanthus altissima* Mill.

Sabeena Nabi, P. A. Khan, K. N. Qaisar and Shabir Ahmad Rather

Faculty of Forestry, Benhama Ganderbal -191 201, India
E-mail: nabisabeena@gmail.com

***Abstract**:* The experiment was conducted to find out the influence of different growing media and container size on germination and plant per cent of *Ailanthus altissima* Mill. The germination percentage and plant survival was maximum in Soil: Sand: FYM :: 2:1:1 media and container size 300cc. Soil: Sand: FYM (2:1:1) media had better water holding capacity, CEC, regulates nutrient uptake and container size 300 cc plays a role in holding more media i.e. more and regular nutrient supply and moisture for germinating seeds and towards survival.

Key Words: *Ailanthus altissima, G*ermination, Plant per cent

Ailanthus altissima is afforested in most of the states of India for soil conservation works particularly in Jammu and Kashmir and also as an avenue plantation (Luna, 1995). Besides, its use as an avenue/ornamental plant, it is also used for wood, medicinal use and as a host plant to feed silkworms of the moth *"Samia Cynthia*". Leaves can be effective in treating boils, abscesse, itches and baldness. A tincture of root bark has been used successfully in treating cardiac palpitation, asthma and epilepsy (Huang, 1997). Keeping in view the importance of this species especially its medicinal uses and in the economic potential, it was important to evaluate the suitable medium and container/root trainer for the germination and plant survival of this tree species. Overview of this species reveals that no work has been done on this aspect so far. The aim of this study was to evaluate the influence of growing media and container/root trainer size for uniform and maximum germination and plant survival. The study was conducted in the nursery site of SKUAST-K, Srinagar during 2011. Seeds of *Ailanthus altissima* were collected from the university campus. The experiment was in Completely Randomized Design with three replications each represented by 12 seeds. There were 21 combinations of seven growing media and three containers (Table 1).

The germination percentage of seeds were recorded upto 28 days as per the International Seed Testing Association (ISTA, 1999). The experiment was kept free from any kind of weed growth for better survival and the observations regarding plant survival was recorded at the end of the experiment(after 8 months).

The observations regarding influence of growing media and container/root trainer size are presented in Table 2. The results observed significant differences ($p \leq 0.05$) among the treatments for germination and plant survival.

Effect of growing media: The growing medium exhibited significant differences ($p \leq 0.05$) in germination percentage and plant survival. The growing medium M_4 (Soil: Sand: FYM:: 2:1:1) recorded maximum germination percentage and plant survival of (88.18) and (69.83), respectively. Ahmadloo *et al*. (2012) also obtained best results in *Cupressus arizonica* and *Cupressus sempervirens* with growing mixture containing Soil: Cattle manure: Decomposed litter in the ratio of 5:1:1. Similar observations were reported by Sharma and Rana (2007) in *Jatropha curcus.* This corroborates to good soil structure, water holding capacity, FYM improving CEC, and more aeration pore volume that could maintain higher levels of oxygen for better germination of seeds and to the developing seedlings towards maximum plant survival.

Table 1. Main features of growing medium and container/root trainers

Growing media		
Media	Ingredients	Proportion
M_1	Soil: Sand: FYM	1:0:0
M_2	Soil: Sand: FYM	1:1:0
M_3	Soil: Sand: FYM	1:1:1
M_4	Soil: Sand: FYM	2:1:1
M_5	Soil: Sand: FYM	2:2:1
M_6	Soil: Sand: FYM	0:1:0
M_7	Soil: Sand: FYM	1:2:1
Container features		
Container size/volume (cc)	Length (cm)	Diameter (cm)
C_1 (150cc)	10.0	5.00
C_2 (250cc)	10.0	7.00
C_3 (300cc)	16.5	7.00

Effect of container size: The maximum germination (77.77%) and plant survival (61.59) was observed in container/root trainer of 300cc size (Table 2). The highest germination percentage in 300 cc container/root trainer size may be attributed to the fact that high density plastic body of 300 cc container enhances solar radiation absorption and keeps the growing media warm for longer time and hence accelerated rate of germination, big drainage hole for oxygen, more growing media holding capacity, which results in making available more nutrient reserves to the germinating seed for longer time, presence of more soil bacteria and fungi that has a role for digestion of seed coat. This is in conformity with Qaisar *et al*. (2008), Alam *et al.* (2005) and Sharma and Rana (2007).

Reasons for maximum plant per cent in container/root trainer size 300 cc may be due to more growing media holding capacity, thus making more and regular supply of nutrient reserves available to the developing seedlings for longer time, big drainage hole for regular and higher levels of oxygen sufficient for root development on which seedling survival depends. The observations are in unison with the findings of Mhango *et al*. (2008) and Sofi and Bhardwaj (2007).

Table 2. Main effect of growing medium and container/root trainer size on seed germination and plant per cent of *Ailanthus altissima* Mill. under field conditions

Treatment	Germination percentage	Plant per cent
Growing medium		
M_1 (Soil: Sand: FYM ::1:0:0)	72.96	57.78
M_2 (Soil: Sand: FYM::1:1:0)	65.92	52.21
M_3 (Soil: Sand: FYM::1:1:1)	80.69	63.91
M_4 (Soil: Sand: FYM::2:1:1)	88.18	69.83
M_5 (Soil: Sand: FYM::2:2:1)	74.51	59.01
M_6 (Soil: Sand: FYM::0:1:0)	60.36	47.81
M_7 (Soil: Sand: FYM::1:2:1)	69.92	55.38
CD (p=0.05)	5.34	4.23
Container size		
C_1 (150cc)	68.13	53.96
C_2 (250cc)	73.75	58.41
C_3 (300cc)	77.77	61.59
CD (p=0.05)	3.49	2.77

Combined effect of growing medium and container size: The growing medium and container size combination resulted in significant differences ($p \leq 0.05$) in germination percentage and plant survival recorded (Table 3). The combination M_4C_3 recorded maximum germination percentage which was at par with M_4C_2, M_4C_1 and M_3C_3. Similarly, M_4C_3 recorded maximum plant survival which was at par with M_4C_2 and M_4C_1.

The combination of growing medium M_4 (Soil: Sand: FYM:: 2:1:1) and container size C_3 (300cc) was most effective resulting in high germination and plant survival.

Table 3. Combined effect of growing medium and container/root trainer size on seed germination and plant per cent of *Ailanthus altissima* Mill. under field conditions

Growing medium x container size	Germination percentage	Plant per cent
$M_1 C_1$	67.11	53.15
$M_1 C_2$	74.44	58.95
$M_1 C_3$	77.33	61.24
$M_2 C_1$	61.44	48.66
$M_2 C_2$	63.88	50.59
$M_2 C_3$	72.44	57.37
$M_3 C_1$	76.44	60.54
$M_3 C_2$	82.55	65.38
$M_3 C_3$	83.10	65.82
$M_4 C_1$	83.55	66.17
$M_4 C_2$	88.99	70.48
$M_4 C_3$	91.99	73.60
$M_5 C_1$	69.33	54.91
$M_5 C_2$	76.10	60.27
$M_5 C_3$	78.10	61.86
$M_6 C_1$	53.99	42.76
$M_6 C_2$	59.44	47.08
$M_6 C_3$	67.66	53.58
$M_7 C_1$	65.11	51.56
$M_7 C_2$	70.88	56.14
$M_7 C_3$	73.77	58.43
CD (p=0.05)	9.25	7.33

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Variability in Different Sources of Glory Lily (*Gloriosa Superba* L.) under Subtropical Plains of Jammu

L. M. Gupta, Sandeep Kumar, Meenakshi Gupta, K. K. Sood and S. K. Gupta
Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu -180 009, India
E-mail: guptalm@gmail.com

Abstract: Eight sources of glory lily collected from different states viz. J&K, HP, MP and UK were evaluated for growth and yield parameters to identify superior genotype. Maximum seed yield per plant of 5.32g was observed in Nauni source (HP) followed by Nandani, J&K (5.07g) and Giripul, HP (4.49g), whereas, minimum (2.21g) was recorded in Jabalpur source (MP). Wide range of variability is observed in height, leaves, branches, flowers, fruits and seed yield parameters. Higher heritability and genetic advance observed in height, leaves, flowers and seed yield per hectare indicate ample potential for improvement in the species through selection of these traits.

Key Words: Colchicine, *Gloriosa superba,* Genetic evaluation, Gout , Variability

Species extinction is a well known tragedy. Unchecked extraction of plants or their parts for various uses from natural habitats along with various other reasons have led to extinction of many species, especially medicinal plants. This situation is causing concern not only for loss of species diversity but also the availability of raw material. *Gloriosa superba* L. a perennial climber belonging to family Liliaceae is one among such species which is widely used in both traditional and modern therapies. It is a cosmopolitan species in India, distributed from Jammu & Kashmir to Tamil Nadu, in the tropical and sub-tropical climate, upto an altitude of 2100m above mean sea level. Its roots are traditionally used to heal snake and scorpion bites, for promoting labour pain and as abortifacient (Singh *et al.*, 2005). In Indian system of medicines, seed and tubers are also used for treating gout, rheumatism, cholera, typhus, Bright's disease, piles, gonorrhoea and chronic ulcers. Alkaloid colchicine ($C_{22}H_{26}O_6H$), present in tubers and seed is used for treating gout, cancer control and for inducing polyploidy in plants. Recently, the species is reported to have anticoagulant properties and found effective for controlling the larvae of various livestock parasites (Kee *et al.*, 2008; Zahir *et al.*, 2009). The flowers are used as cut flowers due to their colour and shape.

Due to its widespread use, the species was largely extracted from its niche areas in the past. Present status of this species is threatened due to unchecked extraction of tubers coupled with low seed yield in nature. Therefore, cultivation is the only alternative to conserve the species *vis-a-vis* to meet the demand of industry. Besides manipulation of agro-techniques, identification of genetically superior lines among the exiting population is an important strategy to enhance the production of any plant species. Keeping in view, eight sources of glory lily collected from different areas/regions were evaluated for growth and yield parameters to identify superior germplasm.

The present investigations were carried out at Experimental Farm of Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu. The experimental site falls under sub-tropical zone of Jammu division of Jammu and Kashmir State, with hot dry summers, hot humid rainy and cold winter months. The experiment was conducted under randomized block design with eight sources (four sources from Jammu and Kashmir - Nagrota, Nandani, Nagbani and Dhiansar; two from Himachal Pradesh - Giripul and Nauni and one each from Jabalpur, Madhya Pradesh and Dehra Dun, Uttarakhand) in three replications. Tubers were planted at a spacing of 60cm x 40cm, accommodating nine plants per plot. Observations for growth and yield parameters were recorded on 5 plants per replication per treatment. The data were analyzed and variability estimates for different characters were calculated using SPSS package.

Tables 1-2 revealed significant variation among the eight sources of *Gloriosa superba* on the basis of mean performance of all the characters. From evaluation of different sources, it emerged that Nauni source of Himachal Pradesh state had outstanding performance for ten characters under study viz. plant height (141.13cm), number of branches per plant (4.30), number of flowers per plant (32.10), number of seed plant^{-1} (18.31), fruit length (4.68cm), fruit diameter (1.62cm), 100-seed weight (3.20g), seed yield fruit^{-1} (0.56g), seed yield plant^{-1} (5.32g) and estimated seed yield hectare^{-1} (221.95kg ha^{-1}). For the remaining characters, this source ranked second. Although, Nandani (J&K) source ranked at second number and Giripul (HP) source at third, but were statistically at par with Nauni source in terms of most of the growth and yield parameters. The overall performance of eight sources/genotypes revealed that Nauni (HP), Nandani (J&K) and Giripul (HP) sources are superior over others. These genotypes recorded higher values than other sources as for as the characters contributing to the economic yield are concerned. The results obtained for various parameters are in concurrence with the earlier reports of various studies on *Gloriosa superba* (Raina and Gupta, 1999; Gupta and Raina, 2001). However, dry seed yield plant^{-1} of *Gloriosa superba* (2.21-5.32g) was much less compared to the dry seed yield of 4.97-93.90g plant^{-1} reported by Chitra and Rajamani (2009). This might be due to genotypic variation between the sources coupled with climatic variation at two different places. It also suggests that there is a further scope of screening more genotypes particularly from southern parts of India.

Estimate of variability and genetic parameters: The mean values of different characters had wider range indicating the presence of good amount of variability (Table 3). The narrow range in 100-seed weight, fruit length and diameter indicates slow improvement in selection, if these characters are taken into consideration. Higher value of genotypic coefficient of variation for most of the characters are near to phenotypic coefficient of variability, which indicates less effect of environment on the genotypes. Plant height, number of leaves plant^{-1}, number of branches plant^{-1}, number of flowers plant^{-1}, number of fruits plant^{-1}, seed yield plant^{-1} and estimated seed yield hectare^{-1} registered higher range of genotypic coefficient of variation, indicating higher range of genetic variability among these characters. On the other hand, days taken to sprouting and initiation of flowering, fruit length, seed yield fruit^{-1} and 100-seed weight, could give low genetic coefficient of variation, which was less than the environment coefficient of variability, thus indicating the influence of environmental factors on the expression of characters. These findings are in accordance with the reports of Gupta *et al.* (2010), where wide range of variability and variation in genetic parameters was observed in *Bunium persicum* under temperate climate of Jammu.

Higher heritability along with higher genetic advance was observed in plant height, number of leaves plant^{-1} and seed yield hectare^{-1}, whereas, number of flowers plant^{-1} had high heritability with moderate genetic advance (Table 3). Higher heritability observed for these characters might be due to additive effects and selection pressure could be profitably applied on these characters for yield improvement. Number of days taken to initiation of flowering, fruit length and 100 seed weight revealed low genetic gain.

Table 1. Mean performance of growth parameters in different sources

Source	Days taken to sprouting	Days taken to initiation of flowering	Plant height (cm)	No. of leaves plant^{-1}	No. of branches plant^{-1}
Nagrota (J&K)	47.52	84.33	80.93	93.13	2.10
Nandani (J&K)	40.02	76.70	139.47	171.26	3.80
Nagbani (J&K)	37.06	72.19	111.47	119.60	2.60
Dhiansar (J&K)	47.12	83.12	99.47	110.20	2.00
Giripul (HP)	51.12	85.27	98.13	104.00	2.57
Nauni (HP)	38.19	73.24	141.13	162.70	4.30
Dehra Dun (UK)	50.50	88.27	81.43	84.70	2.10
Jabalpur (MP)	49.49	79.93	72.24	82.50	1.50
CD (p=0.05)	7.741	10.271	12.487	9.512	0.388

Table 2. Mean performance of yield and yield attributing traits in different sources

Sources	No. of flowers plant^{-1}	No. of fruits plant^{-1}	Fruit length (cm)	Fruit dia. (cm)	No. of seed fruit^{-1}	100-seed weight (g)	Seed yield fruit^{-1} (g)	Seed yield plant^{-1} (g)	Estimated seed yield (kg ha^{-1})
Nagrota (J&K)	19.30	6.20	4.21	1.37	15.01	3.11	0.46	2.70	112.58
Nandani (J&K)	30.00	9.93	4.51	1.56	17.01	3.12	0.52	5.07	211.45
Nagbani (J&K)	25.48	7.53	4.23	1.47	15.70	2.98	0.45	3.42	142.45
Dhiansar (J&K)	21.01	7.00	4.37	1.48	16.30	2.92	0.47	3.31	138.12
Giripul (HP)	23.14	8.51	4.54	1.59	17.51	3.10	0.53	4.49	187.08
Nauni (HP)	32.10	9.64	4.68	1.62	18.31	3.20	0.56	5.32	221.95
Dehra Dun (UK)	15.13	6.06	4.46	1.49	16.51	3.01	0.48	2.81	117.08
Jabalpur (MP)	11.51	5.30	4.12	1.34	14.50	3.00	0.43	2.21	92.20
CD (p=0.05)	5.794	1.411	0.378	0.077	1.922	0.111	0.068	0.855	15.917

Thus, these characters seem to be controlled by non-additive gene action. On the other hand, plant height, number of leaves plant^{-1}, number of branches plant^{-1}, number of flowers plant^{-1}, seed yield plant^{-1} and estimated seed yield hectare^{-1} indicate high genetic gain and thus can safely be considered for obtaining more of genetic improvement in a population through selection. Such types of observations have also been reported earlier in *Gloriosa superba* (Mamatha *et al.*, 1993). Higher heritability and genetic advance observed in height, leaves, flowers and seed yield hectare^{-1} indicate ample potential for improvement in the species through selection of these traits.

Table 3. Estimate of variability and genetic parameters for different characters

Character	Range	Mean	Co-efficient of variation (%)	Co-efficient of variability (%)			Heritability (%)	Genetic advance (%)	Genetic gain (%)
				Genotypic	Phenotypic	Environmental			
Days taken to sprouting	38.19-51.12	45.14	7.74	26.57	44.98	36.29	34.90	14.59	32.33
Days taken to initiation of flowering	72.19-88.27	80.38	10.27	11.37	29.33	27.04	15.03	7.30	9.08
Plant height (cm)	72.24-141.13	103.03	12.49	65.52	70.36	25.64	86.71	129.50	125.69
No. of leaves plant^{-1}	82.50-171.26	116.01	9.51	76.69	78.63	17.35	95.13	178.75	154.08
No. of branches plant^{-1}	1.50-4.30	2.62	8.38	94.81	99.89	31.47	90.07	4.85	185.35
No. of flowers plant^{-1}	11.51-32.10	22.20	14.75	77.30	95.00	55.20	66.20	28.76	129.56
No. of fruits plant^{-1}	5.30-9.93	7.52	10.61	55.45	68.19	39.69	66.12	6.98	92.88
Fruit length (cm)	4.12-4.68	4.35	4.92	9.20	20.57	18.39	20.00	0.36	8.47
Fruit diameter (cm)	1.34-1.62	1.49	2.94	16.42	20.11	11.62	66.67	0.41	27.65
No. of seed fruit^{-1}	14.50-18.31	16.37	6.65	14.68	28.86	24.86	25.86	2.52	15.38
100-seed weight (g)	2.92-3.20	3.06	2.05	6.54	10.53	7.30	23.08	0.07	15.71
Seed yield fruit^{-1} (g)	0.43-0.56	0.49	7.86	15.87	33.04	28.86	40.00	0.26	8.52
Seed yield plant^{-1} (g)	2.21-5.32	3.67	13.17	78.51	92.70	49.27	71.72	5.02	136.97
Estimated seed yield (kg ha^{-1})	92.20-221.95	152.85	15.92	82.52	85.41	22.03	93.34	251.04	164.24

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Cost and Return Analysis of Sheep Rearing in Rajouri district of Jammu and Kashmir State

Jyoti Kachroo, Diraj Gangal and Anil Bhat*
Division of Agricultural Economics and Agribusiness Management
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180009, India
**E-mail: drbhatanil@gmail.com*

Abstract: Rajouri district being a hilly area falls under intermediate zone having potential of sheep rearing. The overall per animal rearing cost of sheep in Rajouri district was Rs.914. The cost was highest in medium rearers due to higher imputed value of family labour. The cost A was highest in medium rearers due to higher depreciation on fixed capital, whereas, cost B and C were maximum medium rearers (Rs.366) and minimum in large rearers (Rs.243). The overall return per animal was Rs.919. For cost of sheep rearing, the imputed value of family labour is highest in all the blocks with overall value of Rs.541 per animal and Rs.70527 per flock.

***Key Words*:** Costs, Returns, Rearing, Sheep

Indian economy is predominantly agrarian contributing 14.5% to national GDP, out of which the share of livestock sector is 27% and of which small ruminants contribute about 4 per cent to the total value of livestock sector (Anonymous, 2011*)*. Thus, livestock form an important economic and ecological niche in agricultural systems throughout the developing countries. The population of goats and sheep in Asia is 514.4 and 452.3 million, respectively, which comes out to be 59.7 and 42.0 per cent, respectively out of the total world population (Anonymous, 2011). The average annual fine quality wool production per sheep is between 3.5 to 5.5kg in Australia, New Zealand and U.S.S.R., whereas, in India, the average is less than 1.0 kg of inferior quality (Khanvilkar *et al.,* 2009) with exception in Magra sheep, which annually yields more than 2 kg wool of average staple length of 5.8 cm. The demand for animal protein in India is increasing at a very faster rate and annual meat consumption has increased from 3 million tonnes in 1983 to 4 million tonnes in 1993 and the projection for 2020 is 8 million tonnes (Delagado, 1999). Trends reveal that though mono-gastric have become important meat suppliers over time, the role of small ruminants in meat supply is growing in India as meat of these species are still the most preferred.

The state of Jammu and Kashmir comprises of three regions namely Jammu, Kashmir and Ladakh. The climatic suitability equips the state of Jammu and Kashmir with a unique comparative edge over the consumption of sheep in the form of meat, wool, milk, etc. In the higher hills, sheep are like a poor man's cash crop. Rajouri district being a hilly area falls under intermediate zone and is having lot of potential of sheep rearing. The sheep supplies the wool for domestic use and as a medium for procuring other needs of life. It also leads to better employment opportunities for family labour through small-scale industry for the manufacturing of Shawls, Pattus, Blankets (patties) and Lahangs (cloth for coat and trouser). The state has 61.95 lakh small ruminant population out of which 41.27 lakh population is of sheep and 20.68 lakh was of goat, with 318.00 lakh kg of mutton and 78.77 lakh kg wool productions (Anonymous, 2011). Out of total small ruminant population of the State, Jammu region has 66.44 per cent (41.16 lakh) of small ruminant with 62.76 per cent (25.9 lakh) and 73.99 per cent (15.26 lakh) of sheep and goat population, respectively out of total sheep and goat population of the state. The total mutton and wool production of Jammu division is 199.28 lakh kg and 47.6 lakh kg, respectively, During 2010-11 the average yearly consumption of mutton in Jammu and Kashmir was more than the annual production of 318 lakh kg, that is why the state had imported about 13 lakh sheep and goat from outside the state. Fortunately, the sheep importation has not increased much i.e. 2.86 per cent over a period of 10 years from 2001-02 to 2011-12. This indicates that there is wider scope for further increase in production and then export of same for income generation. Keeping this in view, a need has been felt for working out cost and return analysis of sheep rearing and its income pattern, thereby indicating the margin of profit of sheep, which can play a vital role in motivating the rearers for increasing efficiency and ultimately will improve their economic conditions.

MATERIAL AND METHODS

The study was conducted in Rajouri district of

Table 1. Cost and return/yield of sheep in block Budhal of Rajouri district (Rs)

Particular	Per animal				Per flock			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Average flock size per household					48	135	200	127
Variable cost								
Feed cost								
Green fodder	54	54	54	54	2592	7290	10800	6894
Dry fodder	18	18	18	18	864	2430	3600	2298
Mineral nutrient	45	64	80	63	2165	8640	16000	8935
Veterinary expenditure	9	7	8	8	427	999	1600	1009
Total variable cost	126	143	160	143	6048	19359	32000	19136
Fixed cost								
Depreciation	86	79	60	75	4128	10692	12000	8940
Government grazing charges	0	44	0	15	0	5994	0	1998
Cost A	272	322	262	285	13056	43470	52400	36309
Interest on fixed capital	60	55	42	52	2880	7425	8400	6235
Cost B	332	377	304	337	15936	50895	60800	42543
Imputed value of family labour	388	453	589	476	18643	61195	117800	65879
Cost C	720	830	893	814	34579	112090	178600	108423
Cost C*	792.	913	982	895	38035	123295	196400	119243
Return								
Wool yield (kg)	1.05	1.00	1.11	1.05	41.28	79.92	222.00	114.40
Value of wool	105	100	111	105	4130	7999	22200	11443
Value of animal sold	1550	1650	1600	1600	90444	99994	320000	170146
Value of added stock	326	259	250	278	15667	34965	50000	33544
Gross returns	1655	1750	1711	1705	1102423	143038	342200	198494
Flock business income	1383	1428	1449	1420	97187	99568	289800	162185
Family labour income	1323	1373	1407	1367	94307	92143	281400	155950
Net income over cost C	934	919	818	890	75663	30948	163600	90070
Net income over cost C*	862	836	728	808	72207	19743	145600	79183

Table 2. Cost and return/yield of sheep in block Kalakote of Rajouri district

Particular	Per animal				Per flock			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Average flock size per household					59	121	209	129
Variable cost								
Feed cost								
Green fodder	54	54	54	54	3186	6534	11286	7002
Dry fodder	18	18	18	18	1062	2178	3762	2334
Mineral nutrient	64	71	73	69	3776	8591	15257	9208
Veterinary expenditure	11	16	8	12	649	1936	1672	1419
Total variable cost	147	159	153	153	8673	19239	31977	19963
Fixed cost								
Depreciation	71	63	33	56	4189	7623	6897	6236
Government grazing charges	0	49	11	20	0	5929	2299	2743
Cost A	218	271	197	229	12862	32791	41173	28942
Interest on fixed capital	50	44	23	39	2950	5324	4807	4360
Cost B	268	315	220	268	15812	38115	45980	33302
Imputed value of family labour	590	869	630	696	34810	105149	131670	90543
Cost C	858	1184	850	964	50622	143264	177650	123845
Cost C*	944	1302	935	1060	55684	157590	195415	136230
Return								
Wool yield (kg)	1	1	1	1	61	126	209	132
Value of wool	104	104	100	103	6136	12584	20900	13207
Value of animal sold	1740	1900	1850	1830	102660	229900	386650	239737
Value of added stock	331	309	277	306	19529	37389	57893	38270
Gross returns	1844	2004	1950	1933	108796	242484	407550	252943
Flock business income	1626	1733	1753	1704	95934	209693	366377	224001
Family labour income	1576	1689	1730	1665	92984	204369	361570	219641
Net income over cost C	986	820	1100	969	58174	99220	229900	129098
Net income over cost C*	900	702	1015	872	53112	84894	212135	116713

Table 3. Cost and return/yield of sheep in block Nowshera of Rajouri district

Particular	Per animal				Per flock			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Average flock size per household					76	127	280	161
Variable cost								
Feed cost								
Green fodder	54	54	54	54	4104	13716	15120	10980
Dry fodder	18	18	18	18	1368	4572	5040	3660
Mineral nutrient	50	39	62	50	3800	9906	17360	10355
Veterinary expenditure	12	11	8	10	912	2794	2240	1982
Total variable cost	134	122	142	133	10184	30988	39760	26977
Fixed cost								
Depreciation	59	71	44	58	4484	18034	12320	11613
Government grazing charges	0	23	10	11	0	5842	2800	2881
Cost A	193	216	196	202	14668	54864	54880	41471
Interest on fixed capital	41	49	31	40	3116	12446	8680	8081
Cost B	234	265	227	242	17784	67310	63560	49551
Imputed value of family labour	515	375	302	397	39140	95250	84560	72983
Cost C	749	640	529	639	56924	162560	148120	122535
Cost C*	824	704	582	703	62616	178816	162935	134789
Return								
Wool yield (kg)	1	1	1	1	79	264	280	208
Value of wool	104	104	100	103	7904	26416	28000	20773
Value of animal sold	1603	1550	1450	1534	121828	393700	406000	307176
Value of added stock	250	216	223	230	19000	54864	62440	45435
Gross returns	1707	1654	1550	1637	129732	420116	434000	327949
Flock business income	1514	1438	1354	1435	115064	365252	379120	286479
Family labour income	1473	1389	1323	1395	111948	352806	370440	278398
Net income over cost C	958	1014	1021	998	72808	257556	285880	205415
Net income over cost C*	883	950	968	934	67116	241300	271071	193162

Table 4. Cost and return/yield of sheep in block Rajouri of Rajouri district

Particular	Per animal				Per flock			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Average flock size per household					67	120	293	160
Variable cost								
Feed cost								
Green fodder	54	54	54	54	3618	6480	15822	8640
Dry fodder	18	18	18	18	1206	2160	5274	2880
Mineral nutrient	42	72	45	53	2814	8640	13185	8213
Veterinary expenditure	13	8	11	11	871	960	3223	1685
Total variable cost	127	152	128	136	8509	18240	37504	21418
Fixed cost								
Depreciation	75	86	49	70	5025	10320	14357	9901
Government grazing charges	0	50	20	23	0	6000	5860	3953
Cost A	202	288	197	229	13534	34560	57721	35272
Interest on fixed capital	53	60	34	49	3551	7200	9962	6904
Cost B	255	348	231	278	17085	41760	67683	42176
Imputed value of family labour	465	378	441	428	31155	45360	129213	68576
Cost C	720	726	672	706	48240	87120	196896	110752
Cost C*	792	799	739	777	53064	95832	216586	121827
Return								
Wool yield (kg)	1	1	1	1	67	120	290	159
Value of wool	100	100	99	100	6700	12000	29007	15902
Value of animal sold	1500	1550	1500	1517	100500	186000	439500	242000
Value of added stock	283	250	181	238	18961	30000	53033	33998
Gross returns	1600	1650	1599	1616	107200	198000	468507	257902
Flock business income	1398	1362	1402	1387	93666	163440	410786	222631
Family labour income	1345	1302	1368	1338	90115	156240	400824	215726
Net income over cost C	880	924	927	910	58960	110880	271611	147150
Net income over cost C*	808	851	860	840	54136	102168	251921	136075

Table 5. Cost and return/yield of sheep in block Sunderbani of Rajouri district

Particular	Per animal				Per flock			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Average flock size per household					40	113	190	114
Variable cost								
Feed cost								
Green fodder	54	54	54	54	2160	6102	10260	6174
Dry fodder	18	18	18	18	720	2034	3420	2058
Mineral nutrient	66	56	39	54	2640	6328	7410	5459
Veterinary expenditure	12	8	10	10	480	904	1900	1095
Total variable cost	150	136	121	136	6000	15368	22990	14786
Fixed cost								
Depreciation	93	87	46	75	3720	9831	8740	7430
Government grazing charges	0	53	31	28	0	5989	5890	3960
Cost A	243	276	198	239	9720	31188	37620	26176
Interest on fixed capital	65	61	32	53	2600	6893	6080	5191
Cost B	308	337	230	292	12320	38081	43700	31367
Imputed value of family labour	697	422	454	524	27880	47686	86260	53942
Cost C	1005	759	684	816	40200	85767	129960	85309
Cost C*	1106	835	752	898	44220	94344	142956	93840
Return								
Wool yield (kg)	1	1	1	1	42	118	190	116
Value of wool	104	104	100	103	4161	11752	19000	11638
Value of animal sold	1850	1750	1650	1750	74000	197750	313500	195083
Value of added stock	395	222	295	304	15800	25086	56050	32312
Gross returns	1954	1854	1750	1853	78160	209502	332500	206721
Flock business income	1711	1578	1552	1614	68440	178314	294880	180545
Family labour income	1646	1517	1520	1561	65840	171421	288800	175354
Net income over cost C	949	1095	1066	1037	37960	123735	202540	121412
Net income over cost C*	849	1019	998	955	33940	115158	189544	112881

Table 6. Cost and return/yield of sheep in block Thannamandi of Rajouri district

Particular	Per animal				Per flock			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Average flock size per household					55	106	200	120
Variable cost								
Feed cost								
Green fodder	54	54	54	54	2970	5724	10800	6498
Dry fodder	18	18	18	18	990	1908	3600	2166
Mineral nutrient	44	42	48	45	2420	4452	9600	5491
Veterinary expenditure	12	9	13	11	660	954	2600	1405
Total variable cost	128	123	133	128	7040	13038	26600	15559
Fixed cost								
Depreciation	36	62	59	52	1980	6572	11800	6784
Government grazing charges	0	28	22	17	0	2968	4400	2456
Cost A	164	213	214	197	9020	22578	42800	24799
Interest on fixed capital	25	43	41	36	1375	4558	8200	4711
Cost B	189	256	255	233	10395	27136	51000	29510
Imputed value of family labour	779	514	582	625	42845	54484	116400	71243
Cost C	968	770	837	858	53240	81620	167400	100753
Cost C*	1065	847	921	944	58564	89782	184140	110829
Return								
Wool yield (kg)	1	1	1	1	55	106	198	120
Value of wool	100	100	99	100	5500	10600	19800	11967
Value of animal sold	1800	1500	1700	1667	99000	159000	340000	199333
Value of added stock	247	235	306	263	13585	24910	61200	33232
Gross returns	1900	1600	1799	1766	104500	169600	359800	211300
Flock business income	1736	1387	1585	1569	95480	147022	317000	186501
Family labour income	1711	1344	1544	1533	94105	142464	308800	181790
Net income over cost C	932	830	962	908	51260	87980	192400	110547

Table 7. Overall cost and return/yield of sheep in whole Rajouri district

Particular	Per animal				Per flock			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Average flock size per household					57	120	228	135.00
Variable cost								
Feed cost								
Green fodder	54	64	54	57	3105	7641	12348	7698
Dry fodder	18	21	18	19	1035	2547	4116	2566
Mineral nutrient	52	65	58	58	2936	7760	13135	7944
Veterinary expenditure	12	12	10	11	667	1425	2206	1432
Total variable cost	136	161	140	146	7742	19372	31805	19640
Fixed cost								
Depreciation	69	88	48	68	3921	10512	11019	8484
Government grazing charges	0	45	16	20	0	5454	3542	2998
Cost A	213	305	210	242	12143	36575	47766	32161
Interest on fixed capital	48	61	34	48	2745	7308	7688	5914
Cost B	261	366	243	290	14889	43883	55454	38075
Imputed value of family labour	569	568	487	541	32412	68187	110984	70528
Cost C	830	934	730	831	47301	112070	166438	108603
Cost C*	913	1027	803	914	52031	123277	183072	119460
Return								
Wool yield (kg)	1	1	1	1	58	136	232	142
Value of wool	101	113	102	105	5755	13558	23151	14155
Value of animal sold	1721	1759	1612	1697	98072	211057	367608	225579
Value of added stock	300	288	249	279	17090	34536	56769	36132
Gross returns	1867	1920	1714	1834	106438	230457	390760	242552
Flock business income	1654	1616	1504	1591	94295	193882	342994	210390
Family labour income	1606	1555	1471	1544	91550	186574	335306	204476
Net income over cost C	1038	987	984	1003	59138	118386	224322	133949
Net income over cost C*	955	893	911	919	54408	107180	207655	123081

Jammu and Kashmir state during the year 2013. The Rajouri district was selected purposely due to its highest population and high density of small ruminants. A three stage sampling was adopted for the selection of samples (blocks, villages and respondents). Budhal (45.3%), Kalakote (16.6%), Thanamandi (15.6%), Rajouri (13.5%), Nowshera (5.6%) and Sunderbani (2.4%) blocks were selected. From each village 10 rearers were selected randomly and ultimately comprising of 180 rearers. These rearers were categorized into small, medium and large category on basis of <100,101-174 and >175 sheep, respectively.

The data was collected on various aspects of rearing the small ruminant's mainly sheep i.e, the costs involved then returns, input-out relation, and economic viability.

Cost concepts: Items of cost:

Cost A: It included wages of hired labour, medical expenses, mineral (salt) cost, private grazing charges, government grazing charges, shearing expenses, miscellaneous expenses, interest on working capital, depreciation/ appreciation on fixed capital (value of equipments and flocks)

Cost B: Cost A + interest on fixed capital (value of equipments and flocks)

Cost C: Cost B + imputed value of family labour

Cost C*: Cost C + 10 per cent of cost C to account for the value of management input.

Return concepts: Flock business income = Gross income – Cost A

Family labour income = Gross income – Cost B

Net income over Cost C= Gross income – Cost C

Net income over Cost C*= Gross Income – Cost C*

RESULTS AND DISCUSSION

Cost and return: The overall per animal cost of sheep was maximum in Kalakote block (Rs.1060.41) and minimum in Nowshera (Rs.703.3). The cost A varied between (Rs. 197) in Thannamandi to Rs.285 in Budhal and highest in medium rearers in all the blocks except in Thannamandi due to higher depreciation on fixed capital, higher expenditure incurred on green fodder and mineral nutrient. Cost B include expenditure incurred on interest on fixed capital and varied between Rs. 36 in Thannamandi to Rs. 53 in Sunderbani block. varied betwIn Budhal block Cost C* was maximum in large rearers (Rs.9820) whereas in Rajouri and Kalakote blocks it was maximum in medium rearers with their values Rs. 798 and Rs. 1032, respectively. In rest of the blocks, it was maximum in small rearers. The overall net income over cost C* per animal was maximum (Rs.955.08) in Sunderbani block and minimum (Rs. 808) in Budhal block. The per animal gross return was maximum in medium rearers and minimum in small rearers in Budhal, Kalakote and Rajouri blocks whereas, in Nowshera and Sunderbani block, it was maximum in small and minimum in large rearers. The results are in close conformity to the results given by Wani *et al*. (2009). The per flock overall cost was maximum (Rs.136230) in block Kalakote and minimum (Rs. 93840) in Sunderbani, whereas, overall net income over cost C* was maximum (Rs. 193162) in Nowshera block because of the large flock size and minimum (Rs. 79183) in Budhal block.

The overall per animal cost of sheep in Rajouri district was Rs.914 with maximum of Rs.1027.3 in medium rearers due to higher imputed value of family labour. The cost A was also maximum in medium rearers due to higher depreciation on fixed capital, higher expenditure incurred on green fodder and mineral nutrient. The cost B, C and C* was also maximum in medium rearers with their values Rs.365.69, Rs.933.92 and Rs.1027.3, respectively. The overall return per animal was Rs.919.49. The per animal gross return was maximum in medium rearers and lowest in large rearers. The net income over cost C and C* was maximum in small rearers and lowest in large rearers. The table further revealed that overall per flock cost C* was Rs.119460 with maximum of Rs. 183072 in large rearers and minimum (Rs. 52031) in small rearers. The per flock business income was maximum in large rearers and minimum in small rearers. The results are in close conformity to the results given by Wani *et al*. (2009).

CONCLUSION

The imputed value of family labour is maximum in all the blocks with overall value of Rs. 541 animal^{-1} and Rs. 70528 flock^{-1} in Rajouri district as a whole. The cost incurred on mineral nutrient is maximum followed by cost on green fodder, whereas, cost on veterinary expenditure is minimum. The returns with respect to sale of dung and skin is found to be nil but returns from sale of animal was maximum while as the value of added stock was next to sale of sheep and sale of wool was in third place.

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Effect of Stocking Density on Survival and Growth of Stinging Catfish, *Heteropneustes fossilis* (Bloch) Fry

Vaneet Inder Kaur, Asha Dhawan, Grishma Tewari and Geeta Jassal

Department of Aquaculture, College of Fisheries
Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141 004, India
E-mail: vinnygulati@gmail.com

Abstract: Fry of stinging cat fish, *Heteropneustes fossilis* were reared at four stocking densities 5, 7, 9 and 11 m^{-2} for 90 days. Fish growth was affected significantly with increase in stocking density (SD) from 5 to 7 m^{-2}, while survival was affected with increase in SD from 7 to 9m^{-2}. Fish reared at 5 m^{-2} recorded significantly higher growth in terms of net weight gain (220.61%), specific growth rate (1.28%) and protein efficiency ratio (1.53). Maximum utilization of feed was observed in 5m^{-2}, evident from least value of feed conversion ratio (1.86) followed by 7, 9 and 11 m^{-2}. Maximum fish survival was also recorded at 5 and 7 m^{-2}, however, the total fish biomass was highest at 11/m^2. Stocking density had no undesirable affect on the water quality as all the water quality parameters remained within the recommended optimum range required for fish culture. Hence, the present study revealed that for rearing fry of *H. fossilis,* the optimum stocking density, in terms of survival, growth and profitability from sale of fingerlings is 5 m^{-2} i.e., 50000 fry ha^{-1}.

Key Words: Fry rearing, Growth, *Heteropneustes fossilis*, Stocking density, Survival

Air breathing fish culture holds great promise in rural India, which abound several thousand hectares of derelict swampy water area which is not suitable for carp culture. Among air-breathing fishes, freshwater catfishes are popular owing to their ability to survive in poorly oxygenated waters, good taste and high nutritional value. Among freshwater catfishes, *Heteropneustes fossilis* (Bloch.) commonly known as 'Singhi' or 'Stinging catfish' is one of the highly demanded species in the Indian subcontinent and Southeast Asian region. It is impounded in all types of inland water bodies and can survive in captivity even under shallow water conditions due to its accessory respiratory organ. The ability of *H. fossilis* to adapt to poorly oxygenated fresh / brackish waters and grow under poor environmental conditions, makes it an extremely valuable species for small and large scale rural fish farming (Pillay, 2001). It is one of the hardiest cat fish and needs less management practices for commercial production. Moreover, it is very popular and highly priced fish due to its high digestibility, palatability, medicinal qualities and nutritive value, besides having lesser spines. It can be reared in both monoculture and poly-culture (along with carps) systems (Haniffa, 2009).

Optimizing stocking density is a pre-requisite for developing package of practice for rearing any species under controlled conditions. Stocking density is considered as one of the important parameter in fish culture, since it has direct effect on growth, survival and productivity of fish. Overstocking reduces fish growth and survival in a culture system (Shugunan, 1997). Considering the importance of stocking density on growth performance of fish (Khan *et al.,* 2003; Kohinoor *et al.,* 2012), the present investigation was undertaken to study the survival and growth of *H. fossilis* (Bloch.) under different stocking densities with same feeding management.

MATERIAL AND METHODS

The study was conducted at College of Fisheries, GADVASU, Ludhiana for a period of 90 days in fiber reinforced plastic (FRP) pools (1.5×1.0×0.75m), with 1.5' soil layer, 0.25 m water depth and polyvinyl chloride (PVC) hide outs. Bore-well water was used for initial filling and compensating evaporation losses during the study.

Healthy fry of *H. fossilis* (average weight - 1.3 g, average length - 5.4 cm) were procured from College of Fisheries, GADVASU and stocked at four different stocking densities i.e. 5, 7, 9 and 11 fry m^{-2} (in triplicate) and designated as treatments T_1, T_2, T_3 and T_4, respectively. The fry were fed with formulated pellet dry diet [groundnut meal (30%), rice bran (29%), boiled egg yolk (40%) and vitamin-mineral mix (1%)], containing 35.23 and 14.75 % crude protein and crude fat (on dry matter basis), respectively @ 10 % of fish body weight in two split doses daily. Amount of feed was adjusted every month, in proportion to increase in fish body weight.

Water quality in all the treatments was analyzed at weekly intervals with respect to temperature, pH, dissolved oxygen, alkalinity, hardness and ammonia, as per standard methods of APHA (2005). Water samples were collected during the morning hours. Fish growth in terms of total body length and BW was recorded at monthly intervals. At the end of the study, survival of fish and fish growth were calculated as follows

%TLG = Final total body length (cm)-initial total body length (cm) /initial total body length (cm) x 100

NWG = Average final BW (g) - Average initial BW (g)

SGR = ln final BW (g) – ln initial BW (g) / culture days x 100

Where, ln = Natural Logarithm

ADG = Weight gain (g) / Culture days

FCR = Feed given (g) / Weight gain (g)

PER = Weight gain (g) / Protein intake (g)

PI **=** Weight gain (g) / Culture days x Survival rate

The data was statistically analyzed using SPSS-16 software. One way ANOVA was applied for determining significant differences among the treatments at 5% significance level (P <0.05).

RESULTS AND DISCUSSION

Differences among different treatments with respect to temperature, pH, dissolved oxygen, alkalinity, hardness and ammonia were not significant and all the water quality parameters were within the optimum range required for freshwater aquaculture as suggested by Boyd and Tucker (1998). 100 % fish survival was in T_1 and T_2 followed by T_3 and T_4, respectively (Table 2). The results revealed that survival of fish was not affected with increase in stocking density from 5-7 /m^2, whereas, with further increase in stocking density to 9 to11 m^{-2}, it declined to 91.6 and 86.3 % respectively, which is attributed to more competition among the fishes leading to stressful conditions. Similar findings have been reported by many researchers for fish species like catfish, *H. fossilis* (Narejo *et al*., 2005), carps, *Labeo rohita* (Narejo *et al.,* 2010) and mrigal, *Cirrhinus mrigala* (Iqbal *et al.,* 2014) and perch, *Anabas testudineus* (Rahman and Monir, 2013). Fish growth in terms of average final total body length (cm), total length gain (%), final body weight (g) and net weight gain (%) was significantly higher in T_1 (8.60, 45.76, 4.2, 220.61) followed by other treatments. The results revealed that unlike survival of fish, growth of fish in terms of net weight gain was affected with increase in stocking density from 5 to 7 m^{-2} and declined further by 36.33 and 34% with increase in stocking density to 9 and 11 m^{-2} respectively. Average daily gain and performance index was found to be significantly higher in T_1 as compared to all other treatments, which was in accordance with respective weight gain and survival of fish in

Table 1. Physico-chemical parameters of water in different treatments

Treatments	pH	Temperature (^oC)	D.O. (mgl^{-1})	Ammonia (mg l^{-1})	Ortho-phosphate (mg l^{-1})
T_1	8.14^a	20.60^a	4.22^a	0.251^a	1.57^a
T_2	8.14^a	20.43^a	4.64^a	0.338^a	1.63^a
T_3	8.19^a	20.49^a	4.68^a	0.448^a	1.49^a
T_4	8.19^a	20.47^a	4.36^a	0.435^a	1.47^a

Values with same superscripts in a column do not differ significantly (P<0.05)

Table 2. Growth parameters of fry of *H. fossilis* reared at different stocking densities

Parameters	T_1	T_2	T_3	T_4
Initial total body length (cm)	5.9^a	5.9^a	6.0^a	5.9^a
Final total body length (cm)	8.6^a	8.0^b	7.9^b	8.04^b
% Total body length grain	45.76^a	35.59^b	31.67^c	36.27^b
Initial body weight (g)	1.31^a	1.26^a	1.24^a	1.25^a
Final body weight (g)	4.2^a	3.26^b	3.08^b	3.14^b
Net body weight grain (g)	2.89^a	2.00^b	1.84^{bc}	1.91^b
Daily weight gain	0.032^a	0.022^b	0.020^b	0.021^b
Performance index	3.2^a	2.02^b	2.0^b	1.81^c
% Net weight gain	220.61^a	158.73^b	148.38^c	151.20^{bc}
Specific growth rate	1.28^a	1.05^b	1.01^b	1.04^b
Protein efficiency ratio	1.53^a	1.06^{bc}	0.98^c	1.02^{bc}
Feed conversion ratio	1.86^c	2.70^b	2.93^a	2.82^a
Survival (%)	100^a	100^a	91.6^b	86.3^c
Production (kg m^{-3}90 days^{-1})	0.021^b	0.022^b	0.028^a	0.029^a

$^{a, b, c}$ Values bearing different superscripts in a row differ significantly (P <0.05) the treatment.

Generally, higher stocking density results in reduced fish growth and survival along with increase in food conversion ratio (Samad *et al.,* 2005). Gibtan *et al.* (2008) too recorded highest weight gain in tilapia, *O. niloticus* at stocking density of 50 fish m^{-2} as compared to 100, 150 and 200 m^{-2}, when reared in cages. The results of present study in terms of significantly higher fish growth at stocking density of 5 m^{-2} are also in agreement with the previous studies conducted with cat fishes, *H. fossilis* (Narejo *et al.,* 2005; Kohinoor *et al.,* 2012; Rahman *et al.,* 2014 and Monir and Rahman, 2015), *C. gariepinus* (Jamabo and Keremah, 2009), *Pangasius hypothalamus* (Malik *et al.,* 2014), carps, *L. rohita* (Narejo *et al.,* 2010), and perch, *A. testudineus* (Rahman and Marimuthu, 2010; Rahman and Monir, 2013).

The specific growth rate (SGR) of *H. fossilis* fry at different stocking densities ranged between 1.01 to 1.28 with highest SGR at stocking density of 5 m^{-2}. Likewise Rahman *et al.* (2014) also reported 18.5 m^{-2} as optimum stocking density in comparison to higher stocking densities of 20 and 22.5 m^{-2} for *H. fossilis* fingerlings in terms of SGR. Rahman *et al.* (2012) and Kapinga *et al.* (2014) also observed highest SGR, when larvae of catfish, *C. batrachus* and tilapia, *O. niloticus* were reared at stocking density of 18 larvae $liter^{-1}$ (in comparison to 24 and 30 larvae $liter^{-1}$) and 3 larvae $liter^{-1}$ (in comparison to 5,10,15 and 20 larvae $liter^{-1}$), respectively.

Poor growth performance at higher stocking densities might lead to social stress due to aggressive feeding behaviour, which eventually lead to impaired fish growth (El-sayed, 2002). Nwipie *et al.* (2015) indicated best growth performance of post fry of cat fish, *C. gariepinus*, in terms of specific growth rate, condition factor and performance index, at stocking density of 5 and 10 $liter^{-1}$ of water as compared to 15, 20 and 25 $liter^{-1}$.

The FCR in T_1 was significantly lowest (1.86) followed by T_2, T_4 and T_3. This might be attributed to the higher intake, digestibility and proper utilization of feed in stress free conditions at stocking density of 5 m^{-2} (Mensah *et al*., 2013).

In comparison to significantly higher individual fish growth at 5 m^{-2}, highest fish biomass per unit area (kg m^{-3}) was obtained in T_4 (0.029 kg m^{-3} 90 day^{-1}) followed by T_3, T_2 and T_1, indicating showing positive relationship with numbers of fish stocked. Previous studies by Narejo *et al*. (2005); Rahman and Marimuthu (2010); Malik *et al.* (2014) and Iqbal *et al.* (2014) also indicated maximum fish production at highest stocking densities. However, in terms of the relative economics involved, substantially higher net benefits were obtained with higher market price of the larger fingerlings produced with lower stocking density (T_1), as compared to smaller fingerlings produced at higher stocking densities (T_3 and T_4). Rahman *et al*. (2005) also found similar results for mahseer (*Tor putitora*) reared in earthen nursery ponds, where higher net benefits were obtained from ponds stocked with 0.6 million hatchlings ha^{-1} than those from 1.0 million ha^{-1} and 0.8 million ha^{-1} stocking densities, respectively.

The present study revealed that survival of *H. fossilis* fry is affected if stocking density is increased to 9 m^{-2}, while its growth is affected if the stocking density is increased to 7 m^{-2}. Hence, the present study reveal that for rearing fry of *H. fossilis,* the optimum stocking density, in terms of survival, growth and profitability from sale of fingerlings is 5 m^{-2} i.e. 50000 fry ha^{-1}.

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Evaluation and Identification of Potential Bivoltine Silkworm Hybrids of *Bombyx mori* L.

Mokshe Sajgotra and R. K. Bali
Division of Sericulture,
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Udheywalla-180 001, India
E-mail: mokshesajgotra@gmail.com

Abstract: In the present study, an attempt was made to evaluate fifty-six silkworm bivoltine hybrids raised by involving full diallel set of bivoltine breeds including four hypersericigenous (PO_1, PO_3, ND_2 and ND_5) and four thermotolerents (Udhey-1, Udhey-3, Udhey-4 and Udhey-6) along with ruling bivoltine hybrid, SH_6 x NB_4D_2 in order to identify adaptable, high yielding bi x bivoltine potential silkworm hybrids. Observations were made on eight economically important cocoon and silk yielding traits namely, larval weight, crop weight, single cocoon weight, single shell weight, shell ratio, average filament length, non-breakable filament length and denier. The data was analyzed using multiple trait indexes (Evaluation index) method. Twenty two hybrid combinations recorded mean evaluation index (E.I.) values of >50 ranging from 67.61-51.13, whereas, control scored E.I value of 49.21 only. Eight hybrid combinations, PO_3 x ND_5 (67.61), ND_5 x PO_1 (63.35), PO_1 x PO_3 (61.34), Udhey-6 x ND_2 (61.25), Udhey-6 x ND_5 (60.65), Udhey-4 x ND_2 (60.19) and ND_2 x Udhey-6 (60.11) emerged as a potential hybrids recording average E.I value >60 for all the characters.

Key Words: Adaptable, Bivoltine, Hypersericigenous, Evaluation, High yielding, Thermo-tolerant

Sericulture is an important component of the diversified agriculture which plays a vital role in generating employment opportunities for the masses of the farming community including women and the farmers with small land holdings to land less in the rural areas for livelihood. The trend of sericulture development in India has shown a quantum jump in mulberry silk production with an annual production of 20,000 MT during the last three decades (Lakshmanan and Kumar, 2012) and it enjoys the comfortable second position for the production of silk in the world next only to China, in which silkworm breeding and development of bivoltine hybrids have played a vital role. India being predominantly a tropical country with marginal sub-tropical and temperate sericulture zones, mostly multi x bivoltine hybrids is reared in tropical areas of the country which do not meet the international standards. The silk produced by multivoltine breeds or multi x bivoltine hybrids is not so superior and cannot be sold in the international market. Thus, there is great need and scope for improving the bivoltine sericulture of the country (Datta *et al.*, 2001). As a result, more emphasis needs to be given to bivoltine sericulture, if India has to produce international grade silk. Realizing the importance of bivoltine sericulture, efforts are being made by silkworm breeders (Babu *et al*., 2005; Guruswami, 2006; Moorthy *et al*., 2007) of the country to evolve high yielding bivoltine silkworm breeds/hybrids for commercial purpose over years through conventional breeding approach and genetic improvement of multiple traits. Most of the silkworm breeding programmes now-a-days are oriented towards boosting the bivoltine silk yield and fiber quality. Accordingly, the present investigation was carried out to evaluate and identify the newly developed bivoltine hybrids for commercialization.

MATERIALS AND METHODS

The present study was undertaken at Sher-e-Kashmir University of Agricultural Sciences and Technology, Udheywalla, Jammu, to identify new bivoltine hybrids suitable for commercial rearing. For this purpose, four hypersericigenous (PO_1, PO_3, ND_2 and ND_5) and four thermotolerents (Udhey-1, Udhey-3, Udhey-4 and Udhey-6) breeds were prepared by employing complete diallel pattern (Table 1) and compared with commonly used bivoltine hybrid, SH_6 x NB_4D_2 to identify the thermotolerent, adaptable, high yielding bi x bivoltine silkworm hybrids. These hybrids along with the control were reared in the completely randomized block design with three replications each. Standard rearing techniques were followed (Krishnaswamy, 1988). Data was recorded on larval weight, effective rate of rearing (by weight), single cocoon weight, single shell weight, shell ratio, average filament length, non-breakable filament length and denier (filament size) and was analyzed using multiple trait index (Evaluation index) method.

Evaluation index: The data on the economically important traits was collected, pooled and analyzed. The Evaluation Index (EI) (Mano *et al.,* 1993) was calculated:

$$\text{Evaluation Index} = [(A-B/C) \times 10] + 50$$

Where, A= Value of the particular hybrid combination
B= Mean value of all the hybrid combinations

Table 1. Diallel crosses of eight parental breeds

Breeds	Udhey-1	Udhey-3	Udhey-4	Udhey-6	PO_1	PO_3	ND_2	ND_5
Udhey-1	U*-1 x U-1	U-1 x U-3	U-1 x U-4	U-1 x U-6	U-1 x PO_1	U-1 x PO_3	U-1 x ND_2	U-1 x ND_5
Udhey-3	U-3 x U-1	U-3 x U-3	U-3 x U-4	U-3 x U-6	U-3 x PO_1	U-3 x PO_3	U-3 x ND_2	U-3 x ND_5
Udhey-4	U-4 x U-1	U-4 x U-3	U-4 x U-4	U-4 x U-6	U-4 x PO_1	U-4 x PO_3	U-4 x ND_2	U-4 x ND_5
Udhey-6	U-6 x U-1	U-6 x U-3	U-6 x U-4	U-6 x U-6	U-6 x PO_1	U-6 x PO_3	U-6 x ND_2	U-6 x ND_5
PO_1	PO_1 x U-1	PO_1 x U-3	PO_1x U-4	PO_1 x U-6	PO_1 x PO_1	PO_1 x PO_3	PO_1 x ND_2	PO_1 x ND_5
PO_3	PO_3 x U-1	PO_3 x U-3	PO_3 x U-4	PO_3 x U-6	PO_3 x PO_1	PO_3 x PO_3	PO_3 x ND_2	PO3 x ND_5
ND_2	ND_2 x U-1	ND_2 x U-3	ND_2 x U-4	ND_2 x U-6	ND_2 x PO_1	ND_2 x PO_3	ND_2 x ND_2	ND_2 x ND_5
ND_5	ND_5 x U-1	ND_5 x U-3	ND_5 x U-4	ND_5 x U-6	ND_5 x PO_1	ND_5 x PO_3	ND_5 x ND_2	ND_5 x ND_5

Control – SH_6 x NB_4D_2(* =Udhey)

C= Standard deviation of all the hybrid combination
10= Standard Unit
50= Fixed Value

The EI value fixed for the selection of hybrid is 50 or >50 for the characters. The hybrid, which scored above the limit, is considered to possess greater economic value.

RESULTS AND DISCUSSION

The rearing and reeling performance of new bivoltine hybrids along with control was studied. The intake of food during total larval life is reflected by larval weight. Seven hybrids scored E.I value >60 for larval weight (Table 2). Economic characters like cocoon yield (by weight), cocoon weight, cocoon shell weight and cocoon shell percentage are inter-related and moreover they influence the productivity. In the present study, a great deal of variability was observed in the expression of crop weight. Seven hybrid combinations scored E.I >60 (Table 2) for this trait. Malik *et al.* (2001) suggested that cocoon yield/10,000 larvae by weight, single cocoon weight, shell weight and shell ratio percentage are important parameters for a quality cocoon crop.

The cocoon weight, shell weight and shell ratio are the important commercial parameters for cocoon stage and reeling performance. The cocoon weight has a negative correlation with shell ratio but positive correlation with shell weight whereas shell weight has a positive correlation with shell ratio. Cocoon characters are commercially important and in the present study ten hybrids scored E.I >60 for single cocoon weight. Sarat Chandra *et al*. (1992) has reported superior mulberry variety particularly triploids responsible for higher cocooning characters. Shell weight has a positive co-relation with cocoon shell ratio. Eleven hybrids scored E.I. value of >60; whereas, control remained at 31.90 for single shell weight character. Higher shell ratio percentage is an important character for silk filament. In hybrids, five combinations were found scoring E.I. value >60 for shell ratio parameter. However, control hybrid, SH_6 x NB_4D_2 remained at E.I. value of 31.90 only (Table 2). Cocoon yield, pupation rate, single cocoon weight, single shell weight and shell ratio combined constitute the major qualitative and quantitative traits of the silk industry.

Among post cocoon parameters, filament length and denier are considered as important characters from economic point of view and have direct bearing on the merit of a breed or hybrid. Increase or decrease in filament length is dependent on increase or decrease in the thickness of silk filament and cocoon shell weight of breeds and hybrids (Kobari and Fujimato, 1966; Nagaraju and Kumar, 1995). Results of the present study revealed fluctuations in filament length and non-breakable filament length in different hybrids. Eleven and seven hybrids respectively, crossed the bench mark of >60 for both filament length and non-breakable filament trait (Table 2). The results are in agreement with the findings of Rao *et al*. (2004) who observed variations in F1 hybrids. Rajalakshmi *et al.* (1998) opines that the quality of the good hybrid is to have minimum or no breaks during reeling. Nine hybrid combinations including control crossed E.I. >60 for filament size (denier). The control hybrid SH_6 x NB_4D_2 could not qualify for total filament length and non-breakable filament length character.

Malik *et al.* (2002) and Ram *et al*. (2003) suggested that the superiority and potential of a hybrid mainly depends on the ranking and considering all the major larval, cocoon yield and silk contributing parameters. Based on these facts, ten hybrid combinations PO_3 x ND_5 , ND_5 x PO_1, PO_1 x PO_3, U-6 x ND_2, U-6 x ND_5, U-4 x ND_2, ND_2 x U-6, ND_5 x U-3, ND_5 x U-6, PO_1 x ND_5, ND_2 x PO_3, U-6 x PO_1, ND_2 x U-1, ND_5 x U-4, U-3 x ND_2, PO_1 x ND_2, PO_1 x U-6, ND_2 x U-4, PO_3 x ND_2, U-3 x U-6, ND_2 x PO_1 and U-3 x PO_1 were found to be heterotic scoring E.I value >50, whereas, control hybrid scored E.I of 49.21 only. By considering the average EI value of all the traits, PO_3 x ND_5 (67.61), ND_5 x PO_1 (63.35), PO_1 x PO_3 (61.34), U-6 x ND_2 (61.25), U-6 x ND_5 (60.65), U-4 x ND_2 (60.19) and ND_2 x U-6 (60.11) scored E.I. value >60 for eight commercially important characters and may be utilized for commercial exploitation.

Table 2. Evaluation Index (E.I) values of superior cross combinations or heterotic hybrids for commercial characters

Hybrids	Characters								
	Larval weight (g)	Effective rate of rearing (by weight) (kg)	Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)	Average filament length (m)	Non-breakable filament length (m)	Denier (d)	Average E.I
SH_6 x NB_4D_2 (control)	50.83	45.11	64.82	49.66	31.90	45.62	44.87	60.89	49.21
PO_3 x ND_5	68.55	59.00	62.50	66.71	61.78	75.79	76.59	70.00	67.61
ND_5 x PO_1	59.26	64.66	66.92	68.00	56.26	67.22	66.17	58.27	63.35
PO_1 x PO_3	64.40	59.72	55.00	57.87	56.66	66.12	67.89	63.07	61.34
U*-6 x ND_2	61.44	60.16	60.83	67.27	65.35	66.22	67.98	40.76	61.25
U*-6 x ND_5	67.36	68.10	63.33	63.03	55.00	62.43	48.25	57.56	60.65
U* -4 x ND_2	53.75	61.60	59.16	63.93	61.78	57.25	51.74	72.30	60.19
ND_2 x U*-6	64.46	57.79	60.00	62.33	56.37	66.72	57.07	56.17	60.11
ND_5 x U*-3	50.05	56.89	55.08	58.66	57.00	62.20	69.88	64.03	59.22
ND_5 x U*-6	55.40	57.49	56.92	61.33	58.75	64.88	55.48	61.93	59.02
PO_1x ND_5	58.49	68.34	70.00	62.72	47.38	48.17	51.74	56. 92	58.12
ND_2 x PO_3	63.44	39.53	44.12	59.33	73.39	62.95	61.49	60.36	58.07
U*-6x PO_1	57.30	55.52	54.16	56.36	56.19	64.72	66.63	47.69	57.32
ND_2 x U*-1	48.63	52.13	65.17	62.00	49.60	64.38	55.04	59.31	57.03
ND_5 x U*-4	50.12	57.41	52.10	59.00	61.46	54.75	53.53	62.98	56.42
U*-3 x ND_2	55.53	62.81	62.50	61.51	53.33	48.17	51.74	51.53	55.89
PO_1 x ND_2	59.67	57.40	60.83	60.90	55.00	53.56	56.59	41.53	55.68
PO_1 x U*-6	47.84	65.56	59.82	59.00	51.55	53.07	51.94	53.03	55.23
ND_2 x U*-4	68.64	50.09	55.61	59.00	56.84	51.06	43.28	55.65	55.02
PO_3 x ND_2	56.71	57.12	51.66	54.24	55.00	52.36	55.51	40.76	52.92
U*-3 x U-6	47.84	53.31	43.33	45.45	49.88	54.85	57.75	63.07	51.93
ND_2 x PO_1	54.77	48.06	56.75	59.00	55.38	44.78	45.14	45.18	51.13
U*-3 x PO_1	42.51	51.54	56.66	53.63	48.21	52.96	56.05	43.84	50.67

CONCLUSION

The PO_3 x ND_5 (67.61), ND_5 **x** PO_1 (63.35), PO_1 x PO_3 (61.34), U-6 x ND_2 (61.25), U-6 x ND_5 (60.65), U-4 x ND_2 (60.19) and ND_2 x U-6 (60.11) emerged as potential hybrids, which can be exploited in the field at farmer's level for better prospects of bivoltine sericulture in the country.

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Improving Marketing Efficiency of Broiler for Small Production Units in Jammu and Kashmir State of India

Sudhakar Dwivedi, Morup Dolma and Pawan Kumar Sharma[1]
Division of Agricultural. Economics and Agribusiness Management, [1]Krishi Vigyan Kendra, Poonch-180 009, India
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India
E-mail: dwivedi.sudhakar@gmail.com

Abstract: A study on marketing of broiler by small production units in Jammu district of Jammu & Kashmir state was conducted by categorizing broiler growers into three sizes; growers with less than 500 birds, 501-1000 birds and more than 1000 birds. The data from 60 growers were collected by selecting randomly 20 growers from each category in the year 2014. Marketing channels for broiler were identified and various marketing parameters namely marketing cost, marketing margin, price spread and marketing efficiency were estimated. As the number of birds increases, growers switch from the channel producer-retailer-consumer to the channel producer- trader-retailer-consumer. The marketing efficiency was highest under the direct channel of producer-consumer, followed by channel producer to retailer to consumer and producer to trader to retailer to consumer. The channel producer to retailer to consumer was found to be more efficient and more feasible channel among the three identified marketing channels of broiler in and around Jammu city.

***Key Words*:** Broiler farms, Marketing channel, Marketing cost, Marketing efficiency

Broiler farming is an important source of income for a large number of marginal land holders in underdeveloped countries. Production and marketing of broiler also provides gainful employment to rural youths. An increase in per capita consumption by one egg and 50 grams of poultry meat can create employment for about 26,000 persons per year (Kazi, 2003). India's broiler production has shown a continuous growth and reached at 3900 thousand tonnes in 2014-15. Poultry population as per livestock census 2003 in the state of Jammu and Kashmir has been recorded as 55.68 lakhs in the state, out of which 29.71 lakhs are in Kashmir valley, with the per capita per month consumption of 1.7934 eggs and 0.0921 kg of poultry meat (Gandhi and Zhou, 2010). The state of Jammu & Kashmir and particularly, the Jammu district has favourable environment for broiler production. However, due to the marginal and small size of land holdings, the majority of the broiler production operating in the district is small in size, with capacity of birds ranging between 100 and 5000 at a particular point of time.

Marketing of broiler like any other agricultural enterprise is an important activity, as the marketing practices would determine the real returns from the whole business. The marketing of broilers however, has some distinct features; like deterioration in quality with every passing minute after the birds attain marketable weight. So, broiler marketing resembles with fruit marketing in the sense that both depreciate in their market value if not disposed off quickly. Due to the unique features of broiler's marketing, it is important to study the practices and marketing channels adopted by the growers and to determine the ways for efficient marketing practices for greater share of growers' in consumers' rupee. This is the reason that many studies have been conducted in the field of broiler's marketing in India and abroad (Bandara and Dassanayake, 2006; Shaikh and Zala, 2011; Sultana, 2012) for recommendation of better marketing channels and practices. This study on broiler's marketing has been conducted for small scale broiler units with the same objectives in Jammu district of Jammu and Kashmir State.

MATERIAL AND METHODS

The majority of broiler farms in Jammu district are have been existed in and around Jammu city. A list of such broiler farms was collected from state department of animal husbandry, which was then categorized into different categories:

I category	:	less than 500 birds
II category	:	501-1000 birds
III category	:	more than 1000 birds

Sixty broiler farms were randomly selected in total (20 from each category) in order to study the marketing practices and marketing channels for estimation of marketing cost, marketing margins and marketing efficiency in broiler's marketing. Besides, two big traders of Jammu city and ten retailers were also selected randomly for estimation of price spread in the marketing of broiler.

Marketing cost: The total cost, incurred on marketing either in cash or in kind by the producer – seller and by the various intermediaries involved in the sale and purchase of the commodity till the commodity reaches the ultimate consumer, was computed as under.

$$C = C_F + C_{m1} + Cm_2 + Cm_3 + ... + C_{mn}$$

Where, C = Total cost of marketing of the commodity, C_F = Cost paid by the producers/farm owners and C_{mi}= Cost incurred by the i^{th} middleman in the process of buying and selling the product.

Average gross margin method: $MT = Ó [(S_i-P_i)/q_i]$

Where, MT is the total marketing margin, S_i is the sale value of a product from the i^{th} firm, P_i is the purchase value paid by the i^{th} firm, Q_i is quantity of the product paid by the i^{th} firm.

Marketing margin of middleman: $A_{mi} = P_{ri} – (P_{pi}+C_{mi})$

Where, P_{ri} is the total value of receipts per unit (sale price), P_{pi} is the purchase value of good per unit (purchase price), C_{mi} is the cost incurred on marketing per unit

Price spread: It is the difference between the two prices, i.e., the price paid by the consumer and the price received by the producer.

$$\text{Price Spread} = P_1-P_2,$$

Where, P_1 is price at one level or stage in the market, P_2 is price at another level

Marketing efficiency: Marketing efficiency has been estimated as given by Acharya:

$$MME = FP/ (MC+MM)$$

Where, MME is modified measure of marketing efficiency, FP is price received by farmers, MC is marketing cost and MM is marketing margin

Producer share in consumer rupee: PS = (PF/PR)*100

Where, PF is price received by the farmer, PR is retail price (consumer price)

RESULTS AND DISCUSSION

Marketed surplus of broiler under different categories: Marketed surplus under different categories of growers after deducting the mortality, home consumption and kind payments was highest in third category due to the highest number of birds under this category. The per cent deduction in terms of home consumption and kind payments was highest in first category.

Marketing channels for broiler: The chain of various intermediaries/functionaries involved in the marketing process is known as marketing channel which generally comprises of agencies like producers, traders, retailers and consumers, etc. The most common marketing channels identified in broiler marketing in and around Jammu city are identified as producer to consumer; producer to retailer to consumer and producer to trader to retailer to consumer.

Frequency of marketing channels followed by broiler growers: In the first channel, it was found that either the consumer themselves went to broiler farms for buying from production point or producers went to the house of recognized consumers to sale the broilers. In case of first category maximum produce is sold through second channel (producer-retailer- consumer), where as in case of second and third category more than 70 per cent of produce was sold through third marketing channel (Producer-Trader-Retailer-Consumer).

Birds, quantity and value disposed under different channels: The producers belong to first category disposed majority of their produce through second channel, and also received more value under this channel (Table 2).

Marketing cost, marketing margins and price spread: The per quintal total cost of marketing of broiler came to be Rs. 150.00, Rs. 293.30 and Rs. 260.50 in channel first, channel second and channel third respectively (Table 3). The producers' share in consumers' rupee was found to be highest in channel 'I' (98.51%), followed by channel 'II' (83.05%) and channel 'III' (82.24%).

Marketing efficiency of different channels: The marketing efficiency was highest under channel 'I' which is the direct

Table 1. Marketed surplus and channels followed under different categories

Broiler farms	Production and surplus			Channels				
	Total production after mortality (q)	Home consumption (q)	Kind payments & Gift (q)	Marketed surplus (q)	Producer to consumer (I)	Producer to retailer to consumer (II)	Producer to Trader to retailer to consumer (III)	Total
<500 birds	113.20 (100.00)	0.25 (0.22)	0.15 (0.13)	112.80 (99.65)	7.00 (35.00)	9.00 (45.00)	4.00 (20.00)	20.00 (100.00)
501-1000 birds	231.04 (100.00)	0.30 (0.12)	0.20 (0.08)	230.54 (99.80)	0.00 (0.00)	5.00 (25.00)	15.00 (75.00)	20.00 (100.00)
>1000 birds	651.40 (100.00)	0.45 (0.06)	0.30 (0.04)	650.65 (99.90)	0.00 (0.00)	3.00 (15.00)	17.00 (85.00)	20.00 (100.00)

Figures in parentheses indicate percentage

Table 2. Number of birds, quantity and value of broiler produced and disposed (Rs. in lakh)

Particulars	Category I	Category II	Category III	Total
		Producer to Consumer (I)		
Birds (No.)	2550	00	00	2550
Quantity (q)	31.64	00	00	31.64
Value (Rs.)	3.21	00	00	3.21
		Producer to Retailer to Consumer (II)		
Birds (No.)	4500	4100	6000	14600
Quantity (q)	56.40	48.87	72.80	178.06
Value (Rs.)	5.27	4.48	6.70	16.45
		Producer to Trader to Retailer to Consumer (III)		
Birds (No.)	2000	15000	46500	63500
Quantity (q)	25.18	182.17	578.60	3249.77
Value (Rs.)	2.28	16.44	52.89	71.61
		Overall		
Birds (No.)	9050	19100	52500	80650
Quantity (q)	113.20	231.04	651.40	3643.06
Value (Rs.)	10.76	20.92	59.59	90.72

Table 3. Marketing cost, marketing margin and price spread of broiler

Particulars		Channel I Rs q^{-1}	Channel II Rs q^{-1}	Channel III Rs. q^{-1}
Marketing cost				
Producer's marketing expenditure		150.50	212.80	0.00
Trader's marketing expenditure		-	-	180.20
Retailer's marketing expenditure		-	80.50	80.30
Total cost of marketing		150.50	293.30	260.50
Selling price				
	Producer	10152.00	9348.94	9046.67
	Trader	-	-	9530.00
	Retailer	-	11000	11000
Producers' share in consumers' rupee		98.51	83.05	82.24
Absolute Marketing margin				
	Trader	0.00	0.00	303.13
	Retailer	0.00	1570.56	1389.70
	Total	0.00	1570.56	1692.83
Percentage marketing margin				
	Trader	0.00	0.00	2.75
	Retailer	0.00	14.27	12.63
	Total	0.00	14.27	15.38
Percentage marketing cost				
	Producer	1.48	1.93	0.00
	Trader	0.00	0.73	1.63
	Retailer	0.00	2.66	0.73
	Total	1.48	5.32	2.36

channel of producer to consumer (Table 4). Under channel 'II' which includes producer to retailer to consumer was estimated to be 4.90 and in channel 'III' i.e. producer to trader to retailer to consumer was 4.63. Thus, channel 'II' was more efficient and feasible marketing channel among the three identified for marketing. Under channel 'II', producers have to search for different retail outlets to sale their entire produce under this channel. The channel 'I' has highest marketing efficiency due to the absence of any middlemen, however practically adopting this channel is impossible for large amount of produce, especially for broiler which cannot be sold in bulk to an individual consumer. The second channel was found to be more efficient and more feasible channel among the three identified for marketing of broilers in and around Jammu city.

Table 4. Marketing efficiency of different channels

Particulars	Channel I Rs.	Channel II Rs.	Channel III Rs.
Producers' price	10152.02	11000.00	11000.00
Net price received by producers	10001.52	9136.14	9046.67
Net marketing margin	0.00	1570.56	1692.83
Marketing cost	150.50	293.30	260.50
Total marketing cost and margin	150.50	1863.86	1953.33
Marketing efficiency	66.45	4.90	4.63

CONCLUSION

Three main marketing channels for broiler namely; producers to consumer; producers to retailer to consumer; and producer to trader to retailer to consumer are prevalent in the system. The total cost of marketing was highest in channel second. Absolute marketing margin was highest in channel third due to presence of more middlemen in that channel. The producer's share in consumer's rupee was highest in channel first, which was due to the absence of any middlemen and also because of high selling price. The first channel is however not seen prevalent for higher quantity of sale. The second channel was found to be more efficient and more feasible channel among the three identified for marketing of broilers in and around Jammu city.

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Evaluation of Organic And Integrated Nutrient Management on Productivity, Economics and Soil Health in Soybean (*Glycine max*) Onion (*Allium cepa)* Cropping Sequence

W. N. Narkhede and R. N. Khandare
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani-431 402, India
E-mail: wasudev1510@yahoo.co.in

Abstract: A Field experiment was conducted for six successive years (2007 to 2012) to study the evaluation of organic, inorganic and integrated nutrient management on yield, economics and soil health in soybean- onion cropping sequence for central plateau zone of Maharashtra, India. The experiment was comprised of seven different nutrient treatments, five of them having use of organic sources and one each having 100% fertilizer and integrated nutrient management (50% through organic and 50% inorganic). The soybean grain yield (2.66 t ha^{-1}), onion bulb yield (23.5 t ha^{-1}), soybean equivalent yield (10.0 t ha^{-1}), system productivity (26.16 t ha-1), per day productivity (109 kg ha^{-1} day^{-1}) and the value for sustainable yield index (0.64) in soybean-onion cropping sequence were highest in application of 100% NPK recommended dose followed by 50% NPK recommended dose combined with 50% N through FYM as compared with other treatments. In organic treatment application of 1/3 N each through FYM, Vermicompost, neem cake with bio-fertilizer containing N and P carriers recorded soybean grain yield (2.14 t ha^{-1}), onion bulb yield (17.5 t ha^{-1}), soybean equivalent yield (7.66 t ha^{-1}), system productivity (19.64 t ha^{-1}), per day productivity (81.83 kg ha^{-1} day^{-1}) and the value for sustainable yield index was 0.54 .The mean maximum net monetary returns (Rs. 144.4 x 10^3 ha-1), B: C ratio (3.06) over six years were recorded in 100% recommended dose of fertilizer with secondary and micronutrients based on the soil test ($ZnSo_4$ 10 kg + S 25 kg ha^{-1}) and organic application of 1/3 N each through FYM, Vermicompost, Neem cake with bio fertilizer containing N and P carriers recorded the mean net monetary returns of Rs. 86.6 x 10^3 ha^{-1} and B:C ratio of 1.44. The organic production system not responded the productivity level to the level inorganic and INM treatment. The integrated nutrient management with 50 % recommended dose + 50% N through FYM recorded the mean net monetary return of Rs. 127.6 10^3 ha^{-1} and B:C ratio 3.03 . Application of 1/3 N through each FYM, Vermicompost, neem cake with biofertilizer containing N and P carriers recorded higher bacterial (21.42 x10^{-6} cfu g^{-1} soil), fungal (23.17 x10^{-3} cfu g^{-1} soil) and actinomycetes (18.25x10^{-4} cfu g^{-1} soil) counts than rest of the organic, inorganic and integrated nutrient management practices.

Key Words **:** Chemical fertilizers, Economics, Farm yard manure, Integrated nutrient, Neem cake, Onion, Organic farming, Soybean, Soil fertility, Vermicompost

Soybean is basically a pulse crop but it gaining importance as an oilseed crop. It is leguminous crop, it helps in fixing atmospheric nitrogen in soil and keep about 30-40 kg nitrogen ha^{-1} for succeeding crop and improve soil fertility and productivity. Besides this it can very well fit in different cropping systems under rain fed and irrigated farming (Gangwar and Ram, 2005)

Onion (*Allium cepa* L.) is one of the leading vegetable crops and it's grown for culinary purpose and medicinal values. Inclusion of vegetables in soybean based cropping system improved the soybean equivalent yield, profitability and provides regular income to the farmers.

The continuous and more excessive use of inorganic fertilizer alone year after year not only polluted the ground water and environment but also declined soil fertility and productivity. The production system developed and adopted during green revolution were explorative and the natural resources like soil and water were subjected to immense pressure beyond carryings capacity. The continuous and imbalanced fertilization also deteriorate the soil health under such situation use of organic sources of nutrients as well as integrated nutrient practices which helps for maintaining soil health and sustaining the productivity of the cropping system. Bio-fertilizers being natural products, eco friendly in nature, assume great significance in organic farming for improves soil health. Use of organic nutrient sources like FYM, Vermicompost, neem cake, bio- fertilizers provide nutrients for the improvement of soil health and also provides nutritious food to consumer for better diet. In view of this, an investigation was planned to study the evaluation of organic, inorganic, integrated nutrient management on productivity ,economics and soil health in soybean(*Glycine max L.*) – onion(*Allium cepa L.*) cropping sequence for central plateau zone of Maharashtra.

MATERIAL AND METHODS

A field experiments were as conducted during 2007-08 to 2012-13 at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, India. Parbhani located at 19°16' N latitude and 96° 41' East longitudes and has sub – tropical climatic conditions and is grouped under assured rainfall zone. The normal rainfall of this region is around 954.9 mm, precipitating mostly between mid June–mid Novembers. The total amount of average rainfall received 673.2 mm from June to March during the experimentation. The average maximum and minimum temperature was 31.2° and 22.6°C, respectively. The soil was clayey in texture, low in nitrogen (143.5 Kg ha^{-1}), medium in phosphorus (11.5 Kg ha^{-1}), rich in potash (340.5 Kg ha^{-1}), low in organic carbon content 0.52% and the soil pH 7.6. The available nitrogen, phosphorus and potassium in soil were estimated by using standard methods. The microbial population in soil was estimated by serial dilution pour plate method by Wollum (1982). The experiment was laid out in randomized block design during *kharif* and *rabi* season with seven treatments and three replications (Table 1). The soybean variety used was cv. MAUS-71 and for onion variety Agri find light red (AFLR). The gross and net plot sizes were 9.00 m x 6. 30 m and 7.20 m x 4.50 m, respectively. The soybean was sown at a spacing of 45 cm x 5 cm during *kharif* season and onion was planted at a spacing of 15 cm x 10 cm during *rabi* season. The recommended dose for soybean was 30:60:30 NPK kg ha^{-1} and for onion was 100:50:50 NPK kg ha^{-1}. Full dose of NPK was applied as a basal dose in both seasons. The micronutrient was applied inorganic treatment with $ZnSo_4$ 10 kg ha^{-1} and S 25 kg ha^{-1} in *kharif* and *rabi* season. The onion seed was firstly planted in nursery with seed treatment of carbendizum 50% wettable powder @1 g kg^{-1} of the seed and after age of 45 days was transplanted into main field. The soybean seed and onion seedlings were inoculated with *Rhizobium* + phosphorus solubilizing bacteria before sowing. Due to yearly variation in price of crops, the cost of cultivation and net return was calculated by taking mean price of six year of respective crops. The soybean grain equivalent yield was calculated as under

$$\text{Soybean equivalent yield (t ha}^{-1}\text{)} = \frac{\text{Bulb yield of onion (t ha}^{-1}\text{) x Market rate of onion (Rs t}^{-1}\text{)}}{\text{Market rate of soybean (Rs t}^{-1}\text{)}}$$

The sustainability is expressed as a sustainable yield index (SYI) was calculated as below.

$$\text{Sustainable yield index} = \frac{\text{Average yield - SD}}{\text{Maximum yield}}$$

Profitability in ha day^{-1} was worked out by dividing the average net return over the year by 365.

RESULTS AND DISCUSSION

Productivity of soybean and onion: The soybean grain and onion bulb yield was significantly influenced by different organic, inorganic and INM treatments up to six year of experimentation (Table 2). The maximum soybean grain yield (2.66 t ha^{-1}) and onion bulb yield (23.5 t ha^{-1}) was in 100% RDF with secondary and micronutrients based on the soil test ($ZnSo_4$ 10 kg + S 25 kg ha^{-1}) and was significantly superior over all the treatments and at par with 50% RDF combined with 50% N applied through FYM and inorganic sources of micronutrients as per soil test. In organic treatment with 1/3 N supplied through each from FYM, Vermicompost and neem cake along with biofertilizer recorded the soybean grain yield (2.14 t ha^{-1}) and onion bulb yield (17.5 t ha^{-1}), which is higher over the rest of the organic treatments. This might be due to greater availability of nutrient in soil, which improved soil environment and higher root development leading to better absorption of moisture and nutrient.

Table 1. Microbial population as influenced by organic, inorganic and INM treatments after six years experimentation

Treatments	Bacterial count x 10^{-6} Cfu g^{-1} soil	Fungal count x 10^{-3} cfu g^{-1} soil	Actinomycetes x 10^{-4} cfu g^{-1} soil
T_1**:** 50% RDF + 50% N through FYM + inorganic sources of micronutrients as per soil test	20.60	18.16	18.25
T_2: Different organic sources each equivalent to 1/3 of recommended nitrogen (FYM + VC + NC)	19.40	15.17	17.45
T_3: T_2 + intercropping of trap crop (*Kharif*-Maize, *Rabi*-Garlic)	19.13	18.16	17.85
T_4: T_2+Agronomic practices for weed and pest control (Organic),	20.15	19.12	16.15
T_5: 50 % N as FYM/other organic sources+ bio fertilizer for N + RP to substitute the P requirement of crops + PSB	17.60	20.15	12.15
T_6: T_2 + bio fertilizer containing N and P carriers	21.42	23.17	18.25
T_7: 100% NPK+ secondary and micronutrient based on the soil test ($ZnSo_4$ 10 kg + S 25 Kg ha^{-1})	17.60	13.52	12.13
CD (p=0.05)	4.63	4.54	4.52

Table 2. Impact of soybean- onion cropping sequence on productivity and profitability (pooled data of six years)

Treatment	Soybean grain yield (t ha^{-1})	Onion bulb yield (t ha^{-1})	SEY (t ha^{-1})	Total System productivity (t ha^{-1})	Productivity (kg ha^{-1} day^{-1})	Profitability (Rs. ha^{-1} day^{-1})	GMR of the sequence (Rs. 10^{3} ha^{-1})	NMR of the sequence (Rs. 10^{3} ha^{-1})	B:C Ratio	SYI	Bulk density Mg m^{-3}
T_1	2.28	21.0	8.85	23.28	97.0	349.6	169.8	127.6	3.03	0.64	1.28
T_2	1.81	15.4	6.65	17.21	71.70	191.2	127.1	69.8	1.23	0.45	1.22
T_3	1.82	16.1	6.89	17.92	74.66	197.5	132.1	72.1	1.20	0.47	1.21
T_4	2.12	16.8	7.15	18.92	78.88	216.4	141.5	79.0	1.27	0.49	1.17
T_5	1.64	14.0	6.02	15.64	65.16	181.4	115.3	66.2	1.38	0.39	1.16
T_6	2.14	17.5	7.66	19.64	81.83	237.3	146.8	86.6	1.44	0.54	1.15
T_7	2.66	23.5	10.0	26.16	109.00	395.6	192.3	144.4	3.06	0.74	1.23
CD (p=0.05)	0.3	1.0	0.5	0.67		-	9.81	9.81		0.61	N.S.

SEY- Soybean equivalent yield, GMR- Gross monetary returns, NMR- Net monetary returns t- ton. For treatment details see Table1

Table 3. Soil fertility status after completion of soybean-onion cropping sequence

Treat ment	N (kg ha^{-1})							P (kg ha^{-1})							K (kg ha^{-1})						
	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	Mean	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	Mean	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	Mean
T_1	151.9	160.3	174.2	177.5	182.5	178.7	170.9	13.0	13.6	12.3	12.6	13.2	13.6	13.1	335.2	349.6	351.0	358.4	362.4	365.2	353.6
T_2	147.6	151.5	154.1	162.5	168.7	170.8	159.2	11.2	11.5	11.8	12.4	12.9	13.0	12.1	331.1	337.6	330.5	335.6	342.5	345.3	337.1
T_3	142.7	145.6	134.8	138.5	148.6	150.7	143.5	11.0	11.5	11.9	12.6	12.7	12.9	12.1	327.3	323.6	330.1	342.5	348.7	350.8	337.2
T_4	140.8	144.7	148.6	152.7	155.6	158.8	150.2	11.0	11.3	11.7	12.5	13.1	13.3	12.2	331.9	335.4	345.8	347.8	356.4	360.5	346.3
T_5	143.2	146.5	154.6	161.8	162.8	165.9	155.8	11.5	12.0	12.2	12.9	12.7	12.8	12.4	326.8	333.2	352.5	357.5	356.4	360.3	347.8
T_6	150.6	155.5	160.2	165.4	172.8	176.6	163.5	12.1	12.6	13.0	12.8	13.4	13.5	12.9	320.8	323.2	330.5	342.7	352.4	362.6	338.7
T_7	159.1	165.3	170.4	175.4	170.8	180.8	170.3	13.2	13.5	13.8	13.5	13.9	14.0	13.7	347.1	354.3	360.4	365.8	364.7	366.2	359.8
Initial reading				143.5							11.5							340.5			

For treatment details see Table1

Soybean equivalent yield: The highest soybean grain equivalent yield (7.66 t ha^{-1}) with the application of recommended 1/3 N each through FYM, Vermicompost and neem cake which was significantly superior over rest of the organic treatments except treatment T_4 (Table 2). The lowest soybean grain equivalent yield recorded in 50% N applied through FYM + rock phosphate. Yadav *et al.* (2013) reported that rice- potato- onion system recorded significantly higher rice equivalent yield and production efficiency with 100% recommended dose of nitrogen through organic manure (1/3 FYM + 1/3 vermicompost + 1/3 poultry manure) + bio fertilizer (*Azotobactor* + phosphorus solubilizing bacteria). The inorganic treatment with 100% RDF + micronutrient based on soil test recorded highest soybean grain equivalent yield (10.0 t ha^{-1}) which was significantly superior over the integrated nutrient management with 50 % RDF + 50% N applied through FYM. and nutrient supplied through organic sources. In organic sources the soybean equivalent yield decrease by 13.44% over the integrated nutrient management treatment and 23.40% over the inorganic sources of application of nutrients. Similar, findings were also observed by Jagdish *et al.* (1998) the combined application of FYM @ 15 t ha^{-1} + PSB inoculation recorded higher yield of soybean.

Total system productivity: The highest system productivity was recorded in inorganic treatment than compared to all other treatment having organic and INM package (Table 2). The 100% RDF with secondary and micronutrients based on the soil test ($ZnSo_4$ 10 kg + S 25 kg ha^{-1}) recorded significantly the highest system productivity (26.16 t ha^{-1}) than organic treatment and at par with 50% RDF applied with 50% N through FYM and inorganic sources of micronutrients as per soil test (23.28 t ha^{-1}). In organic treatment of 1/3 N applied each through FYM, Vermicompost and neem cake recorded highest system productivity (19.64 t ha^{-1}) than rest of the organic treatments. In organic sources the system productivity was decreased by 15.27% and 24.92% over the integrated nutrient management treatment and inorganic sources of application of nutrients, respectively. These findings are in close agreement with Jagdish *et al.* (1998).

Economics : The mean net monetary returns (Rs. 144.4 x 10^3 ha^{-1}) and B: C ratio (3.06) were maximum in 100% RDF with secondary and micronutrients based on the soil test ($ZnSo_4$ 10 kg + S 25 kg ha^{-1}) followed by 50% RDF combined with 50% N through FYM and inorganic sources of micronutrients (Table 2). Soybean based cropping sequence provided high monetary benefit, Bhatia (1995) and Tumbare (2002). In organic treatment application of 1/3 N through each FYM, Vermicompost, neem cake with bio fertilizer containing N and P carriers recorded the mean net monetary returns of Rs. 86.6 x 10^3 ha^{-1}. The cost of production of soybean-onion cropping sequence was higher under organic treatment than inorganic treatment due to higher cost of organic seed, sources of nutrient, manures and higher labour charges for weed management under organic farming except the cost for pest management. These results are in close conformity with Aulakh *et al.* (2013).

Sustainability: Result on sustainability (Table 2) revealed application of 100% RDF with secondary and micronutrients based on the soil test ($ZnSo_4$ 10 kg + S 25 kg ha^{-1}) recorded the value 0.74 of sustainable yield index, followed by 0.64 recorded in 50% NPK recommended dose combined with 50% N through FYM and inorganic sources of micronutrients as per soil test. In organic sources application of 1/3 N through each FYM, Vermicompost, neem cake with biofertilizer containing N and P carriers recorded the sustainable value 0.54. These results are conformity with Chitale *et al.* (2015) and reported that the rice -onion cropping system the sustainability was higher in application of 100% RDF through inorganic fertilizer (0.79) followed by 100% organic N through cow dung +neem cake +composted straw residue (0.77) and 50 % RDF +50% N through FYM (0.76).

Nutrient studies: The highest soil available N, P and K was recorded in 100% RDF with secondary and micronutrients based on the soil test ($ZnSo_4$ 10 kg + S 25 kg ha^{-1}) followed by 50% NPK recommended dose combined with 50% N through FYM and inorganic sources of micronutrients as per soil test. Datt *et al.* (2003) reported that the beneficial effect of organic manures on yield might be due to additional supply of plant nutrients as well as improvement in physical, chemical and biological properties of soil. The application of 1/3 N each through FYM, Vermicompost, neem cake with bio fertilizer containing N and P carriers was best for higher soil nutrient availability and good built of soil health . Similarly, Yadav *et al.* (2013) reported that application of organic manure along with biofertilizers improved the soil status with respect of soil organic carbon and available NPK , this might be due to higher microbial activity in organic treatments which favour the conversion of organic bound nitrogen to inorganic form

Soil health: The 100% RDF with sulphur and zinc recorded the higher NPK balance after the harvest of onion-soybean sequence cropping. The fertility status of soil in inorganic and INM package had the positive gain of nutrient as indicated by NPK content of soil. Similarly, 1/3 N applied each through FYM, Vermicompost and neem cake recorded the positive balance of NPK content in soil but it was less compared to inorganic and INM package. The fertility of soil was improved

Table 4. Balance sheet of organic carbon (%) and available NPK (kg ha^{-1}) influenced by addition of nutrient through organic and inorganic sources under soybean – onion crop sequence

Treatment	Organic carbon (%)			N (kg ha^{-1})				P (kg ha^{-1})				K (kg ha^{-1})			
	Initial	Final	Net gain (+) loss (-)	Removed	Initial Status	Final	Net gain (+) loss (-)	Removed	Initial status	Final	Net gain (+) loss (-)	Removed	Initial status	Final	Net gain (+) loss (-)
T1	0.52	0.97	+ 0.44	317	143.5	170.9	+27.4	75	11.5	13.1	+1.6	96	340.5	353.6	+13.1
T2	0.52	0.65	+0.13	247	143.5	159.2	+15.7	58	11.5	12.1	+0.6	74	340.5	345.6	+5.1
T-3	0.52	0.70	+0.17	248	143.5	143.5	0	59	11.5	12.1	+0.6	74	340.5	344.7	+4.2
T-4	0.5	0.55	+0.02	275	143.5	150.2	+6.7	63	11.5	12.2	+0.7	77	340.5	346.3	+5.8
T-5	0.52	0.65	+0.13	248	143.5	155.8	+12.3	54	11.5	12.4	+0.9	69	340.5	347.8	+7.3
T-6	0.52	0.67	+0.11	296	143.5	163.5	+20.0	66	11.5	12.9	+1.4	85	340.5	352.4	+11.9
T-7	0.52	0.95	+0.43	325	143.5	170.3	+26.8	82	11.5	13.7	+2.2	11	340.5	359.8	19.3

For treatment details see Table1
Recommended dose for Soybean- 30:60:30 and for Onion- 100:50:50 Total Nutrient added N-130 Kg, P-110 Kg, K-80 Kg ha^{-1}

by application inorganic, INM package and in organic the fertility of soil was maintained. The significant variations was not observed in bulk density among the different treatments .

Microbial population: The microbial population of bacterial, fungal and actinomycetes count showed significant variations due to in different treatments (Table 1).Treatment 1/3 N through each FYM, Vermicompost, neem cake with biofertilizer containing N and P carriers recorded higher bacterial (21.42 x10^{-6} cfu g^{-1} soil), fungal (23.17 x10^{-3} cfu g^{-1} soil) and actinomycetes (18.25x10^{-4} cfu g^{-1} soil) counts than rest of the organic, chemical and integrated nutrient management practices. This might be due to better survival and secretions of organic acids through different parts of the plants. These results are in close agreement with Nath *et al.* (2011) and Singh *et al.* (2011).

Thus, it is concluded from the six years study on soybean-onion cropping sequence that the application of 100% RDF along with sulphur and zinc (25 kg sulphur and 10 kg of zinc ha^{-1}) recorded highest soybean grain equivalent yield (10.0 t ha^{-1}), NMR (Rs. 144.4 x10^{3} ha^{-1}) and B:C ratio (3.06) followed by integrated nutrient management with 50% RDF + 50% N through FYM +10 kg zinc and 25 kg of sulphur ha^{-1} recorded the soybean equivalent yield 8.85 t ha^{-1}, NMR (Rs. 127.6 x10^{3} ha^{-1}) and B:C ratio (3.03).

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Effect of Foliar Application of Mineral Nutrients on Anatomical Changes and Hydrolytic Enzymes Activities in Pedicel of Pigeonpea (*Cajanus cajan* L.)

Gagandeep Kaur and Navita Ghai
Department of Botany, Punjab Agricultural University, Ludhiana-141 004, India
E-mail: gkdhaliwal123@gmail.com

***Abstract*:** Mineral nutrients *viz*., $CaCl_2$ (0.01% and 0.02%), KNO_3 (0.5% and 1%), $MgCl_2$ (0.1% and 0.2%) and urea (1% and 2%) were applied as foliar application to pigeonpea varieties (PAU881 and AL201) at green floral bud stage of inflorescence to study their effect on anatomical changes and activities of hydrolytic enzymes in pedicel. Then, the data was correlated with rate of flower abscission. The mineral nutrients enhanced the area of translocatory tissues (xylem and phloem) in pedicel which increased the translocation of assimilates from source to sink tissues and maximum enhancement was noticed with potassium treatments followed by urea treatments. These nutrients application also declined the activities of hydrolytic enzymes *viz*., cellulase and polygalacturonase (PG) in pedicel of treated plants. Correlation matrix data showed that rate of flower abscission was significantly and negatively correlated with the amount of phloem and xylem tissue. However, cellulase and PG activities showed positive correlation with flower abscission. Foliar application of mineral nutrients in our study showed that activities of cell wall degrading enzymes declined in treated plants while, translocatory tissues area increased which ultimately reduced flower abscission in pigeonpea, thereby improving its yield.

***Key Words*:** Flower abscission, Hydrolytic enzymes, Mineral nutrients, Pigeonpea, Pedicel anatomy

Legumes are considered the most important source of food after cereals in the world, as they are main sources of protein and energy for humans (Salih, 2013). Among the legumes, pigeonpea (*Cajanus cajan* L.) is grown extensively but its yield remains low due to high level of flower/fruit abscission (70-96%) leading to a much-reduced realization of sink potential (Tekale *et al.,* 2009). So, it is very necessary to compensate the high degree of flower abscission and increase the pod yield. Nutrients play a pivotal role in increasing the seed yield in pulses (Chandrasekhar and Bangarusamy, 2003). The low availability of mineral elements leads to the abscission of flower buds, flowers and pods. Mineral elements associated with abscission are nitrogen, phosphorous, potassium, sulphur, calcium, magnesium, zinc and iron. Generally, a balanced supply of nutrients is essential for optimum yield and fruit quality (Akhtar *et al.,* 2010). During the phase of abscission, the synthesis of hydrolytic enzymes dissolving polysaccharides of the cell wall mainly cellulases and polygalacturonase are activated. These enzymes dissolve the middle lamella and also the cell walls and the cohesion of cells is weakened (Wouter and Anthony, 1997). Pedicel is responsible for the translocation of substances from source tissues to the developing fruits through vascular tissues (xylem and phloem). So if various mineral nutrients are supplied exogenously they may help in flower retention. The present investigation was, thus planned to study the effect of nutrients on the activity of hydrolytic enzymes and anatomical changes in vascular tissues of flower pedicel in pigeonpea.

MATERIAL AND METHODS

This experiment was conducted in Punjab Agricultural University, Ludhiana during *Kharif* season of 2012-13 and 2013-14. The soil was sandy loam in texture with 318.7 kg ha^{-1} of N, 268 kg ha^{-1} of K, 1.6 meq l^{-1} of Ca and 1.0 meq l^{-1} of Mg. The experiment consisting of two pigeonpea varieties (PAU 881 and AL 201) and eight treatments in a randomized block design with three replications. The treatments were, control (water), 0.01% $CaCl_2$, 0.02% $CaCl_2$, 0.5% KNO_3, 1% KNO_3, 0.1% $MgCl_2$, 0.2% $MgCl_2$, 1% urea and 2% urea and these were applied as foliar spray at green floral bud stage of inflorescence followed by another spray after two days. Anatomical changes and enzyme activities in pedicel were observed after ten days of foliar treatments. For anatomical studies, flower pedicels were stored in FAA (formalin-acetic acid -alcohol) solution (Sass, 1958) and then sections (10 µm thickness) were cut using rotary microtome following the procedure described by Jensen (1962). The sections were stained with erythrosine and crystal violet stain and observed under Leica Bright Field Research Microscope fitted with digital camera and computer imaging systems using software NIS Elements F 3.0 at 10X. Enzymes *viz*., cellulase and PG were extracted from fresh flower pedicel with 0.1M sodium acetate buffer (pH 5.2) at 4^0C and estimated by the method given by Malik and

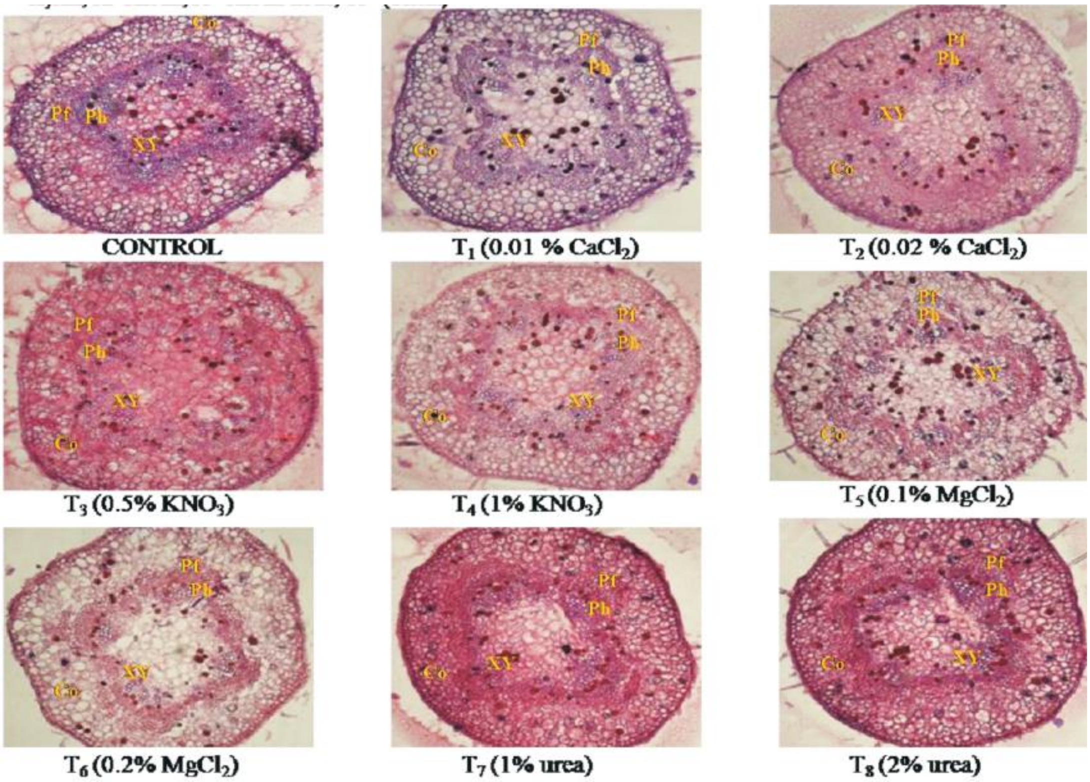

Fig. 1. Effect of various mineral nutrients application on anatomical changes in flower pedicel of the pigeonpea variety PAU 881 (XY=Xylem, Ph=Phloem, Pf=Phloem fibers, Co= (Cortex)

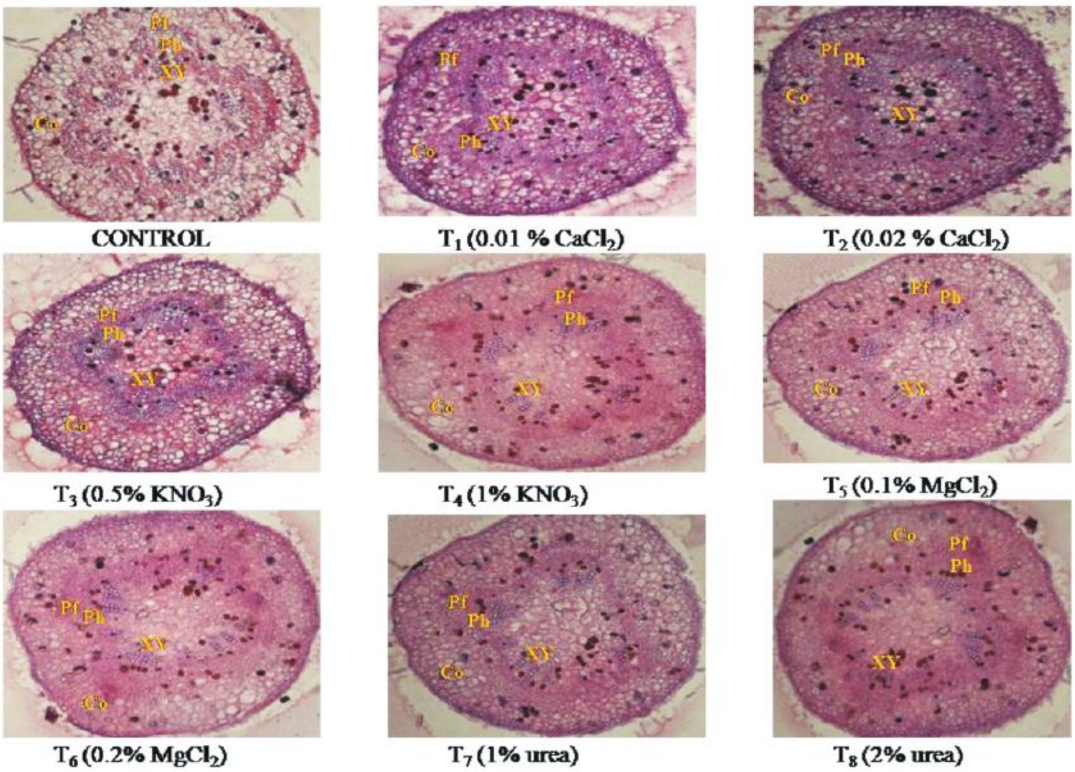

Fig. 1. Effect of various mineral nutrients application on anatomical changes in flower pedicel of the pigeonpea variety AL 201 (XY=Xylem, Ph=Phloem, Pf=Phloem fibers, Co= (Cortex)

Singh (1980). Rate of flower abscission was estimated as described by Fakir *et al.* (1998).

RESULTS AND DISCUSSION

Anatomical changes in pedicel: Maximum amount of phloem tissue was observed in 1 % KNO_3 treated plants followed by 0.5 % KNO_3 and 2 % urea in PAU881 and AL20. In PAU881, maximum amount of xylem tissue was observed in 0.2 % $MgCl_2$ (1.32 cm) treated plants followed by 0.5 % KNO_3 (1.28 cm), 0.1 % $MgCl_2$ (1.27 cm) and 1 % urea (1.20 cm) treated plants while, in AL201, it was maximum with 1 % KNO_3 (2.18 cm) application followed by 0.5 % KNO_3 , 0.1 % $MgCl_2$, 0.2 % $MgCl_2$ and 2 % urea application.

Most of the material on which fruit growth depends, is transported from the stem to fruit through the fruit pedicel, by xylem and phloem (Matthews and Shackel, 2005). Larger phloem area can provide greater assimilate inflow into fruits and faster fruit growth (Zhang *et al.,* 2005). In our study, there was increase in phloem area following mineral nutrients application. Similarly, Rancic *et al.* (2010) also reported enhanced fruit development as a result of increased phloem area of tomato pedicel. Increase in xylem area might be providing mechanical support to developing fruits as reported by Zhang *et al.* (2005). The increase in amount of tissues involved in translocation increased the translocation of assimilates to flower, ultimately causing reduction in flower abscission. Our results are concurrent with the findings of Guan et al. (2005) where authors reported that the weight of apple fruitlet can be significantly and positively correlated with Ca, Mg and K uptake, pedicel diameter, number of vascular bundles and phloem and xylem area of pedicel.

Enzyme activities: Cellulase and PG are the main enzymes engaged in the abscission (del-Campillo *et al.,* 1990; Fang Qi *et al.,* 2014) and our study revealed a decline in activities of these enzymes in the pedicel following various mineral nutrient treatments (Table 2). Although this decline in enzyme activities was non-significant as compared to controls but maximum decline in cellulase activity was observed with 2% urea treatment which was 72.31 (PAU881) and 47.73 (AL201) per cent over the controls followed by 1 % urea application in PAU881 and AL201. Cellulase activity was the highest in pedicel of control plants which was 16.60 (PAU881) and 14.13 (AL201) µg D-glucose released g^{-1} FW min^{-1}. Amongst the treatments maximum decline in PG activity was with 2 % urea application and it was 13.07 (PAU881) and 13.65 % (AL201) less than their respective controls. This reduction in enzyme activity might be due to the formation of more cell wall material in response to mineral nutrients, which could be inhibiting the formation of

Table 1. Effect of foliar application of various mineral nutrients on anatomy of flower pedicel in pigeonpea varieties

Treatments		Diameter (cm)		Cortex (cm)		Phloem fiber (cm)		Phloem (cm)		Xylem (cm)	
		PAU 881	AL 201	PAU 881	AL 201	PAU 881	AL 201	PAU 881	AL 201	PAU 881	AL 201
$CaCl_2$	0.01 %	23.69±0.63	29.54±2.02	4.68±0.37	7.88±0.50	1.18±0.06	1.19±0.24	0.77±0.05	1.44±0.10	1.11±0.04	1.39±0.15
	0.02 %	24.25±0.85	30.87±1.97	4.87±0.40	7.21±0.53	1.20±0.07	1.34±0.23	0.71±0.10	1.46±0.10	1.14±0.04	1.58±0.14
KNO_3	0.5 %	26.42±0.94	38.20±1.98	5.20±0.66	7.06±0.55	1.35±0.07	1.96±0.23	0.88±0.14	1.91±0.09	1.28±0.05	2.13±0.14
	1 %	26.51±1.21	39.00±1.87	4.99±0.73	9.84±0.55	1.44±0.07	2.57±0.25	0.97±0.17	1.84±0.08	1.17±0.08	2.18±0.13
$MgCl_2$	0.1 %	25.54±2.41	30.09±1.02	3.91±0.74	7.21±0.22	1.50±0.16	1.56±0.02	0.85±0.24	1.48±0.05	1.27±0.18	1.77±0.04
	0.2 %	26.38±2.98	33.87±0.79	5.78±0.88	8.20±0.15	1.30±0.28	1.57±0.03	0.72±0.26	1.52±0.04	1.32±0.23	1.64±0.01
Urea	1 %	24.81±2.83	31.20±0.89	4.66±0.85	7.62±0.10	1.23±0.28	1.47±0.01	0.73±0.23	1.68±0.02	1.20±0.23	1.62±0.01
	2%	26.50±2.48	33.86±0.04	5.99±0.70	7.91±0.09	1.32±0.27	1.51±0.01	0.88±0.18	1.72±0.01	1.17±0.22	1.63±0.01
Control		23.69±0.68	29.35±2.04	4.26±0.37	5.99±0.58	0.91±0.09	1.08±0.25	0.71±0.05	1.24±0.12	0.99±0.05	1.13±0.18

Table 2. Effect of various mineral nutrients on the rate of flower abscission and activities of hydrolytic enzymes in pedicel of pigeonpea varieties

Treatments		Cellulase activity (µg D-glucose released g^{-1} FW min^{-1})		Polygalaturonase activity (µg D-galacturonic acid released g^{-1}FW min^{-1})		Rate of flower abscission (%)	
		PAU 881	AL 201	PAU 881	AL 201	PAU 881	AL 201
$CaCl_2$	0.01 %	10.17±1.67	10.00±0.88	17.23±2.19	16.63±0.43	87.67±1.04	85.43±12.13
	0.02 %	10.50±1.72	10.67±0.66	16.63±2.24	15.77±0.39	87.42±1.02	85.12±12.17
KNO_3	0.5 %	13.17±1.78	11.90±0.68	16.93±2.30	15.63±0.37	87.18±12.15	84.08±12.22
	1 %	12.53±1.79	9.93±0.74	16.50±2.35	15.13±0.40	86.91±12.19	83.23±12.62
$MgCl_2$	0.1 %	11.40±1.82	10.67±0.77	16.37±2.43	16.80±0.44	87.41±12.19	85.32±13.07
	0.2 %	11.03±1.89	13.17±0.82	15.87±2.51	16.27±0.47	87.25±12.15	84.43±13.55
Urea	1 %	10.77±1.96	10.53±0.96	15.47±2.61	15.27±0.36	85.96±12.10	82.63±14.09
	2%	9.63±2.04	9.57±0.32	15.30±2.72	14.90±0.12	85.33±12.07	81.86±14.72
Control		16.60±1.81	14.13±2.15	17.30±2.15	16.93±2.86	88.67±1.09	87.35±12.08

abscission zone. Our results are supported by the findings of Kolupaev *et al.* (2005) who reported that calcium application improved the activities of lignin synthesizing enzymes. These materials are required for building plant structure or prevention of abscission layer formation and consequently the reduction in pre-harvest fruit drop.

Rate of flower abscission: Minimum rate of flower abscission (percent) was registered with urea application which was 85.33 and 81.86 (2% urea treatment) and 85.96 and 82.63 (1% urea treatment) as compared to 88.67 and 87.35 in control of PAU881 and AL201, respectively. Mineral nutrients are required for higher seed yield in pulses. The low availability of mineral elements leads to the abscission of flower buds, flowers and pods (Chandrasekhar and Bangarusamy, 2003). In the present study, the foliar application of nutrients at flower initiation stage reduced flower abscission in pigeonpea varieties. Similar results were obtained by Ganapathy *et al.* (2008) in rice. Higher supply of all nutrients at flower initiation stage of crop growth might have caused efficient translocation of photo assimilates from source to sink. Kumar *et al.* (2013) found that foliar application of 2% urea increased the number of pods per plant in soybean. They opined that the reduction in flower drop could be due to more photosynthetic activity of leaves.

Correlation matrix: The rate of flower abscission was significantly and negatively correlated with the amount of phloem tissue ($r = -0.3428$) and xylem tissue ($r = -0.2847$). However, cellulase ($r = 0.1214$) and PG ($r = 0.0932$) activities had positive correlation with flower abscission. Phloem tissue had direct effect ($r = -0.2617$) on flower abscission and indirect effects *i.e.* r = -0.0712, -0.0075 and -0.0024 through xylem tissue, cellulase activity and PG activity, respectively.

Foliar application of mineral nutrients increased the area of translocatory tissues and enhance the translocation of assimilates from source to developing sink through pedicel thereby reducing flower drop. This reduction can also be attributed to diminishing activities of hydrolytic enzymes in the pedicel which led to enhanced flower retention and ultimately, improved the yield of pigeonpea crop with 2% urea being the most effective treatment.

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Impact of Integrated Nutrient Management Strategies on Productivity of Plant and Ratoon Crops of Sugarcane

Rajender Kumar, S. K. Uppal and S. S. Walia*

*Department of Plant Breeding and Genetics, *Department of Agronomy, Punjab Agricultural University, Ludhiana-141 004*
**E-mail: sohanwalia72@yahoo.co.in*

Abstract: An experiment was conducted using CoJ 88 variety of sugarcane to see the impact of integrated nutrient management strategies on yield and yield attributes of plant and ratoon crop. Treatment with application of 100% NPK + 25 % N through FYM+ *Azotobacter* produced the highest cane yield of 89.8 t/ha in plant crop while treatment having application of 100 % of recommended NPK + trash incorporation+ *Azotobacter* produced the highest cane yield of 78.0 t ha^{-1} in case of ratoon crop. There was no significant effect on tillering and millable canes of plant and ratoon crop due to different treatments. Also non significant effect was noticed for juice quality and cane weight of plant crop and cane length of ratoon crop due to different treatments.

***Key Words*:** INM, Organic, Ratoon, Sugarcane, yield

Sugarcane (*Saccharum officinarum* L.) is one of the most important cash crops in India and plays pivotal role in both agricultural and industrial economy of our country. Because of its large biomass yield and long growth period, sugarcane requires a considerable amount of plant nutrients for its vegetative growth and development and as a result of this, sugarcane soils become less fertile and fail to produce higher yield. Henceforth, nutrient replenishment through the addition of manures and fertilizer in the soil is indispensable for achieving sustainable cane production (Bokhtiar and Sakurai, 2005). The fertilizer recommendations for sugarcane in major sugarcane growing states of India vary from state to state depending upon the soil type (Natesan *et al.,* 2007), crop duration, yield level and irrigated/rainfed conditions. The a huge variation in the recommended doses ranged from 70–400 kg N, 0–80 kg P_2O_5 and 0–141 kg K_2O ha^{-1} has been reported by Singh and Yadav (1996). The fertilizer doses recommended are generally higher in tropical states compared to subtropical states. Saini *et al*. (2006) also reported that application of nutrients up to 400 kg N, 170 kg P and 180–190 kg K ha^{-1} is recommended for sugarcane depending upon its duration and fertility status of the soil. To stop the continuous decline in soil fertility it is important to use organic manures in combination with inorganic fertilizers i.e. integrated nutrients management in sugarcane (Kumar and Verma, 2005). But for sustainability in sugarcane and sugar production, neither chemical fertilizers nor organic manures alone but their integrated use has been observed to be highly beneficial (Bangar *et al.,* 1994, Singh and Biswas, 2000). The slow release of nutrients from organics, could help a long duration sugarcane crop to take their complete benefit in one crop season (Ramesh *et al.,* 2004). Use of organic manure not only provide the essential nutrients but improve the water holding capacity, aeration, exchange capacity of soil, solubility of essential nutrients thereby increasing their availability (Sagwal and Kumar 1998). The use of organic manure activates the soil micro-organism which helps in decomposition of crop residues thus maintaining the proper C:N ratio and soil pH. The various organic manures viz. Farm yard manure (FYM), sugar factory waste like pressmud (PM) or pressmud cake (PMC), green manuring can be used in integration with chemical fertilizer to increase the sugarcane production and maintain of soil fertility (Bokhtiar and Sakurai, 2005b). Despite this importance, research on integrated nutrient management practices in sugarcane has not yet been extensively worked out. Hence, an attempt has been made to evaluate the effects of integration of nutrient sources on yield as well as quality of the plant and succeeding ratoon crop of sugarcane.

MATERIAL AND METHODS

Field experiments were carried out in two consecutive growing seasons using CoJ 88 variety of sugarcane at Sugarcane Research Area, Ladhowal, Punjab Agricultural University, Ludhiana. Three budded cane setts were prepared and 1,50,000 buds ha^{-1} were used for planting. The sugarcane was planted in the second week of February, whereas, after harvesting of the plant crop, the ratoon crop was initiated in third week of January in the subsequent year. The soil was sandy loam, low in organic carbon (0.258%), high in available P (24.0 kg ha^{-1}) and high in available K (120.4 kg ha^{-1}).

Treatment details and fertilizer application: The experiment comprised of ten treatments and the detail of the treatment combinations is given in Table 1. Treatments were replicated three times in randomized block design (RBD). Urea, diammonium phosphate (DAP), Muriate of potash (MOP), gypsum and zinc sulphate were used as the source of nitrogen, phosphorus and potassium. The recommended dose of nitrogen is 150 and 225 kg ha^{-1} for plant and ratoon crop, respectively. Phosphorus and potassium is recommended on soil test basis. Since soil of experimental field was medium in available P and high in available K, therefore P and K were not applied. Farm yard manure, composted sulphitation press mud cake (CSPM), biofertilizer *Azotobacter,* vermicompost, trash and *Crotalaria juncea* as source of green manuring were used as the source of organic manure. Recommended dose of biofertilizers *Azotobacter* (10.0 kg ha^{-1}) were applied in furrows at the time of planting and along the cane rows at the time of ratoon initiation. For green manuring as a treatment in ratoon, 45 days old crop of *Crotalaria juncea* was incorporated into soil in the month of June. Trash material of planted cane (5 t ha^{-1}) was thoroughly spread over the ratoon field. Nutrient contents in the different organic manure were analyzed on dry weight basis before application. The percent N P K contents in FYM, CPSM, vermicompost and sugarcane trash were 0.69-0.39-0.69; 0.59-0.74-0.18; 0.49- 0.35-0.55 and 0.50-0.07-0.46, respectively.

Cane yield and yield attributes: Agronomic observations such as cane yield (t ha^{-1}) for plant and ratoon crops were recorded at the time of harvesting. The data on germination and tillers count were recorded at 45 and 120 days after planting (DAP), respectively, whereas, cane weight and millable canes were recorded at the time of harvesting. Juice quality was estimated in randomly selected 10 canes from each replication. The parameters included pol and commercial cane sugar % (CCS%). Pol refers to the percentage of sucrose content in juice. Juice was purified by adding (1 g per 100 ml of juice) lead sub acetate in the flask; juice was poured through Whatman 42 filter paper in a funnel. The filtered juice was poured into a pol tube fitted inside an ADP- 220 polarimeter and the pol reading was recorded.

RESULTS AND DISCUSSION

100% NPK + 25 % N through FYM+ Biofertilizer produced the highest cane yield of 89.8 t ha^{-1}. Earlier, Kumar and Mishra (1992) reported that a suitable combination of organic and inorganic sources may increase fertilizer efficiency and finally the cane yield. The increase in sugar cane yield due to application of organic manures can be attributed to the increased availability of all major, secondary and micronutrients in the soil (Babu *et al.,* 2007). Tyagi *et al.* (2012) also reported that plant cane yield was increased by

Table 1. Treatments used in study

Treatments	Sugarcane plant crop					Sugarcane ratoon crop				
	NPK (%)	FYM	CSPM	Biofertilizer *Azotobacter*	Vermicompost	N PK (%)	Trash incorporation	Green manuring	Biofertilizer *Azotobacter*	Vermicompost
T_1	100	.	×	×	×	100	×	×	×	×
T_2	75	25% (N)	×	×	×	100	Yes	×	×	×
T_3	75	×	25% (N)	×	×	100	Yes	×	×	×
T_4	100	×	×	Yes	×	75	×	Yes	×	×
T_5	75	25% (N)	×	Yes	×	100	Yes	×	Yes	×
T_6	75	×	25% (N)	Yes	×	100	Yes	×	Yes	×
T_7	50	25% (N)	×	Yes	×	50	×	Yes	Yes	×
T_8	50	×	25% (N)	Yes	×	50	×	Yes	Yes	×
T_9	50	×	×	Yes	25%(N)	75	×	×	Yes	25%(N)
T_{10}	100	25% (N)	×	Yes	×	100	Yes	×	Yes	×

27.7% by the application of 100% NPK (inorganics) + 25% N (FYM) + biofertilizers (*Azotobacter* + PSB) as compared to 100% NPK alone through inorganic fertilizers. These all findings indicate a beneficial role of biofertilizers application in increasing cane yield.

Further, for plant crop T_1, T_2, T_3, T_4, T_5 and T_6 having application of recommended fertilizer through inorganic alone or in combination with FYM/CPSM produced significantly higher cane yield than T_7 (50% NPK+ 25% N through FYM+ biofertilizer), T_8 (50% NPK+25% N through CSPM + biofertilizer) and T_9 (50% NPK+ Biofertilizer+25% N through vermicompost). However, Ramesh *et al.* (2004) found that application of farmyard manure, cane trash, pressmud, vermicompost and biocompost in combination with recommended inorganic fertilizers have recorded increased cane yield over inorganic fertilizer alone.

For ratoon crop, application of 100% of recommended NPK + trash incorporation+ biofertilizers produced highest cane yield of 78.0 t ha^{-1}. This finding corroborates the results of Tyagi *et al.* (2011) which revealed that integrated use of 150-60-40 kg NPK/ha + trash 5 tonnes ha^{-1} incorporation with cellulolytic culture 1 kg/tonne of trash + *Azotobacter* + PSB in ratoon provide highest cane yield of 92.1 t ha^{-1}. Tyagi *et al.* (2012) reported that application of 100% NPK + trash incorporation with cellulolytic culture + biofertilizers in ratoon provided 16.2 per cent more ratoon cane yield as compared to 100% NPK alone through inorganic fertilizers. T_{10} yield was 8.03% more than T_1. 25% of the recommended fertilizer in sugarcane can be substituted by green manuring (T_4) or Vermicompost (T_9) as yield levels under these treatments were at par with control treatment (T_1). The treatment T_2, T_3, T_5 and T_6 with trash incorporation produced higher cane yield than T_7, T_8 and T_9, which were without the application of trash incorporation. Recently, Gopalasundaram *et al.* (2012) also reported that instances from North as well as South India can be cited where incorporation of 5 t ha^{-1} cane trash along with N fertilizers increased the cane yield.

The data on different yield parameters of sugarcane crop revealed no significant effect on germination, tillering, millable canes and average cane weight due to different treatments. However, treatment T_5 produced the maximum tiller count of 129000 ha^{-1} as well as millable canes 102300 ha^{-1} and the treatment T_6 recorded the maximum cane weight of 0.989 kg. Similarly, for ratoon crop the data (Table 3) pertaining to tillering, millable canes and cane length showed non-significant differences under different treatments. The treatment T_{10} produced the highest tiller counts of 185000 ha^{-1}, T_6 recorded maximum number of millable canes 100100 ha^{-1} and T_3 provide the highest cane length of 183.3cm. In the present studies, the increased tiller count, milliable canes, cane weight and cane height might be due to the fact that chemical nutrients source applied in combination with organic sources are better used than chemical source alone.

Concerning the juice quality parameters, it was observed that Pol% and CCS% did not vary significantly with different fertilizer treatments (Table 2). However, Tyagi *et al.* (2012) reported that CCS yield was 26.5% more in treatment with application of 100% NPK (inorganic) + 25% N (FYM) + biofertilizers (*Azotobacter* +PSB) when compared with that of 100% NPK only. A judicious mix of chemical fertilizers; organic manures like FYM, CSPM, vermicompost and bio-fertilizers (Azotobacter) to plant crop and subsequently application of organic manure viz., trash, vermicompost, green manure and bio-fertilizers (Azotobacter) helped to improve the soil health in terms of Organic carbon, available nitrogen, phosphorus and potassium over alone recommended chemical fertilizers treatment (Table 4).

The highest cane yield (89.8 t ha^{-1}) in plant crop of sugarcane and 78.0 t ha^{-1} in ratoon during 2006-07 and 2007-

Table 2. Effect of different treatments on yield, yield attributes and quality of sugarcane plant crop

Treatments	Germination %	Tiller count (000 ha^{-1})	Millable canes (000 ha^{-1})	Cane weight (kg)	Yield (t ha^{-1})	Pol %	CCS %
T_1	41.3	111.2	93.4	0.958	84.3	19.40	13.42
T_2	43.3	123.7	99.6	0.810	86.8	19.50	13.52
T_3	43.8	126.0	97.0	0.887	83.3	19.21	13.29
T_4	43.0	115.5	97.5	0.892	88.5	19.39	13.41
T_5	44.0	129.0	102.3	0.803	85.5	19.14	13.26
T_6	43.5	127.8	100.2	0.989	87.0	19.28	13.36
T_7	41.9	124.4	78.7	0.910	70.0	18.78	12.95
T_8	44.7	125.9	87.5	0.898	71.6	18.49	12.70
T_9	44.9	118.7	89.0	0.826	72.8	19.15	13.13
T_{10}	44.7	126.7	100.1	0.920	89.8	18.96	13.12
CD (p=0.05)	NS	NS	NS	NS	8.8	NS	NS

Table 3. Effect of different treatments on yield and yield attributes of sugarcane ratoon crop

Treatments	Tiller count (000 ha^{-1})	Millable canes (000 ha^{-1})	Cane length (cm)	Yield (t)ha^{-1}
T_1	178.3	90.5	183.0	72.2
T_2	171.3	94.8	183.1	73.3
T_3	174.6	87.5	183.3	73.3
T_4	176.6	90.2	180.7	69.1
T_5	181.0	96.9	182.1	73.0
T_6	181.6	100.1	182.0	75.0
T_7	150.3	79.5	178.0	54.8
T_8	154.0	73.5	176.7	58.4
T_9	176.0	90.9	180.3	70.5
T_{10}	185.0	95.4	183.0	78.0
CD (p=0.05)	NS	NS	NS	9.9

Table 4. Effect of different treatments on chemical properties of soil (0-15 cm)

Treatments	Organic carbon (%)	Available nutrients (kg ha^{-1})		
		N	P	K
T_1	0.308	146	24.4	122.4
T_2	0.330	154	27.2	130.8
T_3	0.308	150	25.6	128.2
T_4	0.313	157	24.4	124.6
T_5	0.338	160	28.0	128.8
T_6	0.320	158	25.2	128.4
T_7	0.283	140	25.0	134.8
T_8	0.294	145	24.2	130.6
T_9	0.291	142	24.0	132.2
T_{10}	0.342	162	28.8	136.5
CD (p=0.05)	NS	NS	NS	NS
Initial value	0.258	142	24.0	120.4

08, respectively, were obtained in the treatment getting 100% NPK+ 25% N (FYM) + biofertilizers (*Azotobacter*) in

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Prospects of Long-Term FYM Application on Physical Properties of Sandy Loam Soil under Pearl Millet-Wheat Rotation

Shamsher Singh, B. S. Jhorar, Hardeep Singh Sheoran*, Mohammad Amin Bhat, Dinesh and K. S. Grewal

Department of Soil Science, CCS Haryana Agricultural University, Hisar-125004, India
*E-mail: *sheoranhardeep2008@gmail.com*

Abstract: A field experiment was conducted to study the effect of long-term FYM application on physical properties of sandy loam soil under Pearl millet-Wheat rotation. SOC was higher when FYM was applied in *rabi* than that applied in *kharif* season and it increased by 11.3, 6.9 and 9.2%, respectively with 10, 15 and 30 t FYM ha^{-1} application in *rabi* as compared to similar rate in *kharif* season. Bulk density decreased by 8.4 and 6.9 per cent in *rabi* and *kharif* season, respectively over control. Further, application of FYM significantly increased the saturated hydraulic conductivity of soil over control. Application of FYM in *rabi* increased the saturated hydraulic conductivity significantly (15.7, 26 and 31% with 10, 15 and 30 t FYM ha^{-1}) as compared to *kharif* season (12, 26 and 31% with 10, 15 and 30 t FYM ha^{-1}) over control. Moreover, long-term application of FYM increased the infiltration rate by 23.6 and 19% in *rabi* and *kharif* season, respectively over control. Among seasons, the effect of FYM applied in *rabi* was more pronounced in terms of increased mean weight diameter both dry as well as wet (27.7 and 24.8%) than in *kharif* season (27.4 and 26.8%) over control.

Key Words: Bulk density, FYM, Soil organic carbon, Saturated hydraulic conductivity

Green revolution technologies involving enhanced use of synthetic agrochemicals like fertilizers, pesticides etc. coupled with adoption of nutrient responsive high yielding varieties resulted in a significant boost in productivity of all major crops. This increase in production has however, slowed down or in some cases, there has been a decline per unit arable area in growth and production (Antil and Narwal, 2007). Farmers have been complaining on using higher fertilizers doses every year for the same yields as compared to the last few years. This could be attributed to the decline in organic matter content, imbalanced use of fertilizers, over mining of soil nutrients, low use of organic manures, deficiency of secondary and micronutrients.

To arrest this fall in soil productivity, there is urgent need to revive the age old practice of farmyard manure application (FYM) or other bio-degradable farm wastes for maintenance of soil productivity to supplement essential plant nutrients, including micronutrients. Addition of organic matter enhances soil organic carbon content, which in turn improves soil physical properties and processes including aggregation, water holding capacity, hydraulic conductivity, bulk density and resistance of soil to water and wind erosion. Large volume of literature is available on short-term effects of applied organic matter on soil physical properties in different cropping systems but information is scanty on long-term effects of intensive cropping, chemical fertilization and organic manuring on soil physical properties and process (Narwal *et al.,* 2010).

The FYM containing 60% straw (wheat or maize), 30% livestock dung, and 10% cottonseed (*Gossipium hirsutum*)-press mud on an average, contained 22.8% C, and 0.67% N (Hu *et al.,* 2008). Soil organic matter is one of the most important natural resources. It plays a vital role in governing physical, chemical and biological properties of the soil. Farmyard manure is the principal source of organic manures in our country.

Importance of farm yard manure is being realized again because of the high costs of commercial fertilizers and their long-term adverse effect on soil chemical properties. Besides, supplying macro and micronutrients to the soil (Negassa *et al*., 2001), farmyard manure also improves the physico-chemical properties of the soil (Tirol-Padre *et al*., 2007). However, without its integration with inorganic fertilizers, the use of farmyard manure alone may not fully satisfy crop's nutrient demand, especially in the year of application. Animal manures are also useful in improving the efficiency of fertilizer recovery thereby resulting in higher crop yields (Gedam *et al*., 2008). Combined application of organic manures and chemical fertilizers improved soil fertility, soil physical and chemical properties and increased crop yields (Ezekiel, 2010). In view of the above, present investigation was undertaken to study the long-term effects of the FYM application on physical properties of sandy loam soil under pearl millet-wheat rotation.

MATERIAL AND METHODS

A field experiment was conducted during the year 2012 at CCS Haryana Agricultural University, Hisar (India).

The experimental site is located at 29.16º N latitude and 75.75 ºE and longitude with an altitude of 215.2 m above mean sea level. The soil of the experimental site was sandy loam (54% sand, 22% silt and 24% clay) and classified as Typic Haplustepts (Soil Survey Staff, 1999). The climate of the area is semi-arid with an average annual pan evaporation of 1450 mm and rainfall of 426 mm, 80% of rainfall is concentrated from July to September.

Pearl millet-wheat rotation is practiced since *kharif* 1967. The experiment was laid out in randomized block design with four replications with a plot size of 10mx8m. The ongoing field experiment consisted of 30 treatments but the present study was carried out only with selection of seven treatments as given below in table 1. Mode of application was before wheat sowing (Winter *rabi* season) and before pearl millet sowing (Summer *kharif* season).

Table 1. Treatment combinations during *rabi* and *kharif* season

Treatments*	2007-08	2008-09
L_0 - Control	Without application of FYM and N (both the years)	
Rabi season		
L_1 - 15 t FYM ha^{-1} in (*rabi*) + N	15 t FYM ha^{-1}	5 t FYM ha^{-1}
L_2 - 30 t FYM ha^{-1} in (*rabi*) + N	30 t FYM ha^{-1}	10 t FYM ha^{-1}
L_3 - 45 t FYM ha^{-1} in (*rabi*) + N	45 t FYM ha^{-1}	15 t FYM ha^{-1}
Kharif season		
L_4 - 15 t FYM ha^{-1} in (*kharif*) + N	15 t FYM ha^{-1}	5 t FYM ha^{-1}
L_5 - 30 t FYM ha^{-1} in (*kharif*)+ N	30 t FYM ha^{-1}	10 t FYM ha^{-1}
L_6 - 45 t FYM ha^{-1} in (*kharif*) + N	45 t FYM ha^{-1}	15 t FYM ha^{-1}

* N applied @ 120 kg ha^{-1}

The surface (0-15 cm) soil samples from each treatment were taken after 45 years of pearl millet-wheat rotation in May 2012 (after harvest of wheat) and October 2012 (after harvest of pearl millet). Core samples were taken from each plot for determination of bulk density and hydraulic conductivity. The samples were air-dried, gently ground and passed through a 2 mm sieve and stored for further analysis through standard procedure to record soil properties for OC (Walkley and Black, 1934); bulk density (Bodman,1942); infiltration rate (Malik *et al.,* 1985) and Saturated hydraulic conductivity (Richards, 1954) in the laboratory.

RESULTS AND DISCUSSION

In case of soil pH and EC, there was no specific effect of long-term application of FYM (Table 2).

Soil organic carbon: The long-term effects of farmyard manure applied in *rabi* and *kharif* season on soil organic carbon (SOC) content of 0-15 cm depth (Table 2) was recorded. After 45 year cycle in pearl millet-wheat rotation, the soil organic carbon (SOC) improved significantly as compared to control. Further, it was observed that organic carbon was higher when FYM was applied in *rabi* season than that applied in *kharif* season. The respective increase in SOC was 11.3, 6.9 and 9.2% in L_1, L_2 and L_3 level of FYM applied in *rabi* season, respectively when compared to its same dose applied in *kharif* season. Maintaining and improving the level of soil organic matter is a pre-requisite to ensure soil quality and sustainable productivity influencing soil physical properties. The intensive cropping and imbalanced use of fertilizers have resulted in significantly lowering in soil organic matter content. This differential and higher build up of organic carbon with FYM might be due to the quality and type of FYM incorporated and the prevailing temperature regime in July-September period where it could go up very high (48ºC), whereas, in *rabi*, the area experiences low temperature (sub zero). So, the decomposition of applied organic material is expected to be much faster in summer than in winter. Rasool *et al.* (2007) also observed the higher level of SOC in rice-wheat cropping system in long term application of FYM than inorganic fertilizers. Similarly, Singh *et al.* (2004) reported that application of wheat straw and FYM increased soil organic carbon content in a long-term rice-wheat experiment in a loamy sand soil in Punjab. Similar results were reported by Gupta *et al.* (2003) who observed that long-term application of various doses and modes of farmyard manures increased soil organic carbon from 0.68 in control to 1.82% in the plot receiving the highest annual dose of farmyard manure.

Bulk density: The long-term application FYM in pearl millet and wheat rotation resulted in decreased soil bulk density at all depths as compared to control. Overall, bulk density decreased by 8.4 and 6.9 per cent in *rabi* and *kharif* season, respectively over control (Table 2). Highest decrease in bulk density at 0-5, 5-10 and 10-15 cm in both seasons was in L_3 and L_6 treatments. The bulk density increased with increasing depth irrespective of the treatments. The highest decrease in bulk density was in the top layer (0-5 cm) to the tune of 6.1, 7.6 and 10.7% in *rabi* and 5.3, 9.1 and 6.8% in *kharif* season, respectively over control. As stated earlier, addition of FYM increased the SOC content which consequently increased soil aggregation and consequently decreased the bulk density.

Addition of FYM reduced the bulk density was also reported by Narwal *et al.* (2010). Both, rate and type of organic materials influences the soil bulk density as higher rates of organic material addition resulted in lower bulk density values and hence higher soil porosities (Baezegar *et al.* 2002). FYM has lower bulk density than soil and as the rate of FYM increased, bulk density decreased. The influence of FYM on decreasing the bulk density was more pronounced in upper soil layers (0-10 cm) than the lower layer (10-15 cm) and this is expected also due to mixing of FYM in the surface layer and its movement to the lower layers under semi arid conditions is low. These results are in accordance to the observed decreasing effect of organic materials addition on soil organic carbon content with decreasing soil depths. Similar results were reported by Bhattacharya *et al.* (2004) who found that incorporation of FYM @ 10 t ha^{-1} resulted in an improvement in soil porosity, saturated hydraulic conductivity in surface and sub-surface layers and decreased soil bulk density.

Infiltration rate: The application of FYM on long term basis increased the infiltration rate by 24.1 and 20.4% in *rabi* and *kharif* season, respectively over control. Highest increase was observed at 27.6 and 23.6% for L_3 and L_6 t FYM ha^{-1} application rate in *rabi* and *kharif* season, respectively, and all other treatments were statistically at par. Data on infiltration rate of soil under pearl millet-wheat rotation (Table 3) indicated that long-term application of FYM increased the infiltration rate by 23.6 and 19% in *rabi* and *kharif* season, respectively over control. Maximum increase in infiltration rate was 26 and 23% in L_3 and L_6 t FYM ha^{-1} treatments in *rabi* and *kharif* season, respectively when compared to control. This increase in infiltration rate due to addition of FYM may be attributable to the improvement in pore size distribution which favours water infiltration in the soil.

Saturated hydraulic conductivity: Application of FYM significantly increased the saturated hydraulic conductivity of soil as compared to the control in both the seasons (Table 3). Application of FYM in *rabi* increased the saturated hydraulic conductivity significantly (15.7, 26 and 31 per cent in 15, 30 and 45 t FYM ha^{-1}) as compared to its application in *kharif* season (12, 26 and 31 per cent in 15, 30 and L_3 and L_4 t FYM ha^{-1}) over control. The overall increase in saturated hydraulic conductivity as compared to control was 28 and 24% in *rabi* and *kharif* season, respectively. Highest increase in saturated hydraulic conductivity was in 0-5 cm soil layer as compared to 5-10 cm and 10-15 cm layer in both the season. It depends upon total porosity, pore size distribution and continuity of soil pores. These soil pore characteristics are influenced by texture, structure and organic matter content. Hence, addition of organic materials has potential to modify the saturated hydraulic conductivity favourable for water movement in the soil. The results of present study revealed that saturated hydraulic conductivity of the experimental soil increased with application of FYM. Highest increase in

Table 2. Long-term effect of FYM applied in *rabi* and *kharif* season on pH, EC, SOC and bulk density

Treatment	pH	EC (dS m^{-1})	Soil organic carbon (%)	Bulk density (Mg m^{-3})		
				0-5 cm	5-10 cm	10-15 cm
Lo - Control (No fertilizer no FYM)	8.0	0.18	0.30	1.31	1.38	1.50
L_1 - 15 t FYM ha^{-1} in (*rabi*) + N	7.9	0.15	0.49	1.23	1.21	1.34
L_2 - 30 t FYM ha^{-1} in (*rabi*) + N	8.1	0.14	0.62	1.21	1.24	1.34
L_3 - 45 t FYM ha^{-1} in (*rabi*) + N	8.0	0.21	0.65	1.17	1.27	1.35
L_4 - 15 t FYM ha^{-1} in (*kharif*) + N	7.8	0.33	0.44	1.24	1.19	1.35
L_5 - 30 t FYM ha^{-1} in (*kharif*) + N	7.8	0.25	0.58	1.19	1.22	1.34
L_6 - 45 t FYM ha^{-1} in (*kharif*) + N	7.7	0.18	0.59	1.22	1.23	1.34
CD (p=0.05)	0.1	0.1	0.03	0.02	0.02	0.02

Table 3. Long-term effect of FYM application in *rabi* and *kharif* season on saturated hydraulic conductivity and final infiltration rate at different soil depths

Treatment	Saturated hydraulic conductivity (cm hr^{-1})			Final Infiltration rate (cm hr^{-1})
	0-5 cm	5-10 cm	10-15 cm	0.55
Lo - Control (No fertilizer no FYM)	0.48	0.46	0.38	0.69
L_1 - 15 t FYM ha^{-1} in (*rabi*) + N	0.55	0.54	0.42	0.72
L_2 - 30 t FYM ha^{-1} in (*rabi*) + N	0.65	0.58	0.48	0.76
L_3 - 45 t FYM ha^{-1} in (*rabi*) + N	0.70	0.58	0.50	0.65
L_4 - 15 t FYM ha^{-1} in (*kharif*) + N	0.57	0.52	0.47	0.70
L_5 - 30 t FYM ha^{-1} in (*kharif*) + N	0.67	0.59	0.51	0.72
L_6 - 45 t FYM ha^{-1} in (*kharif*) + N	0.77	0.69	0.63	0.07
CD (p=0.05)	0.03	0.02	0.03	0.55

saturated hydraulic conductivity was in 0-5 cm soil layer as compared to 5-10 cm and 10-15 cm soil layers in both seasons. Narwal *et al.* (2010) also reported that the addition of 45 Mg ha^{-1} of FYM in *rabi* increased the hydraulic conductivity of soil from 2.71 to 7.10, and 2.71 to 7.93 cm hr^{-1} when applied in both (*rabi*+*kharif*) seasons. The increase in saturated hydraulic conductivity may be attributed to the enhanced aggregation due to higher organic carbon content which consequently improved the soil structure. Mosaddeghi *et al*. (2009) reported that in long- term application of manure alone and along with 100% NPK inorganic fertilizers gave higher hydraulic conductivity in a soil. Similar to organic carbon and bulk density, the effect of organic materials on saturated hydraulic conductivity diminished with increasing soil depth.

The soil physical properties can be maintained by FYM application in pearl millet-wheat crop rotation. Application of FYM in *rabi* season proved more beneficial in improving the soil physical properties as compared to its *kharif* season application in this crop rotation. Long-term application of FYM significantly improved the soil organic carbon (SOC) content b.y 46.5% after 45 cycles of pearl millet-wheat cropping system. Moreover, FYM applied in *rabi* increased the soil organic carbon more than FYM applied in *kharif* season. Application of FYM resulted in a decrease in bulk density and the influence of FYM more pronounced in upper 10 cm soil layer than in the lower soil layer (10–15 cm). When FYM was applied in *rabi*, the decrease was higher than when applied in *kharif* season. Farmyard manure significantly increased the saturated hydraulic conductivity of the soil by 24.3 18.7 and 18.1 per cent at 0-5, 5-10 and 10-15 cm depths, respectively when applied in *kharif* season. The saturated hydraulic conductivity decreased with increasing soil depth irrespective of treatments. Maximum increase in infiltration rate was 26 and 23% due to L_3 and L_6 FYM ha^{-1} applied in *rabi* and *kharif* season, respectively when compared with control.

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Interactive Effect of Brassinosteroid and Cadmium on Antioxidative Metabolism in Wheat Seedlings

Ritu Saini, Harnek Singh Saini[1], Anjali Dahiya, Sonali Bajaj and Sweety Sihag

Department of Chemistry and Biochemistry, Chaudhary Charan Singh Haryana Agricultual University, Hisar-125 004, India
[1]Department of Biotechnology Engineering, University Institute of Technology
Kurukshetra University, Kurukshetra-136 119, India
E-mail:ritusaini214@gmail.com

Abstract: The effect of four different concentrations of cadmium chloride ($CdCl_2$) (5, 20, 50 and 100ppm) as well as in combination with Brassinosteroid (BR) (10µl/20ml) was studied on the activities of catalase (CAT), ascorbate peroxidase (APX), guaiacol peroxidase (GPX) and polyphenol oxidase (PPX) in 5 day old wheat seedlings. Under the effect of $CdCl_2$, wheat seedlings showed retarded growth and decreased activities of CAT, APX, PPX and the soluble protein content while GPX activity increased with increase in the concentration of Cadmium (Cd). But when BR concentration were applied with the different concentration of $CdCl_2$ then there was gradual increase in the content of soluble protein & activities of these enzymes indicating that BR alleviated the adverse effect of Cd.

Key Words: Brassinosteroids, Cadmiun, ROS scavenging enzymes, Wheat

Heavy metals such as Cu and Zn are essential for normal plant growth and development since they are constituents of many enzymes and other proteins. However, elevated concentrations of both essential and nonessential heavy metals in the soil can lead to toxicity symptoms and growth inhibition in most plants (Hall, 2002). Toxicity may result from the binding of metals to sulphydryl groups in proteins, leading to inhibition of activity or disruption of structure, or from displacement of an essential element, resulting in deficiency effects (van Assche and Clijsters, 1990). In addition, a heavy metal excess may stimulate the formation of free radicals and reactive oxygen species (ROS), perhaps resulting in oxidative stress (Dietz *et al*., 1999). Antioxidant compounds in food play an important role as a health protecting factor and used to treat free radicals generated due to stresses.

Cadmium is one of the most highly toxic environmental pollutants in the atmosphere, soil and water. In natural soils, Cd concentration in soil solution is estimated to be around 0.04-0.32 mm. Nevertheless, the soil solution with 0.32 mm to nearly 1mm Cd can be considered polluted or toxic. This is a growing concern since Cd can be transferred to plants, resulting in phytotoxicity and threats to animal and human health through the food chain. Cd enters the environment mainly through industrial processes, irrigation with wastewater and application of metal-containing pesticides, municipal based composts and phosphatic fertilizers and atmospheric deposition (Ranieri *et al.,*2005). Cd alters the levels of enzyme activities disturbing the normal physiological processes in plants. Cd induces oxidative stress in plants by generating ROS like superoxide, hydroxyl radical, hydrogen peroxide, alkoxy radical; the later causes oxidative damage in cellular macromolecules of plants.

Brassinosteroids are plant natural polyhydroxysteroids with pleiotropic effects supporting the plant growth, seed germination, cell elongation, photomorphogenesis and senescence (Upreti and Murti, 2004), their structure resembles animal steroid hormones (Bajguz, 2010). In plants, steroid hormones serve as endogenous signaling molecules. Brassinosteroids act as positive growth regulators or as compounds responsible for plant stress tolerance. Besides growth stimulation they have an ability to confer resistance to plants against various abiotic stresses (Priti, 2003).

Heavy metals give rise to antioxidative stress and brassinosteroids can effectively reduce it and induce enhancing of antioxidants under heavy metal stress (Hayat *et al.,* 2007). This study was, therefore, undertaken to understand interactive effect of Brassinosteroids and Cadmium on antioxidative metabolism in germinating wheat seedlings.

MATERIAL AND METHODS

Growth of plant material and imposition of Cadmium and Brassinosteroid treatment: Wheat seeds were surface sterilized with 0.1% $HgCl_2$ for 5 min and rinsed with sterile distilled water for 5-6 times. Surface sterilized seeds were germinated aseptically in petri plates having sterilized wet filter paper. Brassinosteroid solutions of varying concentration were prepared by using "Double" (Godrej Agrovet Ltd., Sachin, India), a commercial formulation of brassinosteroids. The BR concentration in the commercial formulation was 0.04% (w/w). The different concentrations of cadmium chloride ($CdCl_2$) were prepared using distilled water which were**:** $CdCl_2$ (5ppm, 20ppm, 50ppm, 100ppm). Three petri plates were kept for each concentration. To each petri plate, 20 ml of $CdCl_2$ was added. An untreated control was also maintained. Combinations of BR with $CdCl_2$ were also prepared in distilled water i.e 10 ml of BR and 10 ml of $CdCl_2$. The seeds were allowed to germinate in petri plates for 5 days at 28 °C and collected wheat seedlings (samples) were washed with distilled water. From the collected samples enzyme extracts were prepared and used for enzyme assay.

Extraction of enzymes: All antioxidant enzymes studied, were extracted by using common extraction procedure and were assayed by their specifics procedures. Fresh tissue (wheat seedlings) of 250 mg was homogenized in 1.5 ml of ice cold buffer containing 75 µmole of potassium phosphate buffer (pH 7.0), 1.5µmole of EDTA, 2% PVP, 0.05% triton-X-100 using pre-chilled pestle mortar. Homogenate was passed through layers of cheese cloth and then centrifuged at 10000x g at 4^0C for 15 minutes. Supernatant after centrifugation was used as enzyme extract in following assays.

Estimation of catalase activity: Catalase (EC 1.11.1.6) detoxifies H_2O_2 to H_2O and O_2. Catalase activity was measured according to the method of Sinha (1972) and one enzyme unit was defined as the amount of enzyme which catalyzed the oxidation of 1 mole H_2O_2 per minute under assay conditions. Activity was expressed in IU ml^{-1}.

Estimation of guaiacol peroxidase activity: Guaiacol Peroxidase detoxifies H_2O_2 by using reduction power of plant phenol guaiacol. GPX activity was measured according to the method of Putter (1974) by taking 3 ml of reaction mixture containing 50 mM phosphate buffer (w/v), pH 7.0, 20 mM guaiacol (v/v), 12.3 mM H_2O_2 (v/v) and 100 µl enzyme extract. GPX activity was determined by measuring the absorbance at 436 nm and using extinction coefficient of 25 mM^{-1} cm^{-1} .Activity was expressed in IU ml^{-1}.

Estimation of ascorbate peroxidase activity: Ascorbate peroxidase (EC 1.11.1.11) detoxifies H_2O_2 by reducing power of ascorbate. The activity of ascorbate peroxidase enzyme was assayed by the method of Nakano and Asada (1981) following the oxidation of ascorbic acid. The decrease in absorbance at 290 nm was recorded spectrophotometrically which corresponded to oxidation of ascorbic acid. One enzyme unit was defined as 1 mole of ascorbic acid oxidized per min at 290 nm. APX activity was expressed in IU/ml.

Estimation of polyphenol oxidase activity: Polyphenol oxidase (EC 1.14.18.1) activity was assayed by the method of (Kar and Mishra, 1976). To 1 ml of enzyme extract, 2.5 ml of 0.1 M phosphate buffer (pH 6.8) and 0.1 ml of 0.01 M pyrogallol were added. After incubation for 5 min at 4ºC, the reaction was stopped by adding 1.0 ml of 2.5 N H_2SO_4. In the blank, enzyme was deactivated by the addition of 2.5N H_2SO_4. The amount of purpurogallin formed was estimated by measuring the absorbance at 420 nm. One unit (U) of PPX activity was defined as the amount of enzyme that caused an increase in absorbance at 420 nm of 0.01 per min. The enzyme activity was expressed in IU ml^{-1}. Soluble proteins were estimated by the method of Lowry *et al*. (1951).

RESULTS AND DISCUSSION

Under the effect of $CdCl_2$, wheat seeds showed retarted germination and growth. But when brassinosteroid was added with $CdCl_2$, stimulation in the germination and growth of seedlings were noticed. In the present investigation, the effect of four different concentration of $CdCl_2$ (5, 20, 50 and 100ppm) as well as in combination with BR was studied on the activities of CAT, APX, GPX and PPX in the wheat seedlings.

Effect of BR on Catalase: CAT activity in BR-treated germinated wheat seedlings was generally higher as compared to Cd treated seedlings. At the varying concentration of $CdCl_2$, wheat seedlings showed the decreasing activity of CAT. A similar effect of $CdCl_2$ was observed by earlier researchers in other crops. Dey *et al.* (2007) observed that the CAT activity declines in wheat seedlings under Cd stress. But when the concentrations of BR along with $CdCl_2$ were introduced, the activity of CAT was higher than that observed in the presence of $CdCl_2$ alone as shown in following Fig.1a. BR stimulated CAT activity and this is in agreement with the fact that BR acts as an antioxidant.

Effect of BR on Guaiacol peroxidase: The GPX activity in this experiment increased with an increase in the concentration of $CdCl_2$ and BR in combination with $CdCl_2$ in wheat seedlings (Fig.1b) but the activity was substantially higher than in the presence of $CdCl_2$ alone, suggesting a protective role of BR against heavy metal stress. Dey *et al.* (2007) observed that GPX activity declines in wheat seedlings under Cd stress. In contrast, Arora *et al.* (2010a) observed an increase in the activity of GPX under Cd and copper chloride metal stress condition.

Effect of BR on Ascorbate peroxidase: Activity of APX increased gradually under the influence of BR in combination of $CdCl_2$ while it decreased with increased concentration of

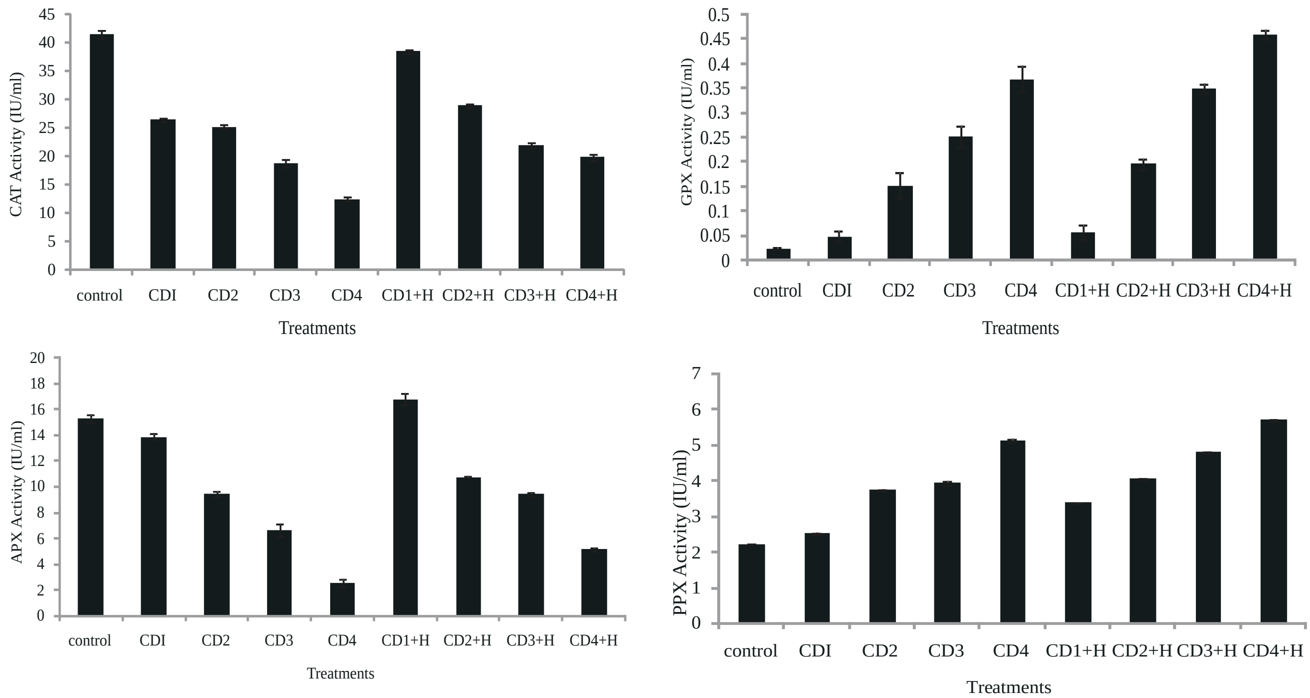

Fig. 1. CAT, GPX, APX and PPX activity (IU/ml) in the 5 day germinated wheat seedling, treated with different concentration of Cd with single concentration of BR. The metal treatments (in ppm) are: control, CDI (Cd 5), CD2 (Cd 20), CD3 (Cd 50), CD4 (Cd 100), CD1+H (Cd 5+BR(10µl/20ml)), CD2+H (Cd 20+BR(10µl/20ml)), CD3+H (Cd 50+BR(10µl/20ml)), CD4+H (Cd 100+BR(10µl/20ml)

$CdCl_2$ alone (Fig.1c). This suggested that the application of both BR and $CdCl_2$ relieved the seedling from the $CdCl_2$ stress by affecting the antioxidative metabolism. APX activity is known to detoxify ROS thereby amelioratin oxidative stress. It plays a key role by reducing H_2O_2 to water through the ascorbate-glutathione cycle. It was studied that by increasing the Cd concentration in medium, APX activity was significantly decreased in wheat seedlings (Nasr, 2013). Reports available on effect of Cd on APX activity have been somewhat contradictory. Cd has been shown to enhance activity of APX in *Cucurbita pepo* (Dipierro *et al.*, 2005) and rice (Sharma and Dubey, 2007). The impact of BRs on and the activity of antioxidant enzymes catalase, peroxidase, ascorbic peroxidase and guaiacol peroxidase in radish seedlings under Cd toxicity was evaluated (Anuradha and Rao, 2007).

Effect of BR on Polyphenol oxidase (PPX): The PPX activity in this experiment was found to enhance with $CdCl_2$ as well as BR treatment (Fig.1d). It seems possible that PPX may play a role in the defense against metal stress. The application of BR increased PPX activity as compared with those $CdCl_2$ treated wheat seedlings. Arora *et al.*(2010) also observed an increase in the activity of PPX under metal stress condition in *Brassica juncea L.*

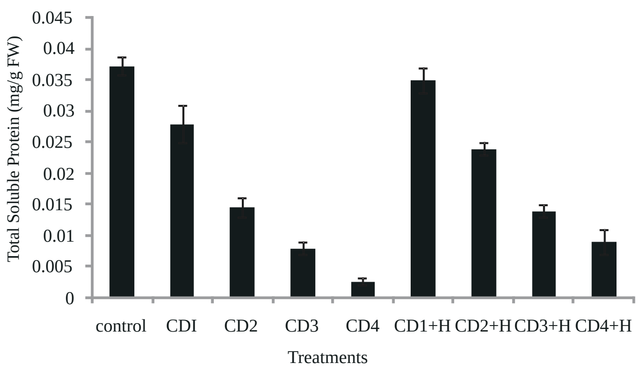

Fig. 2. Different concentration of Cd with single concentration of BR. The metal treatments (in ppm) are: control, CDI (Cd 5), CD2 (Cd 20), CD3 (Cd 50), CD4 (Cd 100), CD1+H (Cd 5+BR(10µl/20ml)), CD2+H (Cd 20+BR(10µl/20ml)), CD3+H (Cd 50+BR(10µl/20ml)), CD4+H (Cd 100+BR(10µl/20ml)

Effect of BR on total Protein Content: In this study, BRs were found to influence the level of total soluble proteins in wheat seedlings. An increase in the soluble protein content might indicate that BR responses were dependent on protein synthesis as suggested by Kalinich *et al.* (1985). In the stress condition of Cd, the content of soluble protein decreased with increase in the concentration of Cd metal. When BR concentrations were applied with the concentrations of Cd metal then there was gradual increment in the content of soluble protein. The application of BRs has been found to enhance protein content in normal plants (Bajguz, 2000; Arora *et al*., 2008; Behnamnia *et al*., 2009; Vardhini and Rao, 2003a, b). The results of this experiment revealed that the BR in combinition with $CdCl_2$ was effective in enhancement of the total soluble protein content as compared to control.

It can be concluded that cadmium adversely effect the antioxidative metabolism while brassinosteroids by inducing the activity of antioxidative enzymes alleviate the negative effect of cadmium chloride in germinating wheat seedlings.

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Integrated Nutrient Management Practices influencing the Productivity of Potato under Subtropical Plains of Jammu, India

Sandeep Chopra, R.K Samnotra, Manoj Kumar and Satesh Kumar
Division of Vegetable Science and Floriculture
Sher-e-Kashmir University of Agricultural Sciences and Technology, Main Campus, Jammu-180 009, India.
E-mail: drsc373@rediffmail.com

***Abstract*:** In order to reduce the use of inorganic fertilizers and to supplement them with organic and biofertilizers sources, an field experiment was conducted to study the effect of biofertilizers, organic and inorganic fertilizers on the growth, yield and quality of potato. The treatments comprised of two levels of nitrogen (i.e. 50% and 75% N), three sources of organic fertilizers (FYM, Vermicompost and Bonemeal) inoculated with two sources of biofertilizers i.e. Azotobacter and PSB. A treatment combination of vermicompost in association with PSB along with 50% recommended dose of nitrogen resulted in maximum plant height, weight of tubers and total yield. Vermicompost in association with PSB and 50% nitrogen resulted in tubers having low sugar content thus influencing the overall acceptability of ware tubers.

Key Words: Days after planting, Integrated nutrient management, Leaf area index, Phosphate solubilizing bacteria

Potato is one of the most valuable non-cereal food crops, grown in most of the temperate and sub-tropical countries of the world. Being a nutrient exhaustive crop, the maintenance of soil fertility is one of the most important aspects for its successful crop production. However, the excessive use of inorganic fertilizers leads to health and ecological hazards, deterioration of physical and chemical properties of soil and ultimately affects the sustainability of crop productivity. The application of organic manure and biofertilizer in judicious combination with chemical fertilizers facilitates profitable and sustainable crop production along with maintenance of soil fertility (Singh and Sinsinwar, 2006). Moreover, with ever increasing cost of chemical fertilizers and widening of the gap between demand and supply, utilization of biofertilizers has emerged as a substitute of the chemical fertilizers. The biofertilizers and organic manures like poultry manure, vermicompost and bone meal have great potential in providing plant nutrients and are an important component of Integrated Plant Nutrient System (IPNS) (Parmar *et al*, 2007). In view of above mentioned facts, the present experiment was conducted to study the effect of combined application of organic manures and inorganic fertilizers on the growth, yield and quality of potato crop in the plains of Jammu region.

MATERIAL AND METHODS

The field investigation on the effect of integrated nutrient management on the growth, yield and quality of potato (*Solanum tuberosum* L.) var. Kufri Badshah was carried out during the years 2010-11 and 2011-12 at Sher-e-Kashmir University of Agricultural Science & Technology of Jammu. The experiment was laid out in randomized block design with three replications. The crop was planted in third week of October at 60 × 20 cm spacing with a gross plot size of 5 × 3 m. during both the years. Recommended dose of phosphorus and potassium was applied in the form of single super phosphate and muriate of potash (Anonymous, 2006). Growth and yield parameters like emergence count, plant height, leaf area index, tuber grade and yield of the crop were recorded during the crop growth period. Quality parameters like dry matter content, reducing sugar, specific gravity and starch content were recorded by following the standard procedures. Yield attributes were calculated 60, 75 and 90 DAP. Total tuber yield /ha was computed on the basis of yield per plot. Tuber grading was done as per tuber size i.e. large (>7.5 cm), medium (5-7.5 cm), small (< 5 cm). For dry matter content determination, the tuber samples were oven dried at 65^{0}C till a constant weight was obtained. The percent dry matter content was calculated by the following formula:

$$\text{Dry matter content (\%)} = \frac{\text{Final dry weight}}{\text{Initial fresh weight}} \times 100$$

Total sugars and reducing sugars were estimated by using phenol -H_2SO_4 method as suggested by Yemm and Willis (1954) and DNS method given by Neolting and Bernfield (1948) respectively. Whereas, for specific gravity water displacement method and the starch content of the tuber was estimated from specific gravity (Scheele *et al.,* 1937) i.e., Starch (%) = 17.546 + 199.07 × (Specific gravity – 1.0988).

RESULTS AND DISCUSSION

Growth and yield characters: The nutrient application does not influence the emergence status of the potato crop. Similar findings have been reported by Raghav and Chandra (2005) and Lal and Khurana (2007) who also got non-significant effect of organic and inorganic sources on the emergence count. The plant height responded favorably towards the applied nutrients. Maximum plant height (51.73 cm) was recorded in combination of vermicompost + PSB + 50% N (Table 1). More plant height in this treatment was due to the reason that nitrogen being the integral part of the chlorophyll encouraged the vegetative growth which leads to more plant height. The results are in conformity with the findings of Lal and Khurana (2007).

Maximum leaf area index (1.01) was recorded with a treatment combination of vermicompost+ PSB +50% N. It might be owe to the fact that nitrogen along with phosphorus facilitated the cell elongation thus prolonging the leaf area duration. Mustonen (2004) also reported that application of 120 kg N ha^{-1} intensified the canopy development and increased leaf area of the crop stand.

Raghav and Chandra (2005) obtained more number of medium sized tubers when soaked in a solution containing 1% Urea, Sodium bicarbonate and followed by Azotobacter and PSB inoculation. This might be due to the facilitation of N uptake by the crop as absorbed urea could have been directly available to the growing plants in the initial stage of growth. Similarly Singh and Kushwah (2006) got highest number of large sized tubers with 75%NPK+30T of FYM. Highest total numbers of tubers were also recorded with 100%NPK+30T of Nadep compost per hectare which was significantly higher than with 100% NPK alone (Singh and Kushwah, 2006). Vermicompost + PSB + Azotobacter resulted in maximum weight of tubers by grade because the biofertilizers in combination with nitrogen through vermicompost resulted in enhanced biological nitrogen fixation, solubilization of phosphorus, better development of root system and secretion of hormones.

Tuber yield is an outcome of the cumulative effect of biofertilizers and the inorganic fertilizers. The integration of nutrients significantly influenced this parameter. The nutrients by their ability to regulate various aspects of plant metabolism ensured maximum production and utilization of other plant foods thereby leading to high yield levels. Yadav *et al.* (2003) reported that Azotobacter inoculation increased the potato yield from 5-14% because it plays a nutritional, stimulatory and therapeutic role for the benefit of crop. Kumar *et al.* (2006) also got an increase in the yield of potato with 1% urea and sodium bicarbonate in combination with Azotobacter and PSB. According to them the possible reason for increase in yield might be associated to better utilization of chemical fertilizers in the presence of biofertilizers and induced biological nitrogen fixation, phosphorus use efficiency and possible synthesis of plant growth promoting substances. The organic amendments like vermicompost promotes humification, increased microbial activity and enzyme production which in turn increased the aggregate stability of soil particles resulting in better aeration for the tuber, thus increasing the total yield (Ansari, 2008).

Quality characters: It was evident from the table that the sugars (total and reducing), specific gravity and starch content responded significantly towards the applied nutrients. However, dry matter content was not influenced by the INM treatments. In line with our observations, Pirkko *et al.* (2003) got non significant effect in dry matter content through the applied inorganic and organic treatments even though the fresh matter yield was high with mineral fertilization. The dry matter was maximum in the treatment in which vermicompost+ PSB+ 50% N was applied. The vermicompost and PSB has the property of binding the mineral particles for the desired porosity to sustain the plant growth and improving the dry matter production. Kumar *et al* (2009) also got maximum dry matter/plant with the application of 40 kg N+ 40kg P_2O_5 ha^{-1} in fenugreek. The inorganic fertilizers increased the total sugar and reducing sugar percentage in the tubers. However, where the biofertilizers were incorporated along with inorganic fertilizers those plots yielded fewer sweet potatoes. Raina *et al.* (2006) got an increased sugar content in tomato in response to the INM treatments which could be attributed to the effect of growth hormones like IAA and cytokinin. As per our treatments, the organic fertilizers with 50% N improved the tuber quality by reducing the sugar content as compared with the inorganic fertilizers applied. Sarkar *et al.* (2007) also reported that increasing the level of chemical fertilizers resulted in reduction in reducing sugar content in potato tubers under West Bengal conditions.

The specific gravity and starch content varied significantly in response to the applied fertilizers. Maximum specific gravity and starch content was in tubers receiving nitrogen in combination with the organic fertilizers more specifically the FYM. Both these are positively correlated to each other. El-Sirafy *et al.* (2008) also got an increase in the specific gravity of the tubers of the tubers in response to the applied farmyard manure. Thus the INM treatment improves the quality of tubers meant for the table purpose. Makaraviciute (2003) reported that the amount of starch content depends upon the varietal properties, meteorological condition and the fertilization. Under favorable conditions the chopped straw combined with one component mineral fertilizer @N_{45}+ P_{45}+K_{90}, one component and complex mineral fertilizer@ N_{90}+P_{90}+K_{180} increased the amount of starch

Table 1. Effect of integrated nutrient management on the growth, yield and quality parameters of potato (pooled data for two years)

Treatment	Emergence count (%)	Plant height (cm.)	LAI	Wt. of tuber by grade (g)	Tuber yield (q ha^{-1})	Dry matter content of tubers (%)	Total sugars (g/100g)	Reducing sugars (g/100g)	Specific gravity	Starch content (%)
Control (RDF:120:60:120kg/ha)	60.47	36.93	0.67	30.50	158.40	18.82	5.97	1.23	1.05	8.49
FYM + PSB + Azotobacter	64.28	40.09	0.90	34.50	170.60	16.09	3.41	1.42	1.04	7.16
FYM + PSB + 50%N	61.42	44.10	0.81	39.20	189.99	18.82	4.91	2.95	1.12	23.08
FYM + PSB + 75%N	62.85	44.38	0.71	38.80	196.46	17.87	4.41	1.13	1.05	8.49
FYM +Bonemeal + Azotobacter	56.66	44.40	0.79	39.80	204.74	16.88	4.04	1.62	1.08	14.46
FYM + Bonemeal + 50%N	59.04	40.09	0.71	51.70	185.48	18.52	3.73	0.98	1.11	19.77
FYM +Bonemeal + 75%N	62.37	47.78	0.71	48.60	181.96	19.56	5.11	0.99	1.05	8.49
Vermicompost + PSB + Azotobacter	52.37	42.90	0.73	36.30	193.50	17.37	3.37	0.73	1.08	14.46
Vermicompost + PSB + 50%N	62.37	51.73	1.01	57.10	219.39	20.83	2.52	0.70	1.09	17.11
Vermicompost + PSB + 75%N	49.52	51.35	0.90	41.80	201.81	19.41	4.61	1.73	1.09	17.11
Vermicompost + Bonemeal + Azotobacter	47.61	51.34	0.74	40.00	205.68	18.62	4.38	0.85	1.07	13.13
Vermicompost + Bonemeal+ 50%N	51.42	51.71	0.71	41.90	202.60	17.38	3.32	0.85	1.06	11.14
Vermicompost+ Bonemeal+75%N	52.38	51.35	0.75	50.09	209.70	19.48	3.44	0.85	1.10	18.44
CD (p=0.05)	NS	8.64	NS	7.20	24.61	NS	1.32	0.84	0.03	7.46

content in potato tubers. So, INM treatments can effectively be used for the potatoes that are meant for ware consumption.

From the present study, It became evident that the nutrient application did not influence the emergence count and leaf area index of potato whereas; it was quite effective in influencing other growth and yield parameters. A treatment combination of vermicompost in association with PSB along with 50% recommended dose of nitrogen resulted in maximum plant height, weight of tubers (by grade) and ultimately total tuber yield. Vermicompost in association with PSB and 50% nitrogen resulted in tubers having low sugar content thus influencing the overall acceptability of ware tubers and can also reduce the nitrogen dose by 50% and producing tubers having good quality and potential yields.

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Influence of Irrigation and Nutrient Schedules on Growth, Biomass Production, Yield and Quality in Coleus (*Plectranthus barbatus* Briq.)

Y. S. Praneeth, A. P. Mallikarjuna Gowda, K. Umesha, M. N. Thimmegowda and G. M. Vinay

College of Horticulture, Bengaluru, University of Horticultural Sciences, Bagalkot- 587 101, India
E-mail: praneethchama@gmail.com

Abstract: Field experiment on irrigation and nutrient schedule for drip fertigation in coleus was conducted and irrigation at 0.7 IW/CPE recorded taller plants, higher number of branches, leaf area, tubers per plant, tuber diameter, tuber length, maximum fresh weight of leaves dry weight of leaves, fresh weight of tubers per plant, dry weight of tubers per plant, fresh tuber yield (32.99 t ha^{-1}), dry tuber yield (4.45 t ha^{-1}) and moisture per cent (6.69%). The total forskolin content was maximum with 0.5 IW/CPE (0.86 %). Among the fertigation schedules, plant height, number of branches, leaf area, number of tubers per plant, maximum tuber diameter, tuber length, fresh weight of leaves, dry weight of leaves, fresh weight of stem, dry weight of stem, fresh weight of tubers per plant (398.77 g), dry weight of tubers per plant (53.01 g), fresh tuber yield (dry tuber yield (4.42 t ha^{-1}) and forskolin yield (37.57 kg ha^{-1}) was registered with fertigation up to 5 months.

Key Words: Coleus, Forkolion, Fertigation schedule, Irrigation regime, Quality, Yield

Irrigation and nutrition are the important factors plant growth, development, yield and quality. Drip irrigation, because of lower water requirement proved successful in a wide range of crops (Bhardwaj, 2001). Coleus is generally surface irrigated once in a week during first two months and thereafter once in 10 days. The crop needs little amount of fertilizer during initial growth stages and more during post vegetative stages. If the recommended dose of fertilizer is applied in 2-3 splits with higher amount during initial growth stages and less amount during lag vegetative period, the effectiveness of the applied fertilizers is reduced considerably. Tuber initiation, tuber bulking and maturity phase are critical stages for nutrients in coleus.

Very little information is available on drip irrigation on tropical tuber crops in general and medicinal coleus in particular. The information on the effect of split application of nutrients through fertigation on biomass yield and quality in medicinal coleus is meager. Therefore, the present investigation was under taken for standardization of irrigation and nutrient schedule for drip fertigation in coleus *(Plectranthus barbatus Briq.).*

MATERIAL AND METHODS

Field experiment was conducted at College of Horticulture, University of Horticultural Sciences Campus, Gandhi Krishi Vignana Kendra, Bengaluru, during September, 2012 to February, 2013 with Coleus var. Aisiri. The experiment was laid out in factorial concept in randomized block design with 3 replications. There were nine treatments comprising of three irrigation regimes (I); I_1: 0.5 IW/CPE, I_2: 0.7 IW/CPE, I_3: 0.9 IW/CPE and three fertigation schedules (F); F_1: up to 4 months (twice in a week), F_2: up to 5 months (twice in a week), F_3: soil application as per recommended dosage (control).

Seedlings were transplanted at a spacing of 40x30 cm. First irrigation was given one day prior to transplanting followed by second irrigation on third day of planting. Subsequent irrigations through drip was given as per treatments based on the pan evaporation values from United States Weather Bureau class A open pan evaporimeter. The recommended dose of fertilizers for medicinal coleus 40:60:50 kg NPK ha^{-1} was adopted in the study. The fertilizer used for supplying NPK were urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O). In case of surface application (F_3) 50% N, full dose of P and K was applied as basal dose and remaining 50% N as top dressed at 30 DAP. In drip fertigation schedule treatments, complete P was applied to the soil as a basal dose and full N and K were given through drip up to 4 months in F_1 and up to 5 months in F_2 accounting to a total of 28 and 34 fertigation, respectively given weekly twice. Fertigation was done by regulating the taps of the laterals by allowing the nutrient solution to the specified plots as per the treatments. All intercultural operations and plant protection measures were taken as per University of Horticultural Sciences, Bagalkot package.

The morphological parameters like plant height (cm), plant spread (cm), number of lateral branches, leaf area (sq. cm plant^{-1}), dry matter accumulation and its distribution were measured at harvest (150 days). Leaf area index (LAI) were measured according to Sestak *et al*. (1971) at harvest stage. The observations on dry matter accumulation and its distribution was recorded by uprooting five plants in each treatment of random outside the net plot area and were separated into leaves, stem, tubers and were oven dried at 65^{o}C till the samples attained a constant weight The yield parameters number of tubers per plant, tubers diameter (cm), tuber length (cm), fresh weight of tubers plant^{-1}, dry weight of tubers plant^{-1}, fresh tuber yield (kg ha^{-1}) and dry tuber yield (kg ha^{-1}) were recorded from the net plot area adopting standard procedure. The moisture per cent is calculated by using the formula, Moisture in dry tubers (%) = (FW-DW)/DW X 100. Forskolin content was estimated as per the protocol given by Yanagihara *et al.* (1998).

RESULTS AND DISCUSSION

Among the irrigation schedules drip irrigation at 0.9 IW/CPE ratio recorded significantly higher canopy cover in East-West direction (58.7 cm), number of branches (51.6), leaf area (5173 cm^{2} plant^{-1}), leaf area index (4.31), fresh weight of leaves (725.7 g), dry weight of leaves (172.8 g), fresh weight of tubers plant^{-1} (395.89 g), dry weight of tubers plant^{-1} (51.48 g), fresh tubers weight (32.99 t ha^{-1}), moisture in dry tubers (6.69%) and it was at par with 0.7 IW/CPE ratio (Table 1 and 2). Irrigation at 0.7 IW /CPE recorded significantly higher plant height (82.6 cm), number of tubers plant^{-1} (25.0), tubers diameter (3.9 cm), tuber length (21.8 cm), dry tubers weight (4.45 t ha^{-1}), fresh weight of stem (1809.5 g), dry weight of stem (291.9 g), dry tuber yield (4.45 t ha^{-1}), forskolin yield ha^{-1} (37.83 kg) and it was at par with 0.9 IW/CPE ratio. The forskolin content was maximum with 0.5 IW/CPE ratio followed by 0.7 and 0.9 IW/CPE (Table 3).

Fertigation schedules showed significant influence on dry tuber yield. The maximum plant height (82.2 cm), number of branches (49.6), number of tubers plant^{-1} (25.5), fresh weight of leaves (734.3 g), dry weight of leaves (174.8 g), fresh weight of stem (1870.3 g), dry weight of stem (301.6 g), fresh weight of tubers plant^{-1} (398.77 g), dry weight of tubers plant^{-1} (53.01 g), fresh tuber yield (33.23 t ha^{-1}), dry tuber yield (4.42 t ha^{-1}) and forskolin yield ha^{-1} (37.57 kg) was registered with fertigation up to 5 months and was at par with fertigation up to 4 months. Surface application of recommended dose of fertilizers recorded significantly lower yield attributes. The forskolin content was not significant under different fertigation treatments. The moisture percentage was higher in F_3 (6.63 %). Among various fertigation schedule, canopy cover in North-South direction, canopy cover in East-West direction (cm), leaf area (cm^{2} plant^{-1}) and leaf area index (LAI) and in irrigation levels canopy cover in North-South direction was found non-significant. The interaction between irrigation levels and fertigation schedule was found non-significant for all the parameters.

Higher vegetative growth, biomass and tuber yield recorded under four and five months fertigation schedule and irrigation regime compared to soil application of fertilizer. The tuber yield under 100% NK fertigation up to 4 months combined with 0.7 and 0.9 IW/CPE and fertigation up to 5 months combined with 0.7 and 0.9 IW/CPE ratio was more compared to soil application of fertilizer with all the irrigation regimes.

Table 1. Growth parameters as influenced by irrigation and nutrient schedule for drip fertigation in coleus at harvest stage

Treatments	Plant height (cm)	Canopy cover in North-South direction (cm)	Canopy cover in East-West direction (cm)	Number of branches	Leaf area (cm^{2} plant^{-1})	Leaf area index (LAI)
Irrigation levels						
I_1: 0.5 IW/CPE	75.8	56.3	53.6	47.6	4629	3.86
I_2: 0.7 IW/CPE	82.6	60.6	57.4	50.9	5093	4.24
I_3: 0.9 IW/CPE	81.3	60.9	58.7	51.6	5173	4.31
CD (p=0.05)	5.0	NS	3.7	3.2	455	0.38
Fertilizer levels						
F_1 - up to 4 months (twice in a week)	81.3	60.2	56.5	52.6	5036	4.20
F_2 - up to 5 months (twice in a week)	82.2	60.4	57.3	49.6	5113	4.26
F_3 - soil application as per recommended dosage (control)	76.2	57.0	55.8	47.8	4746	3.95
CD (p=0.05)	5.0	NS	NS	3.2	NS	NS

Table 2. Effect of irrigation and nutrient schedule for drip fertigation on yield and quality in coleus

Treatments	Number of tubers per plant	Tuber diameter (cm)	Tuber length (cm)	Fresh tubers weight (t ha^{-1})	Dry tubers weight (t ha^{-1})	Fresh weight of leaves (g)	Dry weight of leaves (g)
Irrigation levels							
I_1: 0.5 IW/CPE	21.9	3.3	18.0	30.50	3.99	636.0	151.4
I_2: 0.7 IW/CPE	25.0	3.9	21.8	32.81	4.45	694.1	165.2
I_3: 0.9 IW/CPE	24.8	3.7	21.2	32.99	4.29	725.7	172.8
CD (p=0.05)	1.7	0.4	1.4	1.93	0.30	71.3	17.0
Fertilizer levels							
F_1 - up to 4 months (twice in a week)	25.1	3.9	21.1	32.34	4.29	716.7	170.6
F_2 - up to 5 months (twice in a week)	25.5	3.8	21.3	33.23	4.42	734.3	174.8
F_3 - soil application as per recommended dosage (control)	21.1	3.2	18.7	30.73	4.03	604.7	144.0
CD (p=0.05)	1.7	0.4	1.4	1.93	0.30	71.3	17.0

Table 3. Effect of irrigation and nutrient schedule for drip fertigation on fresh and dry weight of leaves, stem and tuber in coleus (g)

Treatments	Fresh weight of stem (g)	Dry weight of stem (g)	Fresh weight of tubers $plant^{-1}$(g)	Dry weight of tubers $plant^{-1}$(g)	Moisture in dry tubers (%) **	Forskohlin content (%)
Irrigation levels						
I_1: 0.5 IW/CPE	1573.8	253.8	366.00	47.91	6.64	0.86
I_2: 0.7 IW/CPE	1809.5	291.9	393.78	53.45	6.37	0.85
I_3: 0.9 IW/CPE	1785.9	288.0	395.89	51.48	6.69	0.85
CD (p=0.05)	140.2	22.6	23.11	3.56		NS
Fertilizer levels						
F_1 - up to 4 months (twice in a week)	1764.4	284.6	388.11	51.44	6.54	0.85
F_2 - up to 5 months (twice in a week)	1870.3	301.6	398.77	53.01	6.52	0.85
F_3 - soil application as per recommended dosage (control)	1534.4	247.5	368.77	48.39	6.63	0.85
CD (p=0.05)	140.2	22.6	23.11	3.56		NS

Higher moisture levels at the time of tuber initiation probably increased tuber development. Tuber initiation represents one of the most important stage of tuber growth. Therefore, increasing tuber number requires good growing conditions and field management. William Lamont (2004) reported that, keeping soil moisture at 85-90 per cent of field capacity during tuber initiation was necessary for good tuber setting in potato. Number of roots was maximum recorded under drip irrigation at 100 per cent PE at harvest but the tuber weight was more at 80% PE in ashwagandha (Behera *et al.,* 2012). Increased dry matter production, tuber weight and yield under higher moisture regime in coleus had been reported by Kannan (2008). Tognetti *et al.* (2003) also reported higher drip irrigation regime increased the dry matter production in sugar beet.

Continuous nutrient availability along with favourable moisture regime might have enhanced source capacity and sink strength which in turn might have influenced yield attributing characters like tuber number, tuber length and girth leading to increased tuber yield. Mohanramya *et al.* (2010) reported that the soil N application gave lower yield than the fertigated treatments in glory lily. The increase in yield was mainly due to the increase in the diameter of the tubers.

Among the fertigation schedules, fertigation up to 5 months and fertigation up to 4 months recorded the higher fresh and dry tuber yield indicating that higher proportion of nutrient application during the initial period was not necessary. This was also evidenced from dry matter production and nutrient uptake. Kaur *et al.* (2005) reported that three split applications of potassium through drip irrigation recorded higher yield in potato compared to conventional furrow irrigation and soil application of fertilizer. Fertigation with 40:40:20 Kg of NPK increased the tuber yield by 24% (Kannan, 2008).

Drip-fertigation increased the tuber yield, water use efficiency and fertilizer use efficiency compared to soil application of fertilizer in medicinal coleus. Drip irrigation at 0.7 IW/CPE ratio was optimum for medicinal coleus. Recorded higher the tuber yield was higher in fertigation of 100% NK up to 5 months (twice in a week) than fertigation up to 4 months.

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Efficacy of Different Manuring Doses for Harvesting Protein Rich Biomass of *Azolla caroliniana*

Harsimranjit Kaur, Asha Dhawan* and Meera D. Ansal

College of Fisheries
Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141 004, India
**E-mail: dhawanasha@gmail.com*

Abstract: A study was conducted to assess the effect of manuring doses on an aquatic plant *Azolla* (*A. caroliniana*) biomass production from poly-lined culture pits under local climatic conditions of Punjab. Overall results, with respect to production and nutritive value of *Azolla* biomass revealed that up to 250g of *Azolla* can be sustainably harvested daily per m^2 of culture pit with different manuring doses, without affecting the growth and nutritive value of the *Azolla mat*. Although, *different manuring doses* did not affect the water quality parameters like pH, temperature, and ortho-phosphate but ammonical-nitrogen, nitrate-nitrogen increased with increase in manuring dose in T_1 (cow dung @0.5kg m^{-2} week^{-1} and DAP @ 1g m^{-2} week^{-1}) to T_4 (cow dung @ 2kg m^{-2} week^{-1} and DAP @ 4g m^{-2} week^{-1}) and also had significant effect on crude protein (CP) content of *Azolla*. Significantly higher CP content (%) was recorded in T_4 (30.16±0.23 to 37.78 ± 0.51) and during the month of January (28.42 ± 0.50 to 37.78 ± 0.51) in all the treatments. Further, 49.87% higher protein was recorded in treatment having maximum manuring dose from the treatment having least manuring dose. However, crude fibre decreased significantly with the progress of culture period revealing an inverse relation with the CP content.

***Key Words*:** *Azolla*, Biomass, Culture, Manuring dose, Nutritive value

Supplementary feed is one of the key input in aquaculture for elevating production and constitute more than 60% of the input cost. Considering the ever increasing cost of conventional feed ingredients (rice bran, mustard meal, groundnut meal, fish meal etc.) and competition with livestock sector, it is essential to identify locally available nutrient rich low cost non-conventional feed resources (NCFR). Among various NCFR used in aquaculture, aquatic plants, like *Lemna*, *Spirodela* and *Azolla* hold great potential due to their high nutritive value, fast growth rate and low fibre content. Out of these, *Azolla* has been used as a bio fertilizer in rice field and as animal feed including fish (Basak *et al*., 2002; Pillai *et al*., 2002; Leterme *et al*., 2009; Dhawan *et al*., 2010).

Azolla is a free floating aquatic fern (Pteridophyte), belongs to the family *Azollaceae* and fixes atmospheric nitrogen through an associated cyanobacterium, *Anabaena azollae*. It is rich source of protein (13-30%, Dry matter basis), essential amino acids, vitamins and minerals (Leterme *et al*., 2009). *Azolla*, occurs naturally in ponds, ditches and rice fields of warm temperate and tropical regions throughout the world. Although, it can withstand wide range of pH (3.5 to 10.0), but it grows fast at a pH 5.5 to 7.0 under favourable climatic conditions with respect to temperature and nutrient supply. *Azolla* grows very fast under partial shady conditions and doubles its biomass in just 2-3 days and well-developed *Azolla* mat is capable of fixing atmospheric nitrogen @ 1.0-2.6 kg ha^{-1} daily and 300-600 t of *Azolla* wet biomass can be produced from 1ha water surface annually depending upon the nutrient status of water from which 20-40t of high quality protein rich dry matter can be recovered (Leterme *et al*., 2009).

Hence, *Azolla* holds great potential for utilization as bio-fertilizer (in agriculture and aquaculture) as well as fodder/feed ingredient in livestock farming, including fish (Ansal *et al*., 2010). However, it is essential to standardize region specific culture technologies for producing protein rich *Azolla* biomass in different agro climatic zones, with special reference to northern states experiencing more than 3 months of winter season, which is detrimental for growth of *Azolla.* Some region specific *Azolla* culture technologies, with an average productivity of 125-150g m^{-2}, are available (Pillai *et al*., 2002; Reddy *et al*., 2005; Giridhar *et al*., 2013) for southern states of the country. Therefore, the present study was carried out to standardize region specific package of practices for *Azolla* culture with respect to manuring doses under climatic conditions of Punjab.

MATERIAL AND METHODS

The work was undertaken at College of Fisheries, Guru Angad Dev Veterinary and Animal Sciences University Ludhiana, Punjab. *Azolla* (*A. caroliniana*) culture experiment (in triplicate) was carried out in $8m^2$ earthen pits for 160 days (August 2013 to January 2014) which include four treatments viz, T_1, T_2, T_3 and T_4 with respect to different manuring dose D_1 (cow dung @ 0.5kg m^{-2} $week^{-1}$ and DAP @ 1g m^{-2} $week^{-1}$), D_2 (cow dung @ 1kg m^{-2} $week^{-1}$ and DAP @ 2g m^{-2} $week^{-1}$), D_3 (cow dung @1.5kg m^{-2}/ week and DAP @ 3g m^{-2} $week^{-1}$) and D_4 (cow dung @ 2kg m^{-2} $week^{-1}$ and DAP @ 4g m^{-2} $week^{-1}$) with harvesting rate @ 2 kg m^{-2} $week^{-1}$ (@ 250g/m^2).

The *Azolla* culture pit was lined with silplaulin sheet to check seepage of water and nutrient loss. At the bottom of each pit 2-3cm thick soil layer was spread to hasten detritus food chain for decomposition of manure. Culture pits were covered with green net (shade- 75%) to protect *Azolla* from direct sunlight. All the pits were manured/ fertilized with slurry of cow dung and phosphate fertilizer (DAP) at different doses (T_1-T_4) to supply the required nutrients, filled with about 30 cm of water and inoculated with pathogen free *Azolla* @ 1 kg pit^{-1} after 7 days of manuring. The culture pits were regularly manured with slurry of cow dung and phosphate fertilizer (DAP) with different doses every week, for sustained supply of nutrients required for supporting fast multiplication of the *Azolla* mat. Once *Azolla* mat covered the whole water surface in the pit, *Azolla* was harvested daily @ 2kg pit^{-1} from all the treatments. Harvested *Azolla* was sundried and stored for further analysis. Water quality (temperature, pH, ammonical-nitrogen) and nutrient status (nitrate and ortho-phosphate) in each pit was analyzed on fortnightly basis as per standard methods (APHA 1991). Sun dried *Azolla* samples from each treatment were pooled separately and analyzed for proximate composition (crude protein, crude fiber, ether extract and ash) as per AOAC (2007). Due to sudden climatic changes in the month of October, the *Azolla* mat in all the treatments got damaged, which was however revived in month of November.

RESULTS AND DISCUSSION

Water quality: Growth of *Azolla* is influenced by various climatic factors like water availability, temperature, pH, nitrogen, phosphorus etc. In the present study, water pH (7.67-7.74) and temperature (22.40-22.56°C) were within favourable range required for rapid multiplication of *Azolla* in all the treatments throughout the culture period and the differences among treatments were insignificant (Table 1). In all the treatments, ammonical-nitrogen (0.24-0.43 mg L^{-1}), nitrate- nitrogen (0.47-0.78 mg L^{-1}) and ortho-phosphate (0.27-0.38 mg L^{-1}) levels were also found to be within the range reported earlier for the optimum growth of different *Azolla* species (Cary and weerts, 1992; Sherief and James, 1994;) whereas nitrate-nitrogen content increased in different treatments with increase in manuring dose.

***Azolla* biomass:** Total 60kg fresh *Azolla* biomass was harvested from each treatment every month @ 250gm^{-2} day^{-1} (@ 2.0 kg $pit^{-1}$$day^{-1}$). The daily *Azolla* harvest of 2 kg (250g

Table 1. Water quality in the different treatments during the culture period

Parameter	Treatments			
	T1	T2	T3	T4
Temperature (°C)	22.53^{a}	22.40^{a}	22.56^{a}	22.44^{a}
pH	7.71^{a}	7.67^{a}	7.74^{a}	7.74^{a}
Ammonical-nitrogen (mg l^{-1})	0.24^{b}	0.35^{a}	0.43^{a}	0.39^{a}
Nitrate- nitrogen (mg l^{-1})	0.47^{b}	0.50^{ab}	0.66^{ab}	0.78^{a}
Ortho-phosphate (mg l^{-1})	0.27^{a}	0.38^{a}	0.36^{a}	0.34^{a}

Values with same superscripts in a row do not differ significantly (P<0.05)

Table 2. Dry biomass (kg) and % dry matter content of *Azolla* harvested from different treatments

Months	Dry biomass (%)			
	T1	T2	T3	T4
August	$2.27^{c,3}$ (3.78)	$3.05^{b,2}$ (5.08)	$2.99^{b,2}$ (4.98)	$3.42^{a,1}$ (5.7)
September	$3.11^{a,2}$ (5.18)	$3.42^{a,12}$ (5.7)	$3.43^{a,12}$ (5.72)	$3.61^{a,1}$ (6.02)
November	$3.11^{a,2}$(5.18)	$3.35^{a,12}$ (5.58)	$3.60^{a,12}$ (6.00)	$3.67^{a,1}$ (6.12)
December	$3.40^{a,12}$ (5.67)	$3.66^{a,2}$ (6.10)	$3.53^{a,12}$ (5.88)	$3.65^{a,1}$ (6.28)
January	$3.56^{a,1}$(5.93)	$3.61^{a,2}$ (6.02)	$3.70^{a,1}$ (6.17)	$3.77^{a,1}$ (6.28)
Total	15.45 (5.15)	17.09 (5.69)	17.25 (5.75)	18.12 (6.04)

Values in a row with different alphabetical superscripts differ significantly (P<0.05)
Values in a column with different numerical superscripts differ significantly (P<0.05)
Figures in parentheses indicate percent dry matter of the *Azolla* dry biomass harvested

Table 3. Proximate composition of *Azolla* (% on dry matter basis)

Months	Crude protein				Ether extract				Crude fibre				Ash			
	T_1	T_2	T_3	T4	T_1	T_2	T_3	T4	T_1	T_2	T_3	T4	T_1	T_2	T_3	T4
August	22.42^{c,3}	28.44^{b,2}	30.31^{ab,23}	30.62^{a,3}	2.60^{b,3}	3.78^{a,23}	3.74^{a,3}	3.56^{a,23}	16.84^{a,1}	15.81^{a,1}	12.05^{c,2}	14.06^{b,1}	21.31^{c,2}	24.27^{a,1}	22.12^{ab,2}	22.94^{b,1}
September	21.60^{c,3}	25.71^{b,3}	29.15^{a,23}	30.18^{a,3}	3.02^{c,23}	3.54^{ab,3}	3.90^{a,23}	3.27^{bc,3}	14.67^{a,2}	13.94^{ab,2}	13.01^{b,1}	13.60^{b,1}	17.77^{b,3}	21.97^{a,2}	17.74^{b,4}	21.15^{a,2}
November	24.49^{d,2}	26.62^{c,3}	28.49^{b,3}	30.16^{a,3}	3.27^{b,2}	3.95^{a,2}	4.25^{a,23}	4.26^{a,1}	12.67^{a,3}	13.37^{a,2}	13.18^{a,1}	11.42^{b,2}	20.71^{a,2}	20.04^{ab,3}	19.53^{b,3}	18.65^{c,3}
December	28.59^{c,1}	30.48^{b,1}	31.05^{b,2}	33.49^{a,2}	3.12^{b,23}	4.47^{a,1}	4.33^{a,12}	3.47^{b,23}	12.76^{a,3}	11.82^{b,3}	11.73^{ab,2}	9.87^{c,3}	20.17^{a,2}	18.55^{b,4}	20.97^{a,23}	17.93^{b,4}
January	28.42^{d,1}	30.89^{c,1}	33.52^{b,1}	37.78^{a,1}	4.99^{b,1}	4.62^{b,1}	4.66^{b,2}	3.93^{a,12}	9.67^{a,4}	9.89^{a,4}	9.44^{a,3}	8.44^{b,4}	24.57^{ab,1}	24.30^{b,1}	26.23^{a,1}	22.85^{b,1}

Values in a row with different alphabetical superscripts differ significantly ($P<0.05$)
Values in a column with different numerical superscripts differ significantly ($P<0.05$)

m^{-2}) is sustainable from a culture pit of $8m^2$, in all the treatments without affecting growth of *Azolla* mat and it is higher than earlier reports of daily possible harvest of 500g from a $4m^2$culture pit, i.e., 125g $m^{-2}$with regular manuring dose of 1 kg cow dung and 20g super phosphate (Pillai *et al*., 2002). Dry biomass yield (kg) of *Azolla* increased along with progress of culture period in all the treatments (Table 2) and significantly higher dry biomass was recorded in *Azolla* harvested during the month of January in all the treatments. Dry biomass of *Azolla* harvested from different treatment was higher than reported by Leterme *et al.* (2009). The differences among treatments were insignificant in all the months except in August, which can be attributed to differences in culture conditions with respect to manuring and the climatic conditions (Table 2). The percent dry matter content of *Azolla* varied from 3.78-5.93%, 5.08-6.10%, 4.98-6.17% and 5.70-6.28% in treatments T_1, T_2, $T_3$and T_4 respectively during the culture period is in agreement with corresponding values (5-7%) reported by Van Hove (1989) and Leterme *et al*. (2009).

Proximate composition of sun dried *Azolla*: Among all the treatments, crude protein (CP) content of *Azolla* varied from 21.60- 37.78% and it increased significantly with increase in manuring dose from cow dung 0.5 kg and DAP 1g m^{-2} week^{-1} (T_1) to cow dung 2.0kg and DAP 4g m^{-2} week^{-1} (T_4) as well as with the progress in culture period, in all the treatments, which can be attributed to increased nutrients (N and P) in the culture medium with progress of experimental period owing to continuous manuring of the culture pits. The ether extract (EE) of *Azolla* varied from 2.60-4.99% during the culture period and the differences among treatments did not reveal any significant effect of manuring dose on the EE. However, the crude fibre (CF) content of *Azolla* decreased significantly in all the treatments and varied from 8.44-16.84% with the progress of culture period revealing an inverse relation with the CP content. Ash content of *Azolla* varied from 17.74-26.23% in all the treatments during the culture period. The overall proximate composition values (Table 3), with respect to CP, EE, CF and ash content of *Azolla*, obtained in the present studies are in agreement with those reported by Datta (2011), Pillai *et al.* (2002) and Leterme *et al.* (2009). Further, % total crude protein was increased by 24.17 in T_2 , 33.84 in T_3 and 49.87 in T_4 from treatment T_1 (Table 4).

The present study revealed that nutritive value of *Azolla*, in term of crude protein increased significantly with increasing manuring dose, but, ether extract, crude fibre and ash did not showed any particular trend, however, the values for these parameters differ significantly among treatments along with progress of culture period. Hence, best manuring

Table 4. Total crude protein production (dry matter basis) from different treatments

Treatment	Crude protein (kg)	Dry biomass (kg)	% increase in crude protein
T1	3.93	15.45	-
T2	4.88	17.09	24.17
T3	5.26	17.25	33.84
T4	5.89	18.12	49.87

dose for harvesting protein rich *Azolla* biomass (250g m^{-2} day^{-1}) is cow dung and DAP @ 2kg m^{-2} $week^{-1}$ and 4g m^{-2} $week^{-1}$, respectively.

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Effect of Integrated Nutrient Management on Growth and Yield Attributes of Indian Mustard

Vinod Kumar, Ganshyam Singh[1], Ashok K. Shrivatva, V. K. Singh, Rakesh K. Singh and Ashok Kumar

Indian Institute of Sugarcane Research, Lucknow-226 002, India
[1]Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad-224 229, India
E-mail: vinod3808@yahoo.co.in

Abstract: A field experiment was conducted to study the effect of integrated use of FYM, sulphur, PSB and inorganic fertilizers on yield and Growth. Growth and yield attribute viz. number of secondary branches plant^{-}1, leaf area index, dry matter accumulation, number of siliqua plant^{-1}, length of silique, number of seeds siliqua^{-1} and 1000 seed weight were influenced significant with treatment module of 75% NPK + FYM + PSB + sulphur closely followed by 100% NPK + PSB + Sulphur over control. The use of 75% of recommended NPK integrated with 5t FYM, 30 kg S and PSB resulted in significantly higher seed yield of mustard (18.43 q ha^{-1}) followed by 100% NPK+PSB+30Kg S ha treatment (18.05 q ha^{-1}). Balanced fertilization at right time with proper method and source increases nutrient use efficiency and productivity of Indian mustard. Twenty five per cent inorganic fertilizer can be saved by use of FYM, PSB and sulphur without any deterioration in mustard yield.

Key Words: Fertilizer, Nutrient use efficiency, Organic manure, Sustainability

India has the 5th largest vegetable oil economy in the world next to USA, China, Brazil and Argentina accounting for 7.4% world oilseed output; 6.1 % of oil meal production; 3.9% world oil meal export; 5.8% vegetable oil production; 11.2% of world oil import and 9.3% of the world edible oil consumption. Rapeseed and mustard belong to family which is grown in northern India comprising traditionally grown indigenous species namely Indian mustard (*Brassica juncea*), brown *sarson* (*Brassica campestris* var. brown *sarson*), yellow *sarson (Brassica campestris var.* yellow *sarson)*, toria *(Brassica campestris var.* toria) and taramira (*Eruca sativa*) alongwith non traditional species like gobhi *sarson* (*B. napus*), white mustard (*B. alba*) and Ethiopian mustard (*B. carinata*). At global level rapeseed-mustard crops are covering an area of 36.15 m ha with production of 71.09 mt with productivity of 19.70 q ha^{-1}, whereas India is covering area of 6.4 m ha with an average production of 8.02 mt and productivity of 12.62 q ha^{-1} during 2013-14 (*Anonymous* 2015). It is important to exploit the potential of organic manures, composts crop residues, agricultural wastes, bio fertilizers and their synergistic effect with chemical fertilizers for increasing balanced nutrient supply and their use efficiency for increasing productivity, sustainability of agriculture, and improving soil health and environmental safety.

Balanced fertilization at right time by proper method increases nutrient use efficiency in mustard (Saberi and Hassan, 2014). The integrated use of optimal dose of NPK and FYM ensures better and sustainable yields, while correcting some of the micro and secondary nutrients deficiencies. The integrated nutrients management, increasing nutrient-use efficiency, would lower the cost of production. The integrated nutrient management will also help in maintaining soil health and productivity. Phosphorus solubilizing bacteria has been proved as the important and cheapest source of phosphorus particularly in mustard crop. Integrated nutrient management has now assumed great significance mainly because of two reasons, first the need for continued increase in agricultural production based on increased in per hectare yield, requires growing application of nutrients and the present level of fertilizer production in India is not enough to meet the total plant nutrients requirements. Secondary a large number of experiments on manures and fertilizers conducted in the country revealed that neither the chemical fertilizer alone nor the organic sources exclusively can achieve the production, sustainability of the soils as well as crops under highly intensive cropping systems. Energy crisis resulted the high price index of chemical fertilizer is almost from infestation of insect, pest and diseases. The objective of present investigation was to assess the influence of integrated nutrient management on growth and yield attributes and yield of mustard with and without sulphur application.

MATERIAL AND METHODS

A field experiment was conducted on an inceptisol at Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (UP). The experimental soil was silt loam in texture pH 8.0) EC 0.36 dSm^{-1}, available N 110.7, P 17.0, K 260.0 and available S 6.4 kg ha^{-1}. The experiment was laid out in RBD replicated thrice with 16 treatments. The treatments were T_1-control, T_2-100% recommended NPK (90:60:40) kg ha^{-1}, T_3 - 75% NPK + 5t FYM, T_4 - 50% NPK + 5t FYM, T_5 - 100% Recommended NPK + PSB, T_6 - 75% NPK + PSB, T_7 - 50% NPK + PSB, T_8 - 100% Recommended NPK + S 30 kg ha^{-1}, T_9 - 75% NPK + sulphur, T_{10} - 50% NPK + sulphur, T_{11}-100% recommended NPK + PSB + sulphur, T_{12} - 75% NPK + PSB + sulphur, T_{13} - 50% NPK + PSB + sulphur, T_{14} - 75% NPK + 5t FYM + PSB + sulphur, T_{15} - 50% NPK + PSB + sulphur, T_{16} - 5t FYM + PSB + sulphur. Farm yard manure was incorporated 15 day before sowing of the crop. As per treatment 30 kg S ha^{-1} through gypsum, was drilled in row of mustard at the time of sowing. The crop was plant to plant distance 15 cm. Full dose of phosphorus potassium and half amount of nitrogen was applied as basal through urea, DAP and MOP and remaining half amount of N through urea was top dressed after first irrigation. At maturity seed yield was recorded. The seed samples were analyzed for NPK and S (Jackson, 1973). Data on growth attributes were recorded at 90 days after sowing and yield attributes at time of harvest.

RESULTS AND DISCUSSION

The initial plant population were not influenced significantly due to different fertility treatments. This might be due to uniform seed rate and sufficient soil moisture in all plots and soil environment under all treatments. Environment under all the treatments was also homogenous. Primary and Secondary branches of all the treatments were significantly superior over control. Maximum primary and secondary branches at 90 DAS were recorded in the treatment supplied 75% NPK+5t FYM+ PSB+ Sulphur, this might be due to sufficient supply of required nutrient and soil environment. Availability of nutrients in adequate amount resulted sufficient formation of photosynthates which translocation in growing parts of plants, which promote the metabolic activities, accelerated cell division and formation of meristematic tissues, ultimately enhanced the number of branches. These results are in conformity with the findings of Singh and Sinsinwar (2006) and Kumar *et al.* (2007).

Plant height: Plant height at 90 DAS was significantly enhanced by the nutrient management module over control. Maximum increment in plant height at all stages were recorded under treatments consisting FYM either alone or in combination with PSB and sulphur, at both fertility levels. Increase in plant height may be attributed due to the fact that higher nutrient absorption and beneficial effect causing accelerated rate of photosynthesis, assimilation, cell division and vegetative growth. These results are in agreement with the findings of Singh and Sinsinwar (2006) and Kumar *et al.* (2007).

Number of leaves plant^{-1} and leaf area index (LAI): Number of leaves and leaf area index were very much influenced with all the treatments and significantly superior over control. Maximum number of leaves and leaf area index at 90 DAS and at harvest were recorded in the treatment supplied 75% NPK+5t FYM+PSB+ sulphur. This might be due to sufficient supply of required nutrient and favorable soil environment condition provided by treatment. Availability of nutrients in adequate amount resulted sufficient formation of photosynthates, which promote the metabolic activities, accelerated cell division and formation of meristematic tissues, ultimately enhanced the number of leaves. These results are in conformity with the findings of Singh and Sinsinwar (2006).

Dry matter accumulation: Dry matter accumulation at different growth stages in mustard was significantly influenced by nutrient management modules over control. Maximum increment in dry matter accumulation was observed in treatment supplied 75% NPK+5t FYM+PSB+ Sulphur. The increase in dry matter accumulation may be due to improved in plant height, number of branches, number of leaves and other morphological and biological characters. This may be due to stimulated growth which produced photosynthetic surface and assimilation for all round development of plant which ultimately enhanced the dry matter accumulation in treatments of 75% RDF. These results corroborates with the findings.Treatment consisting 75% RDF were found superior in dry matter accumulation in mustard in comparison to treatment consisting 50% RDF. Singh and Kumar and Kumar (2008) and Pal *et al.* (2008) also reported similar findings.

Days taken to 50% flowering: Days take to 50% flowering were not influenced significantly due to different fertility modules. This might be due to inherent character of the variety used in all plots and environment under all treatments was also homogeneous.

Number of siliqua plant^{-1}, length of siliqua, seeds siliqua^{-1} and test weight: Number of siliqua plant^{-1}, seeds siliqua^{-1} and test weight as influenced by various nutrient management modules revealed that maximum number of siliqua plant^{-1}, seeds siliqua^{-1} and test weight were recorded with the application of 75% NPK + 5t FYM + PSB + Sulphur. All the treatments were found significantly superior over control. Increased number of siliqua plant^{-1}, seeds siliqua^{-1} and test weight with these treatments could be explained on the basis of balanced nutrient supply which enhances cell division, photosynthesis and later on converted into

Table 1. Effect of integrated nutrient management on growth attributes of Indian mustard

Treatments	Initial plant population running metre^{-1}	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}	Plant height (cm)	Number of leaves plant^{-1}	Leaf area index	Dry matter accumulation (g plant^{-1})	Days taken to 50 % flowering
T_1	6.06	6.09	6.08	6.08	42.10	2.75	32.17	45.08
T_2	6.74	6.77	6.75	6.76	55.78	4.08	72.93	53.15
T_3	6.40	6.43	6.41	6.42	54.53	3.95	69.84	52.53
T_4	6.40	6.43	6.41	6.42	53.13	3.80	64.42	51.68
T_5	7.07	7.11	7.09	7.10	58.25	4.15	73.83	53.53
T_6	6.40	6.43	6.41	6.42	53.23	3.86	68.95	52.05
T_7	6.40	6.43	6.41	6.42	52.30	3.65	63.66	51.23
T_8	7.07	7.11	7.09	7.10	59.81	4.23	74.13	53.76
T_9	6.40	6.43	6.41	6.42	53.50	3.90	69.13	52.14
T_{10}	6.40	6.43	6.41	6.42	52.49	3.71	64.00	51.50
T_{11}	7.07	7.11	7.09	7.10	62.68	4.39	74.41	54.15
T_{12}	6.40	6.43	6.41	6.42	54.00	3.92	69.38	52.29
T_{13}	6.75	6.78	6.76	6.77	52.60	3.76	64.15	51.58
T_{14}	7.07	7.11	7.09	7.10	65.48	4.58	74.95	54.54
T_{15}	6.40	6.43	6.41	6.42	53.43	3.82	64.52	51.74
T_{16}	6.06	6.09	6.08	6.08	47.71	3.10	38.12	49.73
CD (p=0.05)	NS	1.47	2.39	16.69	6.62	0.47	9.1	NS

Table 2. Effect of integrated nutrient management on yield attributes and yields of mustard

Treatments	Number of siliquae plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}	1000 seed weight	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index (%)
T_1	199.00	5.83	10.00	3.53	10.00	42.00	19.21
T_2	250.00	6.98	12.50	4.49	16.74	58.70	22.18
T_3	238.50	6.88	12.00	4.01	16.21	57.35	22.03
T_4	234.00	6.45	11.49	3.82	15.46	55.38	21.82
T_5	254.50	7.03	12.73	4.42	17.03	59.05	22.38
T_6	234.50	6.76	11.60	3.87	15.68	56.05	21.84
T_7	229.00	6.27	10.68	3.72	15.08	54.87	21.55
T_8	258.00	7.23	12.93	4.53	17.42	59.58	22.61
T_9	236.00	6.80	11.63	3.87	15.82	56.35	21.91
T_{10}	231.00	6.35	10.83	3.77	15.32	55.08	21.75
T_{11}	265.00	8.06	13.25	4.69	18.05	60.30	23.03
T_{12}	237.00	6.82	11.66	3.91	15.97	56.74	21.96
T_{13}	232.50	6.39	10.90	3.79	15.40	55.24	21.79
T_{14}	285.00	8.55	14.10	5.05	18.43	60.73	23.27
T_{15}	235.50	6.47	11.43	3.94	15.63	55.64	21.91
T_{16}	212.50	5.98	11.05	3.73	12.75	51.85	20.27
CD (p=0.05)	28.98	0.82	1.42	0.5	2.32	6.8	NS

reproductive phase resulted more number of siliqua plant^{-1}, seeds siliqua^{-1} and test weight. Similar findings were also reported by Patel *et al.* (2009).

Grain yield and Harvest index of mustard: Grain yield and harvest index of mustard was significantly influenced by nutrient management module. Maximum increment in grain and harvest index was observed in treatment supplied 75% NPK + 5t FYM + PSB + Sulphur. The increase in grain yield and harvest index may be due to improve in yield attributes, morphological and biological characters and better translocation of photosynthates from source to sink. These results corroborates with the findings of Gauri Shankar *et al.*

(2002). Treatment consisting 75% RDF were found superior in seed yield and harvest index of mustard in comparison to treatment consisting 50% RDF. This may be due to stimulated growth which produced photosynthetic surface and assimilation for all round development of reproductive structure which ultimately enhanced the yield attributing characters in treatments of 75% RDF. This might be also due to better translocation of photosynthates from vegetative parts to seed, which increases the proportion of seed yield in total biological yield, ultimately increased the harvest index of the crop. The result was conformity with the findings of Chaudhary *et al.* (2008) and Patel *et al.* (2009).

In the light of present investigations, it may be concluded that growth parameters viz., number of primary and secondary branches, plant height, yield attributing charters and grain yield of mustard was recorded maximum under treatment module of 75% NPK + FYM + PSB + Sulphur closely followed by 100% NPK + PSB + Sulphur. Twenty five per cent inorganic fertilizer can be saved by use of FYM and PSB without any loss in mustard yield. On the basis of results achieved during field investigation recommendation of nutrient management module having 75% recommended NPK + 5t ha^{-1} FYM+PSB +30 Kg S ha^{-1} can be made to the farmers of eastern Uttar Pradesh for enhanced the mustard productivity.

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Effect of Integrated Nutrient Management on Productivity of Sorghum (*Sorghum bicolor* (L) Moench) - Wheat (*Triticum aestivum* L) Cropping System under Vertisol of Marathwada, India

R. N. Khandare and W. N. Narkhede

AICRP on Integrated Farming System, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani-431 402, India
E-mail: ram.khandare11@ gmail.com

***Abstract*:** The application 50% RDF with 50% FYM recorded 26.44 q ha^{-1} and 26.06 q ha^{-1} grain yield of sorghum-wheat, respectively. The organic carbon status maintained by continuous sorghum-wheat cropping sequence up to 30^{th} year of experimentation showed variable impact on available nitrogen, phosphorus and potassium. Integrated nutrient supply had favorable effects on organic carbon build up in soil. The application of recommended dose of fertilizer had positive effects on availability of nitrogen, phosphorus and potassium. Similarly, integration of FYM or glyricidia in combination with chemical fertilizers had more favorable effects on nutrient balance in soil.

***Key Words*:** FYM-Farm yard manure, INM-Integrated nutrient management, RDF-Recommended fertilizer dose, SGEY-sorghum grain equivalent yield

Sorghum (*Sorghum bicolor* (L) Moench)-wheat(*Triticum aestivum* L) / gram (*Cicer aerientinum*) soybean (*Glycine max*)-wheat (*Triticum aestivum*), groundnut (*Arachis hypogaea*)-wheat (*Triticum aestivum*) are the most prominent crop sequences followed under irrigated condition of Marathwada region in vertisol (Central plateau region). The long term fertility experiments are good indicator for maintaining soil quality and crop productivity (Behera *et al.,* 2007). Nature of both these crop possesses a great challenge for sustainable productivity of these crop i.e., sorghum – wheat sequence. The two crop sequence exhaust more nutrient from the soil and such it become necessary to develop a sequence with efficient fertilizer management to improve the fertility of soil, integration of organic and inorganic source of nutrient is important. The main objective to develop suitable integrated nutrient supply systems for sorghum-wheat sequence with more efficient use of fertilizers in combination with organic manures by effective recycling techniques and maintain soil fertility and productivity at higher level. Hence, it is considered imperative to find out the ways and means for sustaining the productivity of sorghum-wheat cropping sequence. However, use of FYM is one of the approach for INM but wheat straw, glyricidia (*Glyricidia maculata)* and subabul (*Leucaena leucocephala)* are the alternatives under non availability of FYM (Shelke *et al*., 1997) Keeping this in view the present investigation was conducted during the rainy season (*Kharif*) and winter season (*Rabi*) of 1983-2012 at, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

MATERIAL AND METHODS

The experiment was laid out in randomized block design with three replications at same site without changing the randomization of treatments to assess the residual effect with *kharif* sorghum and winter *rabi* wheat crop. The gross and net plot was 10.8 x 9.0 and 9.00 x 7.80 m. The soil of experimental field was clayey texture with pH ranging from 8.20 to 8.32. The initial soil- test values were organic carbon 0.55%, available N 104 kg ha^{-1}, available P_2O_5 28 kg ha^{-1} and available K_2O 440 kg ha^{-1}. The availability of nutrient was low in nitrogen, medium in phosphorus and higher in potassium .The average rainfall received at Parbhani centre is 850 mm. but in the five years of experimentation average rain fall received 851.52, 1237.12, 879.58, 1071.3, 893.28 and 764.54 mm during 1983-1987, 1988-1992, 1993-1997, 1998-2002, 2003-2007 and 2008-2012, respectively during crop growth period. There were 14 treatments (Table 1), which included four levels of recommended dose of fertilizer in rainy and winter season and eight chemical fertilizers by using different organic sources like FYM, crop residue (wheat straw) and green manures (*Glyricidia maculata*, *Leucaena leucocephala)* biomass and one unfertilized control and farmer practices of manuring. Farmer practice of manuring consisted of 50% recommended dose of N P K application i.e., 40:20:20 kg ha^{-1} to sorghum and wheat 60:30:30 N P K kg ha^{-1}. The recommended dose of fertilizer to sorghum and wheat 80:40:40 and 100:50:50 N P K kg ha^{-1}, respectively. The N content in different organic materials was determined during each year and their qualities required to substitute a specific amount of recommended N was calculated. These

Table 1. Mean Fertility status of soil after the harvest of wheat crop and nutrient uptake as influenced by different treatment (1983-2012)

Treatment		Organic carbon%	Fertility status of soil (Kg ha^{-1})			Nutrient uptake (Kg ha^{-1})		
Kharif	Rabi		N	P	K	N	P	K
T_{-1} Control (no fertilizer).	Control (no fertilizer).	0.44	94.79	18.54	384.03	23.43	3.08	25.72
T_{-2} 50% NPK (FF)*).	50% NPK (FF)).	0.68	106.42	21.12	402.25	77.90	10.02	85.26
T_{-3} 50% NPK (FF)).	100% NPK (FF)).	0.70	114.76	22.02	421.36	93.14	12.22	97.20
T_{-4} 75% NPK (FF)).	75% NPK (FF)).	0.71	116.75	22.91	433.44	96.63	12.69	103.77
T_{-5} 100% NPK (FF)	100% NPK (FF)).	0.77	130.41	26.87	453.31	111.73	15.34	119.20
T_{-6} 50% NPK (FF)) +50% FYM.	100% NPK (FF)).	0.83	136.86	29.04	466.00	112.91	15.79	126.12
T_{-7} 75% NPK (FF)) +25% FYM.	75% NPK (FF)).	0.83	128.43	25.98	448.51	110.62	15.13	120.03
T_{-8} 50% NPK (FF) +50% Wheat straw	100% NPK (FF)).	0.82	127.27	26.62	443.36	102.89	13.56	109.64
T_{-9} 75% NPK (FF) +50% Wheat straw	75% NPK (FF)).	0.82	125.45	25.87	440.61	100.33	13.23	105.16
T_{-10} 50% NPK (FF)) +50% Glyricidia	100% NPK (FF)).	0.81	134.64	38.71	454.14	107.30	15.18	113.33
T_{-11} 75% NPK (FF)) +25% Glyricidia.	75% NPK (FF)).	0.82	132.48	27.71	452.31	101.01	13.69	110.67
T_{-12} 75% NPK (FF)) +25% Subabul.	75% NPK (FF)).	0.73	104.18	21.39	414.56	77.06	11.18	83.24
T_{-13} 50% NPK (FF)) +50% Subabul.	100% NPK (FF)).	0.82	123.56	25.28	450.10	77.87	10.87	90.11
T_{-14} Farmer's practice (40:20:20)	Farmers practices (60:30:30)	0.82	128.39	24.95	455.2	83.13	11.59	92.46
Initial			104.00	28.00	440.00			

*Fertilizer

materials were incorporated in the soil two week prior to sowing in rainy season. Standard package of practice were adopted for raising the sorghum and wheat crop in sequence. The SYI was calculated by using the following formula.

SYI = Y-SD / Y max

Where,

Y = estimated average yield of practices over years

SD = estimated standard deviation

Y max = observed maximum yield in the experiment

The N P K uptake in grain and straw were determined separately and total uptake was calculated. Soil analysis of important chemical parameters like organic carbon, available N, P and K was carried out every year by using standard methods.

RESULTS AND DISCUSSION

Crop yield and sorghum grain equivalent yield: The significant higher grain and straw yield of both the crops sorghum and wheat was recorded under treatment T-6, where nitrogen requirement of both the crop met through 50% recommended dose of N P K through chemical fertilizers + 50% N through FYM applied to the both crop which was 26.44 and 26.06 q ha^{-1} respectively (Table 2.) followed by treatment 100% recommended dose of N P K through fertilizers. The sorghum and wheat grain yield of the crop in 50 % RDF + 50% *Glyricidia* as well as *Leucaena* lopping was at par with 100% RDF. Similar, trend was observed in case of fodder and straw yield of both crops. However, the application of 50% wheat straw with 50% RDF in sorghum- wheat sequence maintains the yield level to that of 100% RDF application, below that 100% RDF the grain yield of both crop was significantly reduced in crop sequence. These results are corroborate the findings of Singh *et al.* (2008). The lowest grain yield was recorded by control treatment in sorghum- wheat sequence.

The sorghum grain equivalent yield was significantly higher recorded with application 50% RDF + 50% N through FYM in *kharif* (80.34 q ha^{-1}) and at par with 100% RDF. The significantly lower sorghum grain equivalent yield was in 50% RDF + 50%N through wheat straw/ *Glyricidia* and *Leucaena* lopping. In general, application of organic manure showed increased in grain yield as compared to application of chemical fertilizer alone during experimental period. Similar, observation was reported by Rajput and Warsi (1992) in rice –wheat rotation.

Sustainability yield index: Substitution of 50% N through FYM (T_{-6}) and 100% RDF (T_{-5}) to *kharif* sorghum and 100% RDF to *rabi* wheat produced higher sustainable yield index of 0.21 (Table 2) followed by (T-5). The treatment consists of integration of organic and inorganic fertilizers the SYI ranges

Table 2 . Grain and fodder/straw yield , sorghum grain equivalent yield (SGEY),sustainable yield index and nutrient balance as influenced by various treatments (Mean 1983-2012)

Treatment	Yield (q ha^{-1})				SGEY (q ha^{-1})	SYI For sorghum	SYI for Wheat	Nutrient balance at harvest		
	Sorghum		Wheat					N Kg ha^{-1} status at the end	P Kg ha^{-1} status at the end	K Kg ha^{-1} status at the end
	Grain	Fodder	Grain	Straw						
T_{-1}	3.14	17.89	5.90	11.98	15.22	-1.13	-0.20	-9.21	-9.46	-55.97
T_{-2}	18.28	58.35	17.15	29.00	54.74	0.09	0.35	2.42	-6.88	-37.75
T_{-3}	20.49	64.72	20.21	34.07	62.75	0.13	0.40	10.76	-5.98	-18.64
T_{-4}	22.10	68.64	20.76	33.66	66.49	0.15	0.36	12.75	-5.09	-6.56
T_{-5}	26.44	78.21	25.02	36.64	78.85	0.18	0.42	26.41	-1.13	13.31
T_{-6}	26.44	79.00	26.06	38.61	80.34	0.21	0.45	32.86	1.04	26
T_{-7}	25.89	76.09	23.41	35.83	75.81	0.21	0.40	24.43	-2.02	8.51
T_{-8}	22.70	69.45	23.54	36.80	70.53	0.16	0.41	23.27	-1.38	3.36
T_{-9}	23.18	69.95	21.75	34.64	69.04	0.07	0.36	21.45	-2.13	0.61
T_{-10}	24.68	72.66	23.26	37.42	73.16	0.18	0.43	30.64	10.71	14.14
T_{-11}	23.24	70.63	21.34	33.98	69.40	0.16	0.37	28.48	-0.29	12.31
T_{-12}	17.86	58.76	17.08	29.18	54.86	-0.40	0.30	0.18	-6.61	-25.44
T_{-13}	23.08	61.96	21.38	32.11	66.15	0.15	0.60	19.56	-2.72	10.1
T -14	24.09	63.53	23.44	38.83	69.81	0.18	0.46	24.39	-3.05	15.2
CD (p=0.05)	6.43	7.97	2.36	4.32	3.89					

between 0.21 to -1.13 for sorghum and for wheat -0.20 to 0.45. Lowest sustainable yield index was recorded in control plot of sorghum –wheat sequence.

Soil fertility: The soil analysis obtained after harvest of sorghum and wheat crops indicated that the available N, P and K content and the per cent organic carbon of the soil increased with increased levels of nutrients (Table 1). The initial status of major nutrients was 104.0 kg N, 28 kg P_2O_5 and 440.0 kg K_2O ha^{-1}. The nutrient availability recorded by the application of 50% nitrogen substituted through FYM and *Leucaena* green lopping +50% N P K through fertilizer treatment were higher as compared to 100% N, P and K alone through fertilizer. However, improvement in residual soil fertility was observed by the FYM, *Glyricidia* lopping this could be attributed due addition of organic matter and secretion of organic acids from different plant parts. Highest improvement in soil fertility was observed with FYM, *Glyricidia* and *Leucaena* lopping. These results are in line with the finding of Das *et al.* (2004). Level of organic carbon in the soil was enhanced due to addition of nutrients through organic sources. Continuous thirty years of growing *kharif* sorghum -wheat cropping system resulted in maximum organic carbon contain 0.83 % in treatment (T-6). These finding are in close agreement with the observation of Tripathi and Singh (2008).

Nutrient uptake: The maximum nutrient uptake of major nutrients was influenced due to different treatments. The maximum uptake of nutrient (112.91, 15.79, 126.12 N: P_2O_5: K_2O kg ha^{-1}) was observed in T-6 where 50% recommended N P K was applied through fertilizer and 50% N through FYM to sorghum , followed by 100 per cent recommended dose wheat followed by uptake in $T\text{-}_5$ (111.73, 15.34, 119.20 NPK, kg ha^{-1}). However, the lowest uptake was noticed in control plot, where fertilizers were not applied. The fertility of soil was the maximum 136.86 kg N: 29.04 kg P_2O_5 and 466 kg K_2O ha^{-1} at 50% recommended dose of NPK through fertilizer + 50% N through FYM to sorghum, followed by 100 per cent N P K through fertilizer to wheat crop (Table 1). Thus, application of recommended dose of N P K through organic manure also increased the fertility status of soil irrespective of the sources. Increase in the level of nutrient indicated increased uptake of nutrient. Substitution of 50% N through FYM and *Leucaena* loppings resulted in higher N, P, K uptake by sorghum in *kharif* and wheat in *rabi.* The finding is in close agreement with the results reported by the Pathak *et al*. (2005).

Nutrient balance at harvest: The nutrient balance at the end of crops revealed that maximum net gain of 32.86 Kg N 1.04 Kg P_2O_5 and 26.0 Kg K_2O was by the application of 50 per cent recommended through FYM. However, application of recommended dose of nutrient through inorganic sources recorded the loss of nutrients as compared to organic sources (Table 2). The inclusion of organic manures during *kharif* season gave the net gain in the nitrogen, phosphorous and potassium in soil. Similarly, with the addition of *Glyricidia* and *Leucaena* leaves also provide promising increase in nutrient content in soil. Nutrient application through organic manure FYM reduces loss of nutrient ultimately increased the N P K balance in soil at the end of both the crops. Similar, results are reported by Charjan and Gaikwad (2005).

It is concluded that the application of 50% recommended dose of fertilizer through FYM/*Glyricidia* leaves and 50% N from chemical fertilizer to *kharif* sorghum and 100% recommended dose of fertilizer to wheat crop gave maximum yield with maintenance of nutrient status in soil.

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Impact of Nitrogen and FYM Doses on Performance of Japanese Pear (*Pyrus pyrifolia* Nakai) cv. Punjab Beauty

Shahroon Khan, R. K. Godara, Ashwani Kumar, Mohammad Amin[1], Manjeet Singh[2]

Department of Horticulture; [1] Department of Soil Science, [2]Department of Plant Pathology
Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004, India
E-mail-shahroonkhan25@gmail.com

Abstract: The experiment comprising of five levels of nitrogen, i.*e*., 0, 200, 400, 600 and 800 g plant^{-1} and three levels of farm yard manure (FYM), *i.e*., 30, 60 and 90 kg plant^{-1} was laid out in randomized block design. The observations were recorded on growth and yield parameters of pear. Plant growth in terms of shoot length, number of leaves, initial fruit set, final fruit retention and number of fruits per tree was maximum with nitrogen 800g and FYM 90 kg plant^{-1}. The treatment combination of nitrogen 600g and FYM 90 kg plant^{-1} was optimum for fruit weight, fruit length and yield.

Keywords: Farm yard manure, Fruit set, Fruit weight, Pear, Shoot length

Japanese pear (*Pyrus pyrifolia* Nakai), a member of Rosaceae family, which is next only to apple in importance, acreage and production, is one of the most important temperate and subtropical fruit crops of Northern India. It grows wild in temperate regions of Europe and Western and Central Asia. In India, pear is mainly grown in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Punjab and Haryana. However, selection and development of low chill cultivars had made its cultivation possible in subtropical region also. The low chill requiring cultivars like Le Conte, Patharnakh and baggugosha are quite successful in northern plains of India. In Punjab and Haryana, the major area is under sandy pear (Patharnakh) and area under semi-soft pears (Le Conte and baggugosha) is increasing at a faster rate. The quality of semi-soft pears is good and fetches premium price in the market.

The nutrition management in crops is a complex subject involving interplay of many factors. The physico-chemical conditions of the soil in the rhizosphere, the agro-climatic parameters and the cultural practices are important considerations for evolving the nutrient strategy. The continuous growth of the trees, changing root zone and its nutrient absorbing efficiency with the advancing age, varying nutrient needs during seasons and age of plant, and the dynamic nutrients status of soil are to be satisfied through a regulated supply of the nutrients to meet the demand of plants at a particular stage. The performance of fruit crop was evaluated in terms of growth and yield. Therefore, the hypothesis of supplemental application of nutrients has been proposed and probed. Since, little work has been done on Japanese pear in India especially Haryana; therefore, the study was undertaken to evaluate the impact of nitrogen and FYM doses on performance of Japanese pear.

MATERIAL AND METHODS

The experiment was carried out at CCS Haryana Agricultural University, Hisar during 2012-13 on 11 years old uniform trees of semi-soft pear cv. Punjab Beauty grafted on Kainth seedling (*Pyrus pashia*) rootstock (6×6 m spacing). Uniform set of cultural practices were followed throughout the course of investigation. The climate of Hisar is semiarid with very hot summer from May to July, humid and warm in monsoon season and cold in winter months. The total rainfall received was around 180.6 mm during the study period. The soil of the orchard was sandy loam in texture with organic carbon 0.37 per cent, pH 7.8, electrical conductivity 0.48 dSm^{-1}, nitrogen 83 kg ha^{-1}, phosphorus 17 kg ha^{-1} and potassium 348 kg ha^{-1}. The soil fertility status of experimental orchard field was determined before the start of the experiment. The experiment was planned in a randomized block design with three replications. The treatments consisted of five levels of nitrogen (0, 200, 400, 600 and 800 g N plant^{-1}) and three levels of FYM (30, 60 and 90 kg plant^{-1}). Basal dose of 2 kg single super phosphate and 1.5 kg muriate of potash tree^{-1} were applied in December. The data on various parameters of tree growth, fruit set and yield was recorded. The annual extension growth of four current season shoots (light green in colour) were randomly selected on branches from all around the tree and height was recorded with the help of a scale. The number of leaves shoot^{-1} was counted on all tagged shoots on all the sides of tree. Four branches, one on each side of the tree, were marked and the total number of flowers was counted. The observations on fruit set were recorded at the stages of petal fall in first fortnight of April. The total number of fruits was counted in 2nd fortnight of July. The average weight of ten randomly selected fruits from each treatment was recorded. The average length of ten randomly selected fruits was measured with the help of Vernier's calliper. The yield was calculated by multiplying the number of fruits with average fruit weight.

RESULTS AND DISCUSSION

The shoot growth of pear trees significantly increased with increasing doses of nitrogen (Table 1). The maximum shoot length (0.309 m) was recorded with application of 800 g nitrogen per plant followed by 600 g nitrogen per plant and minimum (0.203 m) without nitrogen. Furthermore, the shoot length was significantly affected by different doses of FYM. The maximum shoot length (0.300 m) was recorded with 90 kg FYM plant^{-1} followed by 60 kg FYM plant^{-1}. The interaction between nitrogen and FYM was found significant. Shoot length (0.350 m) was maximum in plants supplied with 800 g nitrogen and 90 kg FYM plant^{-1} followed by 600 g nitrogen and 90 kg FYM plant^{-1} whereas, minimum shoot length (0.163 m) with 0 g nitrogen and 30 kg FYM plant^{-1}. Similar results were reported by Yadav and Bist (2003) in pear cv. Bagugosha and Kumar and Chandel (2004) in pear cv. Red Bartlett. The number of leaves shoot^{-1} of pear plant significantly increased with increasing doses of nitrogen (Table 1). The maximum (17.11) number of leaves was recorded with nitrogen at the rate of 800 g plant^{-1} followed by 600 g plant^{-1} and minimum in control. Moreover, the number of leaves was significantly affected by different doses of FYM. The maximum number of leaves (16.20) was with 90 kg FYM plant^{-1} followed by 60 kg FYM plant^{-1} (13.40), whereas, the minimum (10.67) was observed with 30 kg FYM plant^{-1}. The interaction between nitrogen and FYM was significant. Number of leaves (20.33) was registered maximum in plants supplied with 800 g nitrogen and 90 kg FYM plant^{-1}, which was at par with 600 g nitrogen and 90 kg FYM plant^{-1}.

Initial fruit set (expressed in percentage) increased with increasing levels of nitrogen (Table 2). The maximum initial fruit set (6.24%) was recorded with application of 800 g nitrogen plant^{-1} followed by 600 g nitrogen plant^{-1} and minimum (4.00%) without application of nitrogen. Furthermore, the initial fruit set percentage was significantly affected by different doses of FYM. The maximum fruit set (6.11%)) was with 90 kg FYM plant^{-1} whereas, the minimum (4.34%) was observed in plant with 30 kg FYM plant^{-1}. The interaction between nitrogen and FYM was significant. Initial fruit set was maximum in plants supplied with combination of 800 g nitrogen and 90 kg FYM plant^{-1}, which was at par with 600 g nitrogen and 90 kg FYM plant^{-1}. These finding are supported by Yadav and Bist (2003) in pear cv. Bagugosha. The possible increase in initial fruit set might be attributed to the fact that nitrogen and FYM play important role in various metabolic processes and translocation of various metabolites which improve fruit bud differentiation and flower intensity (Kashyap *et al*., 2012). A favourable C: N ratio predisposes physiological condition in plants for flowering and fruiting. The supplementary application of nitrogen might have forced the latent buds to flower.

The final fruit retention in pear plant increased with increasing levels of nitrogen (Table 2). The maximum fruit retention was with application of 800 g nitrogen plant^{-1} followed by 600 g plant^{-1}. In addition to this, final fruit retention was significantly affected by different doses of FYM. The maximum final fruit retention was with 90 kg FYM plant^{-1} followed by 60 kg FYM plant^{-1}. The interaction between

Table 1. Effect of nitrogen and FYM on shoot length (m) and number of leaves on shoots of pear cv. Punjab Beauty

FYM (kg plant^{-1})	Nitrogen (g plant^{-1})					Mean
	0	200	400	600	800	
			Shoot length (m)			
30	0.163	0.189	0.211	0.243	0.260	0.213
60	0.205	0.228	0.259	0.287	0.317	0.259
90	0.241	0.265	0.304	0.338	0.350	0.300
Mean	0.203	0.227	0.258	0.289	0.309	
CD (p=0.05)	Nitrogen 0.061, FYM 0.050, Nitrogen x FYM 0.105					
			Number of leaves on shoot			
30	7.33	9.00	11.00	12.00	14.00	10.67
60	10.00	12.00	13.00	15.00	17.00	13.40
90	12.00	13.33	16.00	19.33	20.33	16.20
Mean	9.78	11.44	13.33	15.44	17.11	
CD (p=0.05)	Nitrogen 0.78, FYM 0.60, Nitrogen x FYM 1.35					

nitrogen and FYM was significant. The final fruit retention percentage (25.65%) was maximum in plants supplied with 800 g nitrogen and FYM 90 kg plant^{-1}, which was at par with 600 g nitrogen and 90 kg FYM plant^{-1} whereas, minimum was (16.57 %) without nitrogen application and 30 kg FYM plant^{-1}. The increase may be attributed to the fact that FYM helps to retain and conserve soil moisture while as, nitrogen decreases fruit drop thereby increases final fruit retention.

Number of fruits plant^{-1} influenced with increased levels of nitrogen and FYM (Table 2). The maximum (308.4) number of fruits was harvested with application of 800 g nitrogen/plant followed by 600 g nitrogen plant^{-1} (290.0) and minimum (234.0) without application of nitrogen. The number of fruits was significantly affected by different doses of FYM. The maximum number of fruits (284.3) was harvested with 90 kg FYM plant^{-1} followed by 60 kg FYM plant^{-1}, which was at par with 30 kg FYM plant^{-1}. The interaction between nitrogen and FYM was significant. Maximum number of fruits (323.7) was harvested in plants supplied with combination of 800 g nitrogen and 90 kg FYM plant^{-1}, which was at par with 600 g nitrogen and 90 kg FYM plant^{-1} (318.0), whereas, minimum (222) number of fruits with 0 g nitrogen and 30 kg FYM plant^{-1}, which was at par with 200 g nitrogen and 30 kg FYM plant^{-1}.

Similar results were observed by Roan *et al*. (1997) in sandy pear. It might be due to specific role of nitrogen and FYM in various metabolic processes which improve fruit bud differentiation, flower intensity, higher ratio of perfect male flowers, more fruit set and final fruit retention.

Fruit weight increased with increasing nitrogen and FYM levels (Table 3). The results reveal that fruit weight was maximum (107.11 g) with application of 800 g nitrogen plant^{-1}, which was at par with 600 g plant^{-1} and minimum without application of nitrogen. The fruit weight was significantly affected by different doses of FYM. The maximum fruit weight (107.68 g) was recorded with 90 kg FYM plant^{-1} whereas, the minimum fruit weight was observed in fruit with 30 kg FYM plant^{-1}. The interaction between nitrogen and FYM was found significant. Fruit weight (114.21g) was maximum in plants supplied with 800 g nitrogen and 90 kg FYM plant^{-1}, which was at par with 600 g nitrogen and 90 kg FYM plant^{-1} (113.87 g). Similar results were reported in pear cv. Red Bartlett by Kumar and Chandel (2004). The increase in fruit weight with the application of nitrogen and FYM might be due to the fact that nitrogen, phosphorus and potash sufficient plants have better capability for CO_2 assimilation (Kashyap *et al*., 2012). It leads to higher rate of synthesis and supply of carbohydrates in the plants. The fruits are very strong sink for carbohydrates, so more carbohydrates would be transported to the fruits in case of trees well supplied with nitrogen.

The fruit length significantly increased with increased levels of nitrogen and FYM (Table 3). The fruit length was maximum (6.41 cm) with application of 800 g nitrogen plant^{-1}, which was at par with 600 g plant^{-1} and minimum (6.09 cm) without application of nitrogen. The

Table 2. Effect of nitrogen and FYM on initial fruit set, fruit retentionand number of fruits of pear *cv*. Punjab

FYM (kg plant^{-1})	Nitrogen (g plant^{-1})					Mean
	0	200	400	600	800	
30	3.25	3.75	4.35	4.90	5.45	4.34
60	4.00	4.65	5.15	5.78	6.18	5.15
90	4.76	5.30	6.45	6.95	7.10	6.11
Mean	4.00	4.57	5.32	5.88	6.24	
CD (p=0.05)	Nitrogen 0.11,FYM 0.09, Nitrogen x FYM 0.20					
Fruit retention (%)						
30	16.57	17.73	18.86	20.17	21.53	18.97
60	18.12	19.78	20.85	22.61	23.75	21.02
90	18.95	21.45	23.45	25.14	25.65	22.92
Mean	17.88	19.65	21.05	22.64	23.64	
CD (p=0.05)	Nitrogen 0.34,FYM 0.26, Nitrogen x FYM 0.59					
Number of fruits plant^{-1}						
30	222.0	233.7	258.0	264.3	292.3	254.0
60	236.7	234.7	256.7	287.7	309.3	265.0
90	243.3	254.3	282.0	318.0	323.7	284.3
Mean	234.0	240.9	265.6	290.0	308.4	
CD (p=0.05)	Nitrogen 11.4, FYM 11.1, Nitrogen x FYM 12.5					

Table 3. Effect of nitrogen and FYM on fruit weight of pear cv. Punjab Beauty

FYM (kg plant^{-1})	Nitrogen (g/plant^{-1})					Mean
	0	200	400	600	800	
30	80.50	83.42	88.33	92.20	97.11	88.31
60	85.69	99.83	103.19	106.49	110.00	101.04
90	93.14	105.69	111.47	113.87	114.21	107.68
Mean	86.44	96.31	101.00	104.19	107.11	
CD (p=0.05)	Nitrogen 3.45, FYM 3.35, Nitrogen x FYM 2.28					
	Average fruit length (cm)					
30	5.97	6.02	6.09	6.17	6.23	6.10
60	6.08	6.27	6.33	6.41	6.47	6.31
90	6.21	6.43	6.46	6.51	6.53	6.43
Mean	6.09	6.24	6.29	6.36	6.41	
CD (p=0.05)	Nitrogen 0.07, FYM 0.05, Nitrogen x FYM N.S.					
	On yield (kg tree^{-1})					
30	17.87	19.48	22.81	24.38	28.37	22.58
60	20.29	23.46	26.49	30.62	34.04	26.98
90	22.68	26.88	31.46	36.23	36.97	30.84
Mean	20.28	23.27	26.92	30.41	33.13	
CD (p=0.05)	Nitrogen 3.15, FYM 3.12, Nitrogen x FYM 3.27					

maximum fruit length (6.43 cm) was recorded with 90 kg FYM plant^{-1} followed by 60 kg FYM plant^{-1} whereas, the minimum fruit length was observed in fruit with 30 kg FYM plant^{-1}. The interaction between nitrogen and FYM was non-significant. This might be attributed to the fact that increase in fruit weight with the addition of nutrients occurs due to increase in synthesis of chlorophyll resulting in improved photosynthetic activities of plants (Sidhu and Thakur, 2006). The reasons expressed for greater fruit weight may also hold good for greater fruit length.

There was a significant increase in fruit yield with increasing doses of nitrogen and FYM (Table 3). The fruit yield was maximum (33.13 kg) with application at the rate of 800 g nitrogen plant^{-1} that was at par with 600 g plant^{-1} (30.41 kg) and minimum (20.28 kg) without application of nitrogen. The maximum fruit yield was with 90 kg FYM plant^{-1} followed by 60 kg FYM plant^{-1}, whereas, the minimum fruit yield was with 30 kg FYM plant^{-1}. The interaction between nitrogen and FYM was found significant. Fruit yield (36.97 kg) was recorded maximum in plants supplied with 800 g nitrogen and 90 kg FYM plant^{-1}, which was at par with 600 g nitrogen and 90 kg FYM plant^{-1} (36.23 kg), whereas, minimum (17.87 kg) fruit yield with 0 g nitrogen and 30 kg FYM plant^{-1}. This is because; firstly the fruit set was improved with application of nitrogen and FYM. Secondly, fruit weight significantly increased and final fruit retention increased with application of nitrogen and FYM.

The study indicates that the maximum increase in shoot length, number of leaves per shoot, initial fruit set, final fruit retention and number of fruits per tree was with optimum dose of nitrogen (800 g tree^{-1}) and highest dose of FYM (90 kg tree^{-1}).

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Impact of Long Term Integrated Nutrient Management on Groundnut Yield and Soil Properties in Scarce Rainfall Zone of Andhra Pradesh, India

M. Vijaysankar Babu, K. C. Nataraja, A. Srihari, B. Sahadeva Reddy, G. Ravindrachary and Ch. Srinivasa Rao

Agricultural Research Station, Acharya NG Ranga Agricultural University, Anantapur -515 001, India
E mail: vijay7970@rediffmail.com

Abstract: The impact of long-term integrated nutrient management on groundnut yield, soil properties and organic carbon stocks were higher soil organic carbon with application of organics alone and with chemical fertilizers. The initial available phosphorous content 44 kg ha^{-1} increased to 103 kg ha^{-1} with continuous application of chemical fertilizers, while depleting the P content in the control. Significantly higher organic carbon stocks of 12.31 t ha^{-1} recorded in the treatment with 50% RDF+FYM @ 4t ha^{-1}. The soil bulk density reduced over a period of time. Significant higher pod yield was recorded in half RDF+ FYM @ 4 t ha^{-1} (937 kg ha^{-1}).

Key Words: Groundnut yield, INM, Organic carbon stock, Soil properties

Indian agriculture comprise of 58 per cent of the net cultivated as rainfed farming. The rainfed farming is practiced in arid, semi-arid and sub-humid climatic zones, with annual rainfall of 500–1500 mm (Singh *et al.,* 2004). It is estimated that by 2020 about 600 million people would be living in regions of predominantly rainfed farming. Thus, the per capita land availability in these regions is projected to decrease from 0.28 ha in 1999 to 0.12 ha by 2020 (CRIDA 2004). These regions are characterized by erratic rainfalls with uneven periodicity and distribution, poor infrastructure, degraded soils of low organic matter and plant nutrient contents, and low soil moisture reserves (Srinivasarao *et al*., 2012).

In this context of rainfed farming, the predominant system of groundnut mono-cropping in red sandy loam soils of Anantapur district of Andhra Pradesh is needs better nutrient management strategies to sustain the yield levels. The groundnut productivity in this area reached the lowest plateau of 0.8 t ha^{-1}. Low soil fertility is one of the reasons for the low productivity besides low rainfall and frequent occurrence of dry spells. The nutrient use efficiency (NUE) in rainfed ecosystem may be improved through integrated nutrient supply system. Loss of organic matter either by erosion or high temperatures in this ecosystem aggravates nutrient deficiencies. Judicious use of organic manures such as FYM and farm wastes along with chemical fertilizers improves soil physical, chemical and biological properties and improves groundnut productivity. It is essential to identify such practices which bring more sustainability to the production system besides improving the productivity (Balaguraviah. *et al*., 2005). The limited availability of crop residues is the major constraint for practicing INM, which is also exacerbated by low biomass productivity and numerous competing uses (feed, cooking fuel, fencing, etc.). Yet, some crop by-products such as groundnut shells (GNS) are available for use as soil amendments because of a fewer alternate uses. The GNS, containing 1.0, 0.25 and 1.1 % of N, P and K, respectively, almost higher than in farm yard manure (FYM), can be an important component of INM system especially in communities with large area under groundnut. Thus, availability of GNS can be used as a soil amendment to increase pod yields (Srinivasarao *et al.,* 2012). The objective of the present study was to examine the long-term effects of recycling of farm wastes along with or without chemical fertilizers on soil properties and crop yield in a semiarid agro ecosystem.

MATERIAL AND METHODS

A long-term experiment was initiated in the 1985 rainy season (June–October) at the Agricultural Research Station, Anantapur, Andhra Pradesh, India (77° 40' longitude, 14° 42'; latitude, 350 MSL). The climate of the site is arid tropical, with a mean annual rainfall of 526 mm, of which the major portion is received during *kharif* season (June–October). Soil of the experimental site is classified as Rhodostalfs (Voyalpadu soil series). The landscape is characterized by <1% slope, sandy loam in texture, low in organic carbon and available nitrogen, medium in phosphorus, (P_2O_5; 20 kg ha^{-1}) and Potassium (K_2O; 155 kg ha^{-1}). The test crop was groundnut (TMV-2) mono-cropping (1985–2014). The treatments were T_1: Control (no fertilizer); T_2:100 % RDF (20:40:40 N, P_2O_5, K_2O); T_3: 50 % RDF; T_4:

GNS @ 4 t ha^{-1}; T_5: FYM @ 4 t ha^{-1}; T_6 :T_3 + T_4; T_7 :T_3 + T_5; T_8 :T_2 + $ZnSO_4$ @50 kg ha^{-1} (once in three years); T_9 :FYM @ 5 t ha^{-1} replicated thrice in Randomised Block Design. The soil samples were analyzed for physical, physico-chemical and chemical properties by following the standard procedures. The quantity of carbon stock in each depth was calculated by following the method described by Batjes (1996). The procedure follows the multiplying bulk density (t m^{-3}) and thickness of particular horizon (m) with the total carbon (g C g^{-1} soil) of that layer. Soil samples were also analyzed for SOC concentration (Nelson and Sommers, 1996), Organic C stock (t ha^{-1}) = Soil Organic C (g g^{-1}) in that horizon x Bulk density (t m^{-3}) x depth (m) and expressed on a per hectare basis (Srinivasa Rao *et al.,* 2013).

RESULTS AND DISCUSSIONS

Long term application of organic manures, significantly increased soil organic carbon (Table 1), when applied with organics alone or with RDF. The initial available phosphorous content (44 kg ha^{-1}) increased with only 100% RFD (103 kg ha^{-1}). In the control plot, initial available phosphorous levels of 44 kg ha-1was reduced to 23 kg ha^{-1}over 30 years. Mean differential groundnut pod yield of half recommended fertilizer dose (HRFD) + FYM @ 4t ha^{-1} (937 kg ha^{-1}) was at par with recommended fertilizer dose (RFD) applied through inorganics alone (920 kg ha^{-1}). Significantly higher organic carbon (Fig.1) and organic carbon stocks of 12.31t ha^{-1} recorded in the treatment with 50% recommended fertilizers along with FYM @ 4t ha^{-1} and least was in control (4.81Mg ha^{-1}). Subehia *et al.* (2005) observed that application FYM and lime along with chemical fertilizers maintained better nutrient availability (N, P and K) over the soils where only chemical fertilizers were applied. In view of soil inherent nutrient status, the treatment with half recommended dose (10-20-20 N, P_2O_5, K_2O kg ha^{-1}) along with FYM @ 4 t ha^{-1} will be the best option, which not only giving sustainable yields but also enhancing the soil health (Fig. 2).

The soil organic carbon concentration depends largely on the annual turnover of root residues, root exudates and stubbles (Srinivasarao *et al.*, 2012). Thus the increase in SOC concentration during the experiment in the plots treated with 100 % RDF and INM treatments over the control may be explained by the greater yields through fertilization and manuring and associated greater amounts of root residues and stubbles and higher C input. Increase in SOC concentration under complete dose of NPK fertilizers and INM as compared to unfertilized control has also been reported in other long-term studies (Swarup and Wanjari, 2000).

A judicious combination of chemical fertilizers and organic amendments can improve soil fertility and enhance sustainability. In addition, the amount of rainfall and its

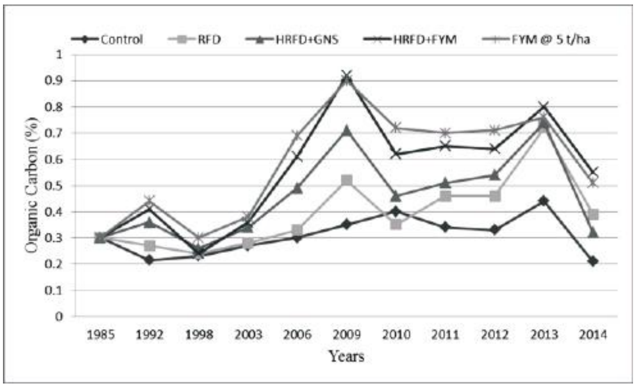

Fig. 1. Effect of INM on organic carbon (%) over years

Table 1. Effect of long term integrated nutrient management on soil properties, organic carbon stocks and mean groundnut pod yield

Treatment	pH	Organic carbon (%)	Avail. P_2O_5 (kg ha^{-1})	Avail. K_2O (kg ha^{-1})	Bulk Density (Mg m^{-3})	Organic carbon stock (Mg ha^{-1})	Groundnut pod yield kg ha^{-1} (30 years mean)
Control	5.67	0.21	23	210	1.53	4.81	713
RFD	5.03	0.39	103	382	1.57	9.20	920
Half RFD	5.37	0.36	80	345	1.58	8.54	855
GNS @ 4 t ha^{-1}	5.67	0.39	46	355	1.55	9.20	819
FYM @ 4 t ha^{-1}	6.43	0.42	48	409	1.51	9.51	879
T_3 + T_4	5.30	0.32	83	494	1.52	7.30	850
T_3 + T_5	6.50	0.55	85	393	1.48	12.31	937
T_2 + $ZnSO_4$ @50 kg ha^{-1}	5.63	0.39	107	388	1.42	8.33	896
FYM @ 5 t ha^{-1}	6.07	0.51	47	433	1.51	11.57	874
CD (p=0.05)	0.89	0.20	17.2	66.08	0.06	1.66	
Initial values	6.6	0.3	44	155	-	-	

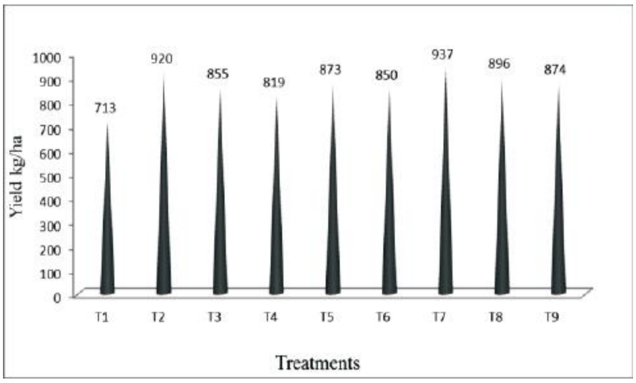

Fig. 2. Effect of long term (1985-2014 integrated nutrient management (INM) on groundnut pod yield

distribution are important to harnessing the benefits of improved soil fertility. Performance of groundnut shells (GNS) is equally good as FYM in terms of increasing yield and improving soil fertility. So it can be a viable alternative as soil amendment/organic nutrient source for improving soil fertility. Benefits of improved soil fertility with nutrient management can only be harnessed when proper distribution of rainfall is received during the growing season, or the drought stress is alleviated with application of supplementary irrigation. The P buildup in all the treatments except control, suggests the possibility of reduction of P dose or skipping P application in alternate year. However, application of organics alone could not sustain high crop yield and application of recommended dose of fertilizer alone could not sustain the soil health for sustainable groundnut yields in rain shadow regions.

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Effect of Integrated Nutrient Management on Seed Yield and Its Attributes in Fenugreek (*Trigonella foenum-graecum* L.)

Ovais Hamid Peerzada, V. S. Mor, O. S. Dahiya and S. K. Tehlan[1]

Seed Science and Technology Section Department of Genetics & Plant Breeding
[1]Department of Vegetable Science, CCS, Haryana Agriculture University, Hisar-125 004, India
E-mail: ovaishamid786@gmail.com

Abstract: A field experiment was conducted to assess the yield and yield attributes of fenugreek seed under different combinations of manures (viz., FYM & Vermicompost), bio-fertilizers (viz., Rhizobium & PSB) and fertilizers application. Experimental results revealed that the bio-fertilizer inoculation of Rhizobium and PSB alongwith 75% nitrogen of recommended dose recorded significantly higher seed yield (15.93), Plant Height (cm) (105.80), Number of branches plant^{-1} (9.70), No. of pods plant^{-1} (111.30), Pod length (cm) (9.93) and Seeds pod^{-1} (19.77) followed by Rhizobium with 100% and 75% nitrogen and PSB with 100% and 75% nitrogen. The number of Days to 50% flowering (71.67) were also recorded less in the treatment Rhizobium and PSB alongwith 75% nitrogen followed by Rhizobium with 100% & 75% nitrogen and PSB with 100% & 75% nitrogen. The study highlighted that the slightly reduced dose of inorganic nitrogen was best when applied in combination with bio-fertilizer (Rhizobium+PSB) for improving yield and yield attributing characters as compared to the rest of treatments.

Key Words: Fenugreek, FYM, PSB, Rhizobium, Vermicompost

Intensive agriculture involving use of high input for increasing production resulted in heavy removal of nutrients from the soil. Thus, there is wide gap between the nutrients removed from the soil and the nutrient supplied. This gap can be bridged with use of chemical fertilizers along with organic sources. Conjunctive use of inorganic and organic sources of nutrients not only supplies nearly all nutrients throughout the growing period of crop but also sustain soil health. Combined use of inorganic fertilizers with organic manures along with biofertilizers in general enhances microbial activity of soil and biological nitrogen fixation in particular.

The cost of inorganic fertilizers has been enormously increasing to an extent that they are out of reach of the small and marginal farmers. The use of biofertilizers in such a situation is therefore a practically paying proposal and is very essential because the insoluble phosphate which is not directly available to plants usually comprises 95-99 per cent of the total soil phosphorous. Integration of various organic manures with inorganic fertilizers and low cost bio-fertilizers inoculation not only reduces the fertilizer requirement but also an ecofriendly approach (Jeyabal *et al.,* 2000). Phosphorous solubilizers are biofertilizers, which solubilize phosphorous in soil and make it available for plants. *Rhizobium,* a heterotrophic nitrogen fixing organism has been reported to be beneficial and economical on several crops. They are known to improve growth, yield as well as productivity of crops.

Fenugreek (*Trigonella foenum-graecum* L.) is an important seed spice and is good source of water soluble protein (10.7 g/100g seed). Coriander, cumin, fennel, and fenugreek occupy the largest area among the seed spices grown in India having high export value in global market as spice mixture (Aishwat *et al.,* 2011). Integrated use of chemical fertilizers as well as organic manures along with biofertilizers in fenugreek can be a more efficient, economical and judicious approach than chemical fertilizers alone. Therefore, the study was undertaken to evaluate the effect of different combinations of organic and inorganic nutrient sources along with biofertilizers on productivity of fenugreek seed (*Trigonella foenium-graecum*).

MATERIAL AND METHODS

The research experiment was conducted in rabi season 2013-14 at CCS Haryana Agriculture University, Hisar, Haryana. The variety "Hisar Suvarna" of fenugreek was grown with the recommended cultural practices and seventeen treatment combinations were evaluated in a Randomized Block Design (RBD) in three replications (Table 1). The plot size for each treatment was 7.2m^2. The plant protection measures were taken up as and when required along with intercultural operations. *T*he biofertilizers Rhizobium and PSB were used as seed treatment @10ml/10kg of seed while FYM and Vermicompost were used @ 20t ha^{-1} and 5t ha^{-1}, respectively. The samples were analyzed for key characters i.e, number of days to 50% flower emergence, plant height, branches and pod, pod length (cm) and seeds pod^{-1} were evaluated by selecting randomly ten plants from each plot and averaged. The seed yield was recorded on whole plot basis and calculated as quintal per hectare (q ha^{-1})

RESULTS AND DISCUSSION

Days to 50% flowering were recorded earliest in treatment Rhizobium+PSB+75% nitrogen followed by Rhizobium+100% nitrogen and PSB+100% nitrogen. The late flowering was observed in the control. Earliness might be due to the enhanced production of growth substances like gibberellic acid, indole acetic acid, dihydrozeatin from bio-fertilizers which had positive influence on the physiological activity of plants which could assist the plants to induce early flowering (Aminifard *et al*., 2012 and Fathollahi *et al.,* 2014). Other yield attributes namely, plant height (cm), number of branches plant^{-1}, no. of pods plant^{-1}, pod length (cm) and seeds pod^{-1} were maximum in (Rhizobium +PSB + 75% nitrogen) followed by Rhizobium +100% nitrogen and PSB+ 100% nitrogen.

The effects due to combined application of Rhizobium + PSB + 75% nitrogen showed a significant variation from those treatments where only pure inorganic and organic sources of nitrogen were applied in relation to different yield attributes. Higher number of branches/plant in T_{15}, T_5 and T_{11} might attribute towards better results of number of pods/plant in these treatments. In T_{15} application of inorganic sources of nitrogen in combination with bio-fertilizers (*Rhizobium* and PSB) lead the plant growth favourably with the fixation of required amount of atmospheric nitrogen by *Rhizobium* which enhanced the vegetative growth resulting in higher plant height of fenugreek. Besides PSB converted the soil phosphorus into available form required for the plants. In this situation flow of assimilates to sink was high and might be the reason of higher pod length and number of seeds per pod. A synergistic interaction among the inputs in the promising treatments might contribute to the better results of yield attributes as explained from the findings of Ruveyde *et al.* (2011) and Soyam *et al.* (2012) .

In case of character seed yield q/ha a significant variation was observed in the treatment Rhizobium + PSB + 75% nitrogen in comparison to the pure inorganic and organic treatment combinations. Maximum seed yield q ha^{-1} was recorded by Rhizobium + PSB + 75% nitrogen followed by Rhizobium +100% nitrogen and PSB+ 100% nitrogen. Minimum yield was recorded in control (To) where no nutrients were applied. Among all the treatments T_{15} proved to be best which showed that greater the efficacy of inorganic nitrogen when applied in combination with bio-fertilizer

Table 1. Effect of integrated nutrient management (INM) on seed yield and its attributes in fenugreek (*Trigonella foenum-graecum* L.)

Treatments	Days to 50% flowering	Plant height (cm)	Number of branches plant^{-1}	No. of pods plant^{-1}	Pod length (cm)	Seeds pod^{-1}	Seed yield q ha^{-1}
T0 - Control	91.00	83.33	4.87	81.06	7.43	14.97	10.67
T1 - Rhizobium + FYM (100%)	77.67	95.40	7.33	102.93	8.67	18.47	14.50
T2 - Rhizobium + FYM (75%)	79.67	91.20	5.53	98.47	8.20	18.07	13.88
T3 - Rhizobium + Vermicompost (100%)	81.33	93.33	8.13	97.52	8.10	17.87	12.70
T4 - Rhizobium + Vermicompost (75%)	82.67	91.47	5.93	93.47	7.90	17.63	12.35
T5 - Rhizobium + Nitrogen (100%)	73.00	102.67	8.67	108.23	9.33	19.20	15.83
T6 - Rhizobium + Nitrogen (75%)	74.67	100.87	7.67	102.27	9.03	18.72	15.44
T7 - PSB + FYM (100%)	75.33	96.47	8.80	101.87	8.20	16.97	14.44
T8 - PSB + FYM (75%)	77.00	93.47	8.27	98.93	7.97	16.67	13.77
T9 - PSB + Vermicompost (100%)	84.33	93.93	5.93	92.07	8.07	16.70	12.60
T10 - PSB + Vermicompost (75%)	83.00	88.33	5.33	89.92	7.87	16.63	12.30
T11 - PSB + Nitrogen (100%)	73.33	102.00	8.53	105.07	9.20	18.93	15.66
T12 - PSB + Nitrogen (75%)	75.00	99.73	6.93	100.20	8.90	18.43	14.90
T13 - Rhizobium + PSB + 75%FYM	77.67	97.33	7.07	99.67	8.93	18.97	15.10
T14 - Rhizobium + PSB + 75%Vermicompost	83.33	94.07	6.47	98.00	8.40	17.67	13.05
T15 - Rhizobium + PSB + 75% Nitrogen	71.67	105.80	9.70	111.30	9.93	19.77	15.93
T16 - N:P:K	75.67	98.00	8.53	104.73	8.73	18.63	14.81
CD (p=0.05)	2.27	3.81	1.35	4.33	0.40	1.01	0.32

(*Rhizobium* + PSB). The other pure inorganic and organic treatment combinations were not able to supply the required amount of nitrogen .The results clearly indicate the necessity of application of inorganic nitrogen in combination with the said bio-fertilizers. Besides, quick availability of plant nutrient from inorganic source, fixation of the required amount of nitrogen, balanced C/N ratio, synthesis of auxin, growth substances, due to inoculation of *Rhizobium* and conversion of insoluble phosphate to soluble form by PSB perhaps helped to increase the yield of fenugreek in T_{15}. The present results are in accordance with the findings of Anitha *et al.* (2015).

From the above findings, the Integrated Nutrient Management (INM) in fenugreek revealed that the treatment Rhizobium + PSB + 75% nitrogen was best for improving yield and yield attributing characters as compared to the rest of INM treatment combinations.

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Response of Summer Groundnut (*Arachis Hypogaea* L.) to Water Soluble Foliar Fertilizers

R. P. Andhale, V. L. Amolic, B. T. Sinare, S. M. Dhadge and R. W. Bharud

Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722, India
E-mail: rpandhale@yahoo.co.in

Abstract: Field experiments were conducted on groundnut to know the effect of water soluble fertilizers on growth and yield of groundnut during summer season in western Maharashtra. The experiment comprised of 12 treatments consisting of combination of FYM and various levels of recommended dose of NPK through soil application and foliar spray of soluble fertilizers at 30, 45 and 60 days after sowing (DAS). Application of FYM @7.5 t ha^{-1} + 100% RDF + foliar spray of fertilizers at 30, 45 and 60 DAS recorded significantly higher dry pod yield (3172 kg ha^{-1}), dry haulm yield (7438 kg ha^{-1}) with maximum gross monetary returns (Rs.102330 ha^{-1}) and net monetary returns (Rs 50066 ha^{-1}). But the growth and yield was on par with the treatment receiving FYM 7.5 t ha^{-1} + 85 % RDF + foliar spray of fertilizers at 30, 45 and 60 DAS. However, the B:C ratio (2.14) was observed maximum under the treatment with application 100% RDF + Foliar spray of fertilizers at 30, 45 and 60 DAS. Therefore, it was concluded that RDF can be reduced to 85% by supplying nutrients through FYM and Foliar sprays.

Key Words: Economics, Foliar spray, Growth, Water soluble fertilizers, Yield

Groundnut (*Arachis hypogaea* L.) is an annual legume and is the source of edible oil and vegetable protein. India occupied an area of 55.27 lakh ha with production of 96.72 lakh tonnes and productivity was 1750 kg ha^{-1} during 2013-2014 (Anonymous 2014). Groundnut is one of the most important oilseed crops of Maharashtra state. The area in Maharashtra during 2013-14 is 3.2 lakh ha with annual production of 4.17 lakh tonnes with productivity of 1373 kg ha^{-1} (Anonymous, 2014). The groundnut productivity in Maharashtra is low due to several production constraints, which include poor and imbalanced nutrition of crop and growing crop on marginal lands. Therefore, it is most essential to pay a great attention to the nutrition of the groundnut to enhance its productivity by supplying adequate but balanced amounts of major and micronutrients. The nutrient requirement of groundnut is high especially at pegging and pod development stages. The requirement at these stages cannot be fulfilled merely by soil application alone and need to be supplemented through foliar application.

The foliar application seems to be promising for ensuring use efficiency of applied nutrients. Foliar spray enables plants to absorb the applied nutrients from the solution through their leaf surface and thus, may result in the economic use of fertilizer. Keeping this in view, the present investigation was planned to study the effect of water soluble fertilizers on growth and yield of groundnut during summer.

Field experiments were conducted at AICRP on Groundnut, MPKV, Rahuri during summer season 2012, 2013 and 2014. The soil of experimental site was sandy clay loam in texture, low in available nitrogen (198 kg ha^{-1}), medium in phosphorus (23 kg ha^{-1}) and high in potassium (341 kg ha^{-1}). The soil was moderately alkaline in reaction (pH 8.2) with EC of 0.45 dSm^{-1}. Field experiment was conducted in randomized complete block design with twelve treatments in three replications. The groundnut cultivar TPG-41 was used for the experiment. Treatments include combination of various levels of recommended dose of NPK and FYM through soil application at the time of sowing and foliar sprays of water soluble fertilizers at 30, 45 and 60 Days after sowing. Foliar application includes starter dose of water soluble grade fertilizer (11:36:24 + trace elements) @ 2% at 30 days after sowing + Foliar application of booster dose of water soluble grade fertilizer (8:16:39 + trace elements) @ 2% at 45 and 60 DAS. Treatments include T_1 = Absolute control (no FYM, no RDNPK and no foliar application of water soluble grade fertilizers, only water spray), T_2 = 100% Recommended dose of fertilizers (RDF) (25 kg N and 50 kg P_2O_5 ha^{-1}), T_3 = Foliar application of water soluble grade fertilizers @ 2%, T_4 = 100% RDF + Foliar application of water soluble grade fertilizer @ 2%, T_5 = 100% RDF + FYM@ 7.5 t ha^{-1}, T_6 = 100% RDF + FYM@ 7.5 t ha^{-1} + Foliar application of water soluble grade fertilizer @ 2%, T_7 = 85% RDF + FYM@ 7.5 t ha^{-1}, T_8 = 85% RDF + FYM@ 7.5 t ha^{-1} + Foliar application of water soluble grade fertilizer @ 2%, T_9 = 60% RDF + FYM@ 7.5 t ha^{-1}, T_{10} = 60% RDF + FYM@ 7.5 t ha^{-1} + Foliar application of water soluble grade fertilizer @ 2%, T_{11} = 35% RDF + FYM@ 7.5 t ha^{-1}, T_{12} = 35% RDF + FYM@ 7.5 t ha^{-1} + Foliar application of water soluble grade fertilizer @ 2%. The growth and yield observations were recorded at the time of harvest.

The growth of groundnut is intense from 30 to 70 days after sowing. Therefore, synchronizing the nutrient

Table 1. Pooled data on growth and yield attributes as influenced by various treatments in summer groundnut

	Treatment	Plant height (cm)	No of branches $plant^{-1}$	Dry matter $plant^{-1}$ (g)	No of pods $plant^{-1}$	Weight of pods $plant^{-1}$ (g)	Shelling (%)	SMK (%)
T1	Absolute control	22.46	5.21	35.95	10.30	9.73	61.77	88.44
T2	100 % RDF (25 : 50 : 00 NPK kg ha^{-1})	23.85	5.87	48.63	14.59	13.27	62.06	89.22
T3	Foliar application of starter dose of WSF 11:36:24 @ 2% at 30 DAS + Foliar application of Booster dose of WSF 8:16:39 @ 2% at 45 and 60 DAS.	24.28	5.67	47.97	14.55	14.53	58.62	89.89
T4	100% RDF + T3	24.10	5.80	51.66	17.95	14.80	58.07	87.89
T5	100% RDF + FYM @ 7.5 t ha^{-1}	25.48	5.53	50.57	13.88	14.67	57.72	87.33
T6	100% RDF + FYM @ 7.5 t ha^{-1} + T3	25.50	6.13	58.21	19.33	15.47	57.46	88.67
T7	85% RDF + FYM @ 7.5 t ha^{-1}	24.57	5.47	53.25	17.28	14.27	61.49	89.22
T8	85% RDF + FYM @ 7.5 t ha^{-1} + T3	25.09	6.00	56.89	18.30	15.40	59.56	90.44
T9	60% RDF + FYM @ 7.5 t ha^{-1}	24.50	5.13	47.27	16.44	12.27	63.56	91.11
T10	60% RDF + FYM @ 7.5 t ha^{-1} + T3	24.72	5.80	47.55	13.40	12.40	64.43	88.78
T11	35% RDF + FYM @ 7.5 t ha^{-1}	24.59	5.20	44.63	12.09	11.87	61.42	89.11
T12	35% RDF + FYM @ 7.5 t ha^{-1} + T3	23.57	5.53	40.32	12.34	11.40	64.90	89.00
	Mean	24.39	5.61	48.58	15.04	13.34	60.92	89.09
	CD (p=0.05)	0.72	0.40	6.41	2.58	1.49	4.96	NS

DAS = Days after sowing, RDF= Recommended dose of fertilizers

Table 2. Pooled data on dry pod, dry haulm, kernel yield and economics of summer groundnut as influenced by various treatments

	.Treatment	Dry pod yield (kg ha^{-1})	Dry haulm yield (kg ha^{-1})	Kernel yield (kg ha^{-1})	GMR (Rs. ha^{-1})	COC (Rs. ha^{-1})	NMR (Rs.ha^{-1})	B:C ratio
T1	Absolute control	1517	2711	787	48746	40140	8606	1.21
T2	100 % RDF (25 : 50 : 00 NPK kg ha^{-1})	2516	5121	1504	80919	42208	38712	1.93
T3	Foliar application of starter dose of WSF 11:36:24 @ 2% at 30 DAS + Foliar application of Booster dose of WSF 8:16:39 @ 2% at 45 and 60 DAS.	1667	3364	944	53673	41298	12376	1.31
T4	100% RDF + T3	2857	6301	1604	92019	43285	48734	2.14
T5	100% RDF + FYM @ 7.5 t ha^{-1}	2933	6561	1639	94475	51197	43278	1.86
T6	100% RDF + FYM @ 7.5 t ha^{-1} + T3	3172	7438	1738	102330	52264	50066	1.97
T7	85% RDF + FYM @ 7.5 t ha^{-1}	2551	5153	1497	82000	50941	31058	1.62
T8	85% RDF + FYM @ 7.5 t ha^{-1} + T3	2840	5719	1560	91383	52012	39371	1.77
T9	60% RDF + FYM @ 7.5 t ha^{-1}	2117	4049	1210	67954	50404	17550	1.36
T10	60% RDF + FYM @ 7.5 t ha^{-1} + T3	2234	4593	1362	71807	51501	20305	1.41
T11	35% RDF + FYM @ 7.5 t ha^{-1}	1900	3677	1043	61078	49982	11096	1.23
T12	35% RDF + FYM @ 7.5 t ha^{-1} + T3	1984	3968	1144	63800	51049	12751	1.26
	Mean	2348.21	4888	1336	910184	48023	27782	1.58
	CD (p=0.05)	914.5	485.17	167.61	5493		5584	0.13

Selling rate: Dry pod q ha^{-1} (Rs 3200/-), Dry haulm t ha^{-1} (Rs 650/-)

supply at these stages through foliar application resulted in growth and consequently higher yields. Further, this period coincides with the pegging and pod development stages wherein the crop requires higher amount of nutrients. The pooled data presented revealed that treatment (T_6) application of FYM @ 7.5 t ha^{-1} + 100% RDF + Foliar spray of fertilizers at 30, 45 and 60 DAS recorded significantly higher growth and yield contributing characters *viz*., plant height (25.50 cm), number . of branches (6.13), dry matter (58.21 g), No. of pods plant^{-1}(19.33), weight of pods plant^{-1}(15.47 g), dry pod yield (3172 kg ha^{-1}), dry haulm yield (7438 kg ha^{-1}) and kernel yield (1738 kg ha^{-1}). The treatment T_6 yielded maximum gross monetary returns (Rs.102330 ha^{-1}) and net monetary returns (Rs. 50066 ha^{-1}). However, the B:C ratio (2.14) was observed maximum under the treatment T_4 i.e. 100% RDF + Foliar spray of fertilizers at 30, 45 and 60 DAS. Amongst the foliar applications, the treatment 85% RDF + FYM @ 7.5 t ha^{-1} + Foliar spray of fertilizers at 30, 45 and 60 DAS recorded the yields at par with that of T_6. It is well established fact that adequate fertilization improved various physiological and metabolic processes in the plant system. Profound influence of water soluble fertilizer grade sprays at pegging and pod development stages might have provided balanced amounts of major and micronutrients at the peak requirement resulting into higher crop growth and yield attributes and finally the dry pod and haulm yield. The results are in conformity with Manasa *et al.* (2015) and Jain and Meena (2015).

In summer, groundnut maximum yield and benefit was recorded with application of 100% RDF + FYM @ 7.5 t ha^{-1} + foliar application of starter dose of water soluble grade fertilizer 11:36:24 + trace elements @ 2% at 30 DAS + foliar application of booster dose of water soluble grade fertilizer 8:16:39 + trace elements @ 2% at 45 and 60 DAS. However, T_8 (85% RDF + FYM @ 7.5 t ha^{-1} + Foliar spray of fertilizers at 30, 45 and 60 DAS) gives the yields at par with that of T_6, hence 15 % fertilizer saving can be achieved with the application of Treatment T_8 (85% RDF + FYM @ 7.5 t ha^{-1} + Foliar spray of fertilizers at 30, 45 and 60 DAS**).**

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Effect of Different Combinations of Organic Manures and Supplementation of Biofertilizers on Yield of Onion (*Allium cepa* L.)

G. Somashekar, Y. P. V. Subbaiah[1] and M. Lakshman Naik[2]

Department of Vegetable and Spice crops, Uttar BangaKrishiViswavidyalaya, Pundibari, Cooch Behar-736 165, India
[1]Department of Vegetable Science, College of Horticulture
Dr.YSR Horticultural University, Rajendranagar, Hyderabad-500 030, India
[2]Department of Vegetable Science, Bidhan Chandra KrishiViswavidyalaya, Mohanpur, Nadia-741 252, India
E-mail: somug43@gmail.com

Abstract: All the yield parameters were improved significantly with the organic manures (FYM, vermicompost, neem cake, Azospirillum and PSB)over inorganic fertilizers. The highest bulb dry weight, number of scales per bulb, bulb length, bulb diam, bulb yield per plot and per hectare (18.66 t ha^{-1}) was maximum in with the application of farmyard manure (50%) + vermicompost (25%) + neem cake (25%) + *Azospirillum*and PSB @ 5 kg ha^{-1}each followed by recommended dose of fertilizers which were at par but significantly superior to all other treatments.

Key Words: *Azospirillum*and PSB, Farmyard manure, Neem cake, Onion, Vermicompost

In India, onion (*Allium cepa* L.) is being grown in an area of 10.51 lakh ha with production of 168.13 lakh tonnes and the productivity is 16.0 tonnes ha^{-1}. In Andhra Pradesh, onion is cultivated in an area of 86.67 thousand hectares with production of 15.60 lakh tonnes and the average productivity is 18.0 tonnes ha^{-1} (NHB, 2013). Green revolution in sixties gave tremendous boost to agricultural production in India. During the era of green revolution, spectacular increase in crop yields resulted primarily from the introduction of fertilizer responsive HYV, extension of irrigated area, high use of chemical fertilizers and pesticides. In this process, relative contribution of organic manures as a source of plant nutrients declined substantially. With increase in cost of inputs, inorganic fertilizers became increasingly more expensive. Another issue of great concern is that the sustainability of soil productivity as lands began to be intensively tilled to produce higher yields under multiple and intensive cropping system. The occurrence of multi-nutrient deficiencies and overall decline in the productivity of the soil under intensive fertilizer use have been widely reported (Chhonkar, 2003). Consequently, many farmers are seeking alternative practice of organic farming to make agriculture more sustainable.

Onion is a heavy feeder of mineral elements. Organic fertilizers has positive effect on root growth by improving the root rhizosphere conditions (structure, humidity, etc.) and also plant growth is encouraged by increasing the population of microorganisms (Shaheen *et al*., 2007). Organic acids, which occur in decomposition of organic fertilizer increases the benefits of nutrients (Anonymous, 2010). FYM consists of rotted straw of plants, urine and faces. It enhances water holding capacity, erosion stability and gas exchange of the soil. Therefore, judicious and proper use of organic manures and fertilizers is very essential not only for obtaining higher yield and quality produce but also to maintain soil health and sustainability for longer period.Vegetables that are produced by using organic manures are gaining importance because of less chemical residues and better taste. Considering the adverse effects on soil health and environment, besides the residual effect, luxurious usage of inorganic fertilizers is not advisable. In India, very little work has been reported regarding the effect of different organics on growth and yield of vegetable crops and in onion particular. Hence the present investigation was taken up to study the effect of different organics on yield of onion.

The present investigation was conducted during *Rabi,* 2013 to study the effect of different combinations of organic manures and supplementation of bio-fertilizers on yieldof Onion (*Allium cepa* L.) at Dr. Y.S.R. Horticultural University, Rajendranagar, Hyderabad, and Andhra Pradesh. The onion variety Agrifound Light Red used as experimental material and the experiment was laid out in randomized block design with three replicated 9 treatments (Table 1). The data were recorded on yield parameters like bulb dry weight (g), number of scales $bulb^{-1}$, bulb length (cm), bulb diameter (cm), bulb yield $plot^{-1}$ (kg) and bulb yield $hectare^{-1}$ (t ha^{-1}).

Growth parameters: The bulb dry weight, length and diameter was significantly affected by the application of FYM, vermicompost, poultry manure, neem cake and bio-fertilizers at different stages of plant growth (Table 1). The maximum bulb dry weight, length, diameter and number of scales per

Table 1. Bulb dry weight bulb dimensions and bulb yield as affected by different organic manures and bio-fertilizers

Treatments	Bulb dry weight (g)	Bulb length (cm)	Bulb diameter (cm)	Number of scales per bulb	Bulb yield (kg plot^{-1})	Bulb yield (t ha^{-1})
T_1: FYM (50%) + Vermicompost (50%)	81.20	6.21	6.60	6.66	9.12	15.20
T_2 : FYM (50%) + Vermicompost (50%) + BF	84.40	6.78	7.37	7.13	9.98	16.63
T_3: FYM (50%) + Vermicompost (25%) + Neem cake (25%)	83.47	6.69	7.20	7.26	10.11	16.85
T_4 : FYM (50%) + Vermicompost (25%) + Neem cake (25%) + BF	89.00	7.60	8.20	8.40	11.20	18.66
T_5: Poultry manure(50%) + Vermicompost (50%)	80.66	6.08	6.35	6.20	8.04	13.40
T_6 : Poultry manure(50%) +Vermicompost (50%) + BF	85.08	6.77	7.32	7.00	8.91	14.85
T_7: Poultry manure (50%) + Vermicompost (25%)+ Neem cake (25%)	83.50	6.64	6.94	6.66	10.46	17.43
T_8 : Poultry manure(50%)+Vermicompost (25%)+ Neem cake (25%) + BF	85.15	6.79	8.00	7.40	10.93	18.21
T_9 : RDF @ 150:60:60 NPK kg ha^{-1}	87.50	7.50	8.12	7.60	11.04	18.40
CD (p=0.05)	2.26	0.70	0.50	0.72	0.002	0.19

BF=*Azospirillum*and PSB @ 5 kg ha^{-1} each

bulb was recorded in farmyard manure (50%) + vermicompost (25%) + neem cake (25%) + *Azospirillum* and PSB @ 5 kg ha^{-1} each) followed by recommended dose of fertilizers, which were at par but significantly superior to all other treatments. The growth parameter were minimum T_5 (with poultry manure (50%) + vermicompost (50%). The bulb dry weight maximum in T_4 (89.00 g) followed by T_9 (87.50 g). The lowest bulb dry weight was in T_5 (80.66 g). The bulb length was significantly affected by the application of FYM, vermicompost, poultry manure, neem cake and bio-fertilizers at different stages of plant growth. Similarly, bulb length was in T_4 (7.60 cm) followed by $T_{9.}$ The lowest bulb length was also recorded in $T_{5.}$ Similar to the bulb dry weight, bulb length the highest bulb diameter was also recorded in T_4 followed by $T_{9.}$

Yield: Similar to the growth parameters the number of scales and, bulb yield significantly affected by the application of FYM, vermicompost, poultry manure, neem cake and bio-fertilizers at different stages of plant growth being maxium in T_4 followed by T_9. The maximum number of scales per bulb was in T_4 followed T_9(7.60), which were significantly superior to all other treatments. The maximum bulb yield per plot was in T_4 (11.20 kg) followed by T_9 (11.04 kg) and was significantly higher than in other treatments. The minimum bulb yield per plot was in T_5 (8.04 kg). The bulb yield per hectare also

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Cultural, Morphological and Pathogenic Diversity Analysis of *Sclerotinia sclerotiorum* causing Sclerotinia Rot in Indian Mustard

Pawan Kumar, A. S. Rathi, Jaywant Kumar Singh, M. K. Berwal[1], Mukesh Kumar[2], Anil Kumar and Dhiraj Singh[3]

Department of Plant Pathology, [1]Department of Biochemistry, [2]Department of Genetics and Plant Breeding
CCS Haryana Agricultural University, Hisar-125 004, India
[3]Directorate of Rapeseed-Mustard Research, Bharatpur-321 303, India
E-mail: pawankasniya@yahoo.co.in

Abstract: The present study was conducted to ascertain the variability among fourteen isolates of *Sclerotinia sclerotiorum* collected from Indian mustard (*Brassica juncea*) from different mustard growing regions of India. Variation in cultural characteristics were observed among the isolates, particularly in colony colour *i.e.* dirty white to whitish; while, the mycelial growth varied from sparse and regular, fluffy and regular to fluffy and irregular. The morphological features like number of sclerotia, size of sclerotia and pattern of sclerotia formation varied among the isolates. Significant variation was observed in the host-pathogen interaction as the average disease intensity of isolates varied from 29.5 to 60.8 per cent. Four isolates viz., HSR, FTH, SRS, and DBW were more virulent and showed average disease intensity of more than 50%, while ALW isolate caused less than 30% disease intensity. The disease reaction studied for the pathogenic variability on Varuna albino cv. showed moderately resistant reaction, while genotypes viz., Varuna, Domo 4 and Midas showed highly susceptible reaction to all the isolates. The identification of the pathogen as isolates of *S. sclerotiorum* were confirmed at the molecular level by using ITS primers. All these information about the pathogen's variability at morpho-cultural and pathogenicity level could confer an important role in understanding the pathogen population and their dynamics in disease development in a particular locality.

***Key Words*:** *Brassica juncea*, Cultural, Morphological, Pathogenic, *Sclerotinia sclerotiorum*, Variability

Sclerotinia rot disease caused by *Sclerotinia sclerotiorum* (Lib.) de Bary, is a serious threat to rapeseed-mustard production causing substantial yield losses world-wide. In India, *S. sclertiorum* has been reported to infect wide range of wild and cultivated host plants including rapeseed-mustard group of crops (Singh *et al.,* 2008). The disease has become wide spread and destructive in mustard growing areas in the country and takes a heavy toll of yield. Incidence of this disease was noticed up to 72 per cent in Rajasthan (Shivpuri *et al.,* 2000; Ghasolia *et al.,* 2004) and up to 80 per cent in Punjab and Haryana (Kang and Chahal, 2000). Once the pathogen is established, it is difficult to manage due to its soil-borne nature and wide host range. In spite of homothallic in nature and having wide host range, this fungus has been reported to show variability in their disease reactions to different genotypes of various *Brassica* species including Indian mustard at different locations in the country (Ghasolia and Shivpuri, 2007). Lack of effective field resistance to stem rot in cultivated species of rapeseed-mustard has stimulated the interest of researchers towards finding out the variability in this fungal pathogen. Variation in cultural and morphological characteristics of *S. sclerotiorum* collected from various hosts has already been reported in literature (Ziman *et al*., 1998; Basha and Chatterjee, 2007). Basha and Chatterjee (2007) studied variability among 20 Indian isolates of *S. Sclerotiorum,* collected from different hosts/soil samples from diverse geographic origins and noticed variations in colony morphology, mycelial growth rate and sclerotial formation. Choudhary and Prasad (2012) evaluated the variation in *S. sclerotiorum* causing stem rot on economically important winter crops in North West Plain Zone of India and observed colony colour of mustard isolate and hirankhuri isolate as light yellow and light brown, respectively, while the mycelial growth as fluffy to compact among the isolates. A prominent difference was reported *by* Ghasolia and Shivpuri (2007) for morphological features viz. colony colour, shape and sclerotial number, size, position and the pattern of distribution among different isolates of *S. sclerotiorum* collected from Rajasthan. As variable responses shown by rapeseed mustard plants to field inoculation with *S. sclerotiorum*, are one of the main limitations for assessing field resistance; there is no clear reason for this variability (Li *et al.,* 2007; Garg *et al.,* 2008). Though an efficient, reliable and inexpensive screening method is needed for large-scale screening of rapeseed-mustard germplasm and cultivars (Bradley *et al.,* 2006), as resistance cultivars would be most effective in conjunction with other cultural practices including crop rotation against stem rot (Garg *et al*., 2008). The variability at genetic level have been reported using Polymerase chain reaction (PCR) primers designed by using nuclear ribosomal DNA internal transcribed spacer sequences (ITS region of rDNA) for detection of *S. sclerotiorum* infection (Freeman *et al.,* 2002). The genetic diversity of *S. sclerotiorum* populations were assessed in North Iran using Simple Sequence Repeat fingerprinting (Barari *et al.,* 2014). In India, very few efforts have been made to determine the cultural, morphological and pathogenic variability among the *S. sclerotiorum* populations infecting oilseeds crops particularly Indian mustard (Sharma *et al*., 2013). The aim of our study was to evaluate the differences in this pathogen within *B. juncea* on the basis of cultural, morphological and pathogenic characters. Therefore, the present study was conducted to ascertain the cultural, morphological and pathogenic variations among different isolates of *S. sclerotiorum* obtained from infected Indian mustard from different mustard growing regions of India.

MATERIAL AND METHODS

Collection, isolation and purification of *S. sclerotiorum* isolates: For this study, isolates of *S. sclerotiorum* in the form of sclerotia were obtained from infected Indian mustard plants from different mustard growing regions of India at the time of harvesting (Table 1). The single sclerotium from each location represented an isolate and these sclerotia were surface sterilized for 30 seconds in 0.1% mercuric chloride solution, rinsed in sterile distilled water for 2-3 times; plated on potato dextrose agar medium (PDA) and incubated at 21±1°C for three days. Each isolate was purified by transferring the single hyphal tip into the fresh medium and provided pure culture of each isolate.

Cultural and morphological variability: Mycelial disc (5mm diameter) of each isolate was taken from actively growing colony of four day old cultures and was transferred on to fresh PDA in Petri plates (90 mm diameter). All cultures of isolates were incubated at 21±1°C in BOD incubator and observations on the cultural characters *viz.*, colony colour, type of growth and mycelial growth (mm) in diameter were recorded at 24, 48, 72 and 96 h after incubations. The morphological characters of isolates were examined on PDA Petri plates, on the basis of the type and pattern of sclerotia formation *i.e.,* initiation of sclerotia formation, number of sclerotia formation, size of sclerotia (measured with help of Vernier calliper in mm) after 10 days of incubation.

Pathogenic variability: Since, standard host differentials are not available; the different rapeseed-mustard genotypes were selected on the basis of wide phenotypic and genotypic variations. Out of the fourteen rapeseed-mustard genotypes, nine were Brassica juncea, three and two were *B. napus* and *B. carinata*, respectively. Among the nine *B. juncea* genotypes, five were from Australia, three from India and one from Canada; among the three *B. napus* genotypes, two were from India and one from Canada, and both *B. carinata* genotypes were of Indian origin. These rapeseed-mustard genotypes were sown on November 20, 2012 in earthen pots (12×6 cm) containing sterilized field soil. A complete randomized block design with four replications and four plants per replication of each genotype × isolate combination was utilized. The fifth leaf of 70 days-old-plant of each genotype was severed near petiole junction using sterilized razor blade, inoculated by placing mycelia of pure culture of each isolate and covered with cello-tape. The Lesion phenotype (LP) index consisting of 0 - 4 scale was enumerated 14 days after inoculations (Zhao *et al.,* 2004). LP index was categorized as follows: 0 = no symptom, no lesion, no water-soaking, and no wilt; 1 = small lesion at stem, no water-soaking, and no wilt; 2 = water-soaked lesion and no wilt; 3 = expanded, sunken water-soaked lesion and initiation of wilting; and 4 = expanded lesion, resulting in complete irreversible wilting. Per cent disease intensity (PDI) was calculated following the formula of Wheeler (1969) as below:

$$\text{PDI (\%)} = \frac{\text{Sum of all numerical ratings}}{\text{(Total No. of stems observed} \times \text{Max. disease rating scale)}} \times 100$$

The reaction of genotype were categorized as PDI <25%=moderate resistance, 26-50% = susceptible, >50% highly susceptible.

Genetic Variability and Identification of *S. sclerotiorum* Isolates using ITS Primers

DNA extraction*:* From 4-5 days old cultures, 5 mm diameter mycelial disc of each isolate was transferred in 100 ml potato

Table 1. Isolates of *S. sclerotiorum* obtained as sclerotia from infected Indian mustard plants from different mustard growing regions of India

Name of isolates	Area of collection	Geographical Location*
HSR	Hisar, Haryana,	29°.15'N - 75°.70'E
FTH	Fatehabad, Haryana	29°.31'N - 75°.27'E
SRS	Sirsa, Haryana	29°.53'N - 75°.00'E
DBW	Dabwali, Haryana	29°.95'N - 75°.73'E
SWN	Siwani, Haryana	28°.92'N - 75°.62'E
BWL	Bawal, Haryana	28°.08'N - 76°.58'E
MHR	Mahendergarh, Haryana	28°.28'N - 76°.15'E
BHR	Bharatpur, Rajasthan	27°.22'N - 77°.48'E
ALW	Alwar, Rajasthan	27°.34'N - 76°.38'E
BKN	Bikaner, Rajasthan	28°.02'N - 73°.31'E
GNG	Shri Ganganagar, Rajasthan	29°.92'N - 73°.88'E
JLN	Jalandhar, Punjab	31°.33'N - 75°.58'E
LDN	Ludhiana, Punjab	30°.91'N - 75°.85'E
MRN	Morena, Madhya Pradesh	26°.30'N - 78°.00'E

Source - *http://www.worldatlas.com/aatlas/findlatlong.htm dextrose broth (PDB) in the 250 ml flasks, and incubated at 21±1ºC in incubator for 5-6 days. Mycelial mats were harvested by filtering through Whatman filter Paper No. 1, washed repeatedly with distilled sterilized water, blot dried, and stored in Al-foils at -20ºC for genomic DNA extraction based on the Cetyl trimethyl ammonium bromide (CTAB) method of Saghai-Maroof *et al.* (1984) with minor modifications. DNA concentration (25 ng/µl) was maintained for each isolate after quantification of DNA by spectrophotometer.

Polymerase chain reaction (PCR) amplification: PCR amplification of all fourteen *S. sclerotiorum* isolates was done by using ITS (Internal transcribed spacer) primers (Table 2) obtained from Integrated DNA Technologies, USA. The PCR reaction was performed in 25 µl reaction mixture containing 1.0 µl DNA (50 ng/µl), 2.5 µl PCR buffer (1X), 0.5 µl dNTP's (10mM of each dATP, dCTP, dGTT, dTTP), 0.5 µl of each primer (0.2 mM), 0.2 µl Taq DNA polymerase (5 U/µl), and 19.8 µl double distilled autoclaved water. The DNA amplification was performed by using Mastercycler epTM gradient thermal cycler (Eppendorf AG, Germany). The PCR conditions consisted of 30 second at 94ºC for initial denaturation, 30 cycles of 30 second at 94ºC for denaturation, 1 min at 55ºC for annealing, 1 min at 72ºC for extension, and final elongation for 5 min at 72ºC, followed by cooling at 4ºC and amplified PCR products were kept at -20ºC. The amplified DNA fragments were resolved on 2.5 per cent (w/v) agarose gels and visualized by staining with ethidium bromide. Agarose gel was prepared in 1X TBE buffer and ethidium bromide was added in the gel at a concentration of 0.5µg/ml. The 100 bp DNA ladder (Fermentas Life Sciences, Canada) was used as a marker.

Table 2. List of Internal transcribed spacer primers used

Primers	Sequence (5'->3')	References
ITS1	TCCGTAGGTGAACCTGCGG	White *et al.,* 1990
ITS2	GCTGCGTTCTTCATCGATGC	White *et al.,* 1990
ITS3	GCATCGATGAAGAACGCAGC	White *et al.,* 1990
ITS4	TCCTCCGCTTATTGATATGC	White *et al.,* 1990
ITS5	GGAAGTAAAAGTCGTAACAAGG	White *et al.,* 1990
ITS1-F	CTTGGTCATTTAGAGGAAGTAA	Gardes and Bruns, 1993

RESULTS AND DISCUSSION

Cultural variability: In the present studies about cultural characteristics, the *S. sclerotiorum* isolates infecting Brassica showed variations in colony colour under *in vitro* conditions, as some of the isolates viz., HSR, FTH, SRS and DBW showed dirty white colony, while rest of the ten isolates showed whitish colony colour in culture (Table 3). Sharma *et al.* (2013) during cultural and growth pattern studies, found differences in colony colour among the isolates as whitish and dirt white, however, off white and grey white colony colour as observed by these workers were not found in any of the isolates in the present study. Similarly, a slight variation was also observed by Ziman *et al.* (1998) in colony colour of different *S. sclerotiorum* isolates collected from different plant hosts, differentiated from white to brown, but the white colour was predominant in most of the isolates. Wide variation in colony colour among isolates of this pathogen collected from different hosts might be due to wide host range of this pathogen. The present study also indicated variation in type of growth, as three isolates viz., BWL, MHR and BHR showed fluffy and regular type of growth, while two isolates viz., ALW and JLN showed fluffy but irregular growth and rest of the isolates showed sparse and regular type of mycelial growth (Table 3). The variation in the growth pattern of *S. sclerotiorum* isolates collected from Brassica species and other host plants has been also reported by Goswami *et al.* (2008) and observed slight differences in the growth pattern varying from sparse and regular growth in isolates from *B. carinata* and *B. juncea*; fluffy and irregular in isolates from *B. rapa*; sparse and fluffy from brinjal and pea; compact and fluffy from *B. napus* and *B. rapa* var. toria, while, compact and irregular in that from *Parthenium*. A wide range of variation in type of mycelial growth pattern have been reported which varied from scattered, smooth and fluffy, compact mycelial growth in diferent *S. sclerotiorum* isolates from different geographical localities (Basha and Chatterjee, 2007; Choudhary and Prasad, 2012; Sharma *et al.,* 2013). A significant difference was observed in the present experiment, among isolates in colony diameter (mycelial growth) up to 72 hours of incubation, wherein, only two isolates (BWL and ALW) out of fourteen showed slow mycelial growth up to 48 h of incubation (Table 3). The similar trend was also reported earlier by Garg *et al.* (2010) and reported significant differences between isolates in relation to the colony diameter measured after 24 and 48 h of incubation. Similarly, isolates of *S. sclerotiorum* from wild fig and canola plants were reported to show variation in mycelial growth rate by Kohli and Kohn (1996). Goswami *et al.* (2008) reported that mycelium of all the isolates of this fungus obtained from different hosts covered the whole Petri plate after 96 h of incubation. Similarly, in the present, study non-significant differences were observed for mycelial growth. Though, Garg *et al.* (2010) found mycelial growth was maximum after 72 h in isolates from *B. rapa* var. toria and *Pisum sativum* that was significantly different from the growth of other isolates, while minimum growth was observed in isolate from *B. carinata* after 72 h of incubation. Basha and Chatterjee (2007) studied variability among 20 Indian isolates of *S. sclerotiorum*, collected from different hosts/soil samples from various localities in India and found variations in colony morphology and mycelial growth rate. But, these reports could only be correlated, not compared with present study as in those; either the isolates were obtained from different Brassica species or different host plants.

Morphological variability: Morphological variability among different isolates collected from *Brassica* species and other plants was observed by Goswami *et al.* (2008), where they noticed the differentiation of white masses into sclerotial bodies after 4-5 days of incubation in all the isolates, except that from the *B. carinata*. While, in the present study, all the isolates were found to initiate white sclerotial bodies and later, it converted into blackening of the rind in 6-7 days old culture, indicating non-significant differences among the isolates for days to initiation of sclerotia after incubation. However, significant variations among the isolates were observed for number of sclerotia, size and pattern of sclerotia formation after 10 days of incubation of the different isolates of *S. sclerotiorum*. Six isolates viz., HSR, FTH, SRS, DBW, GNG and LDN produced more sclerotia ranging between 20-32 sclerotia, while rest of the isolates produced less sclerotia ranging from 9-18 in culture. The maximum number (32) of sclerotia was formed in HSR isolate, while minimum number (9) in BWL isolate. Size of sclerotia also varied, as MHR isolates produced large sized sclerotia having a width to length of 28.7×41.3 mm, while JLN isolate produced small size sclerotia having a width to length of 18.6×21.6 mm, whereas, rest of the isolates produced medium sized sclerotia in culture (Table 4). Interestingly, the present study revealed that the isolates formed four types of sclerotia formation pattern i.e. near the rim, attached to the rim, scattered in the middle, scattered all around in Petri plates. Isolates HSR, FTH, SRS, DBW, SWN, BKN and MRN formed sclerotia near the rim of Petri plates, while GNG, JLN and LDN isolates showed sclerotial pattern attached to the rim. BWL and MHR isolates formed sclerotia which were scattered in the middle, while BHR and ALW isolates showed pattern of scattering all around in Petri plates (Plate 1). Similarly, Ghasolia and Shivpuri (2007) have also observed variability among 38 isolates of *S. sclerotiorum* collected from Rajasthan, which showed variation in their morphological traits like sclerotial number, size, position and pattern. They found variation in sclerotial size (less than 3 mm as small, 3.1-5.0 mm as medium and more than 5 mm as large), number (less than 8, 9-20 and more than 20) and their arrangements (scattered over colony, at inner periphery, at outer periphery and at centre) after 15 days of incubation. Lehner *et al.* (2014) also observed morphology traits and mycelial growth rate among isolates of *S. sclerotiorum* collected from different regions Brazil. They observed high variability among isolates, even among colonies of the same isolate. The variance was found on basis of mycelial growth rate, number, weight, length, width and thickness of sclerotia.

Pathogenic variability: Significant differences were observed between the genotypes in relation to the per cent disease intensity across the isolates tested and all isolates showed varying degree of per cent disease intensity

Table 3. Cultural variability in *S. sclerotiorum* isolates collected from Indian mustard

Isolates	Colony colour	Type of growth	Mycelial growth (diameter in mm)			
			24 h	48 h	72 h	96 h
HSR	Dirty white	Sparse and regular	20	48	75	90
FTH	Dirty white	Sparse and regular	17	43	73	90
SRS	Dirty white	Sparse and regular	18	46	71	90
DBW	Dirty white	Sparse and regular	14	38	70	90
SWN	Whitish	Sparse and regular	15	34	70	90
BWL	Whitish	Fluffy and regular	10	28	68	90
MHR	Whitish	Fluffy and regular	13	45	68	90
BHR	Whitish	Fluffy and regular	17	45	71	90
ALW	Whitish	Fluffy and irregular	8	27	67	90
BKN	Whitish	Sparse and regular	16	52	69	90
GNG	Whitish	Sparse and regular	18	47	71	90
JLN	Whitish	Fluffy and irregular	15	48	69	90
LDN	Whitish	Sparse and regular	16	53	72	90
MRN	Whitish	Sparse and regular	16	42	70	90
CD (p=0.05)			2.50	2.85	2.54	NS

Table 4. Morphological variability in *S. sclerotiorum* isolates collected from Indian mustard

Isolates	Formation of sclerotia				
	Initiation (DAI)	Number (10 DAI) plate^{-1}	Width (mm)	Length (mm)	Pattern
HSR	6	32	25.4	37.2	Near rim
FTH	6	22	24.7	36.3	Near rim
SRS	6	20	23.8	38.6	Near rim
DBW	6	26	22.2	32.0	Near rim
SWN	6	16	28.4	37.4	Near rim
BWL	7	9	28.6	41.1	Scattered in middle
MHR	7	12	28.7	41.3	Scattered in middle
BHR	6	14	22.4	35.2	Scattered all around
ALW	7	18	23.3	36.1	Scattered all around
BKN	6	13	22.4	36.4	Near rim
GNG	6	26	21.2	28.4	Attached to rim
JLN	7	14	18.6	21.6	Attached to rim
LDN	6	28	20.4	24.2	Attached to rim
MRN	6	13	24.2	34.6	Near rim
CD (p=0.05)	NS	2.23	---	---	---

depending on genotype tested. The four isolates HSR, FTH, SRS, and DBW recorded more than 50 per cent average disease intensity, while isolate ALW produced less than 30 per cent average disease intensity. The fourteen isolates varied considerably in virulence; isolate HSR was the most virulent with mean disease intensity of 60.8%, while ALW was the least virulent with disease intensity of only 29.5% (Table 5). Ghasolia and Shivpuri (2007) categorized thirty eight S. sclerotiorum isolates from Rajasthan into 9 groups (G_1 to G_9) and reported varying degree of pathogenicity among these groups; isolates of G_6 group were the most virulent causing maximum disease incidence of 82.44%, followed by G_1 (77.50%) and G_8 (75.01%), while the isolates of G_9 had least disease incidence of only 11.08%. The genotype Varuna albino was identified as moderately resistant to all the isolates with average disease intensity of 18.4 per cent, whereas genotype Varuna was found to be the most susceptible with average disease intensity of 73.3 per cent; most isolates showed intermediate pathogenicity with mean disease intensity of less than 50 per cent (Table 5). Ghasolia and Shivpuri (2007) also showed significant variation in the response of genotypes to different isolates and reported cultivar Varuna as highly susceptible. The similar response were recorded by Goswami *et al.* (2008), and tested virulence of isolates from different hosts and reported *B. rapa* var. *toria* isolate to be highly virulent causing 85 per cent disease incidence, followed by pea (80%), *B. carinata* (75%), and *B. juncea* and *B. rapa* (70%) isolates. Significant differences among *Brassica* genotypes challenged by different S. sclerotiorum isolates from the Mount Barker and the Walkaway regions of Western Australia have also been observed by Garg *et al.* (2010), which supported the above results. They observed that at 4 days post-inoculation, some isolates were less pathogenic on most genotypes, whereas others were highly pathogenic to all *Brassica* genotypes tested; genotypes AG-Spectrum, Purler and Zhongyou-ang No. 4 were found to be strongly and differentially responsive to all isolates of *S. sclerotiorum*. Xu *et al*. (2014) analyzed the pathogenicity of 47 isolates of *S. sclerotiorum* from oilseed rape (*Brassica napus* L.) in Anhui, China, by detached leaf inoculation using the susceptible rape cultivar Wanyou-14. They found all isolates pathogenic to the cultivar and grouped into 3 categories based on the lesion length on the leaves tested: weak pathogenicity type, intermediate pathogenicity type, and strong pathogenicity type. They suggested that there was differentiation in the pathogenicity among the tested strains of *S. sclerotiorum.*

In the present study, isolates were found to vary in their per cent disease intensity on different rapeseed-mustard genotypes and significant host × pathogen interaction was also observed as the average disease intensity of all the fourteen isolates varied on all the genotypes in both the conditions. The disease reaction on Varuna albino (moderately resistant) and on Varuna, Domo 4 and Midas (highly susceptible) across all isolates suggested that these genotypes should be kept as watch dog, while selecting differentials in future studies for the identification of new strain of *S. sclerotiorum* infecting rapeseed-mustard in

Table 5. Per cent disease intensity and disease reaction of *S. sclerotiorum* isolates in rapeseed- mustard genotypes under screen house condition

Genotypes/ Varieties	Isolates of *S. sclerotiorum*														
	HSR	FTH	SRS	DBW	SWN	BWL	MHR	BHR	ALW	BKN	GNG	JLN	LDN	MRN	mean
Brassica 1	41.8 (S)	34.2 (S)	34.2 (S)	21.1 (MR)	28.3 (S)	20.6 (MR)	33.4 (S)	22.5 (MR)	18.4 (MR)	23.4 (MR)	35.1 (S)	21.4 (MR)	28.5 (S)	23.2 (MR)	27.6
Domo 4	85.4 (HS)	81.2 (HS)	84.1 (HS)	80.7 (HS)	79.5 (HS)	58.4 (HS)	68.1 (HS)	63.7 (HS)	51.6 (HS)	70.3 (HS)	53.4 (HS)	68.7 (HS)	76.4 (HS)	68.2 (HS)	70.7
GSL 01	74.5 (HS)	68.3 (HS)	70.3 (HS)	42.4 (HS)	43.6 (HS)	23.3 (MR)	38.4 (S)	64.2 (HS)	21.1 (MR)	37.6 (S)	43.8 (S)	32.1 (S)	43.1 (S)	43.2 (S)	46.1
HC 0212	78.3 (HS)	76.5 (HS)	72.8 (HS)	46.2 (S)	42.5 (S)	21.3 (MR)	37.2 (S)	40.6 (S)	20.4 (MR)	33.8 (S)	52.1 (HS)	42.1 (S)	45.2 (S)	43.1 (S)	46.6
HNS 9605	78.2 (HS)	72.3 (HS)	74.4 (HS)	68.3 (HS)	65.2 (HS)	54.3 (HS)	64.7 (HS)	62.5 (HS)	26.1 (S)	44.7 (S)	58.2 (HS)	58.2 (HS)	52.4 (HS)	46.4 (S)	59.0
JN 031	44.1 (S)	34.4 (S)	37.2 (S)	32.0 (S)	20.2 (MR)	22.8 (MR)	34.4 (S)	22.5 (MR)	20.2 (MR)	23.1 (MR)	36.3 (S)	37.4 (S)	35.1 (S)	24.1 (MR)	30.3
JN 032	23.8 (MR)	21.3 (MR)	21.6 (MR)	37.1 (S)	35.4 (S)	34.6 (S)	48.5 (S)	39.3 (S)	30.3 (S)	40.3 (S)	42.6 (S)	38.3 (S)	41.8 (S)	37.1 (S)	35.1
Kiran	66.5 (HS)	70.5 (HS)	58.4 (HS)	53.1 (HS)	37.8 (S)	38.4 (S)	37.2 (S)	41.3 (S)	24.4 (MR)	35.7 (S)	63.1 (HS)	31.7 (S)	61.5 (HS)	32.7 (S)	46.6
Midas	84.1 (HS)	78.7 (HS)	82.1 (HS)	80.2 (HS)	81.6 (HS)	63.4 (HS)	58.2 (HS)	61.3 (HS)	53.2 (HS)	76.2 (HS)	53.4 (HS)	52.2 (HS)	57.6 (HS)	72.3 (HS)	68.2
RH 30	73.2 (HS)	68.6 (HS)	62.3 (HS)	60.2 (HS)	40.6 (S)	48.6 (S)	35.8 (S)	44.4 (S)	30.2 (S)	41.7 (S)	52.5 (HS)	34.4 (S)	52.4 (HS)	35.7 (S)	48.6
Varuna	88.5 (HS)	83.2 (HS)	86.6 (HS)	85.8 (HS)	82.5 (HS)	54.2 (HS)	65.2 (HS)	65.5 (HS)	54.2 (HS)	78.5 (HS)	64.1 (HS)	78.4 (HS)	62.3 (HS)	77.1 (HS)	73.3
Varuna albino	21.2 (MR)	24.2 (MR)	24.4 (MR)	16.7 (MR)	18.2 (MR)	12.5 (MR)	14.8 (MR)	16.2 (MR)	10.2 (MR)	14.2 (MR)	22.1 (MR)	18.6 (MR)	22.4 (MR)	22.1 (MR)	18.4
ZEM 1	43.3 (S)	34.2 (S)	28.7 (S)	34.7 (S)	27.1 (S)	22.2 (MR)	36.7 (S)	45.5 (S)	26.5 (S)	43.6 (S)	36.6 (S)	42.3 (S)	45.5 (S)	43.1 (S)	36.4
ZEM 2	48.1 (S)	42.3 (S)	43.0 (S)	48.4 (S)	42.3 (S)	23.8 (MR)	42.8 (S)	45.8 (S)	26.3 (S)	42.1 (S)	35.3 (S)	21.3 (MR)	23.3 (MR)	45.3 (S)	37.9
mean	60.8	56.4	55.7	50.5	46.1	35.6	44.0	45.4	29.5	43.3	46.3	41.2	46.3	43.8	46.1

Per cent Disease Intensity (PDI) <25%=Moderate Resistant (MR), 26-50% = Susceptible (S), >50% Highly susceptible (HS)

Factors	CD(p=0.05)	SE(d)	SE(m)
Isolates (A)	0.46	0.23	0.16
Genotypes (B)	0.65	0.33	0.23
(A X B)	1.74	0.88	0.63

India. Moderate resistant reactions of *B. juncea* lines JN 031 and JN 032 to HSR isolate in our study (Table 5) is similar to those reported by Singh *et al.* (2008). Garg *et al.,* 2010 suggested that genotypes showing most consistent and promising responses across a range of *S. sclerotiorum* isolates should be used as standards in disease screening and commercial breeding programmes, as these are the most likely genotypes to perform consistently across different national and international geographic locations in Australia. Such differences of genotypes depending upon the isolate, also suggested that resistance in *Brassicas* against *S. sclerotiorum* is most likely to be polygenic. In accordance with Garg *et al.* (2010), there are very few published reports of significance between genotype × *S. sclerotiorum* isolate interactions, probably because in most previous studies either too many isolates were included on a very few genotypes or too many genotypes were subjected to infection by few isolates (Auclair *et al.*, 2004; Ekins *et al.*, 2007).

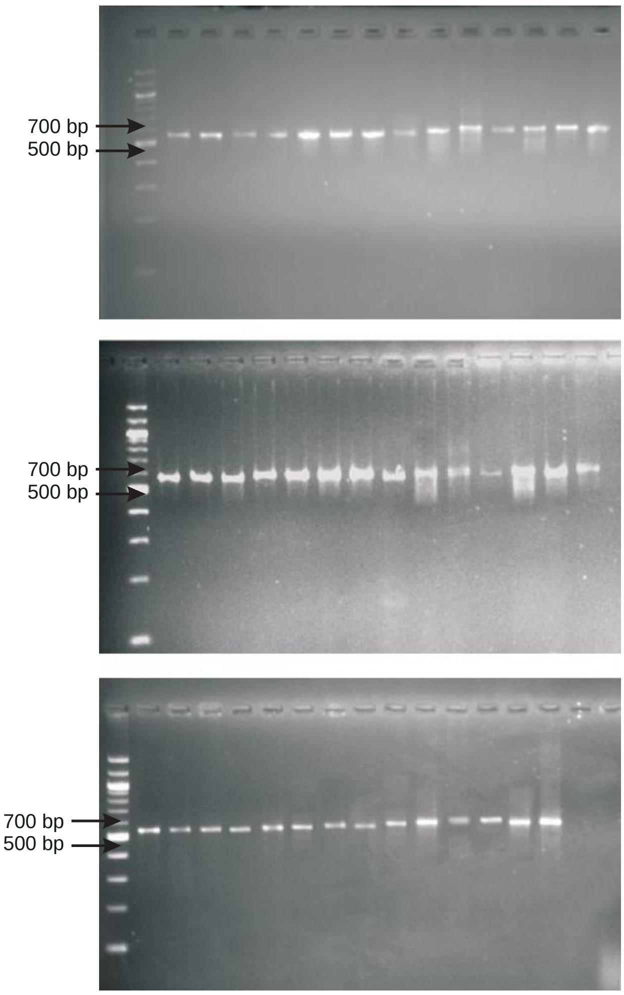

Fig. 1. Different primer combinations showing amplification of *S. sclerotiorum* isolates, Line M= 100 bp molecular marker, Line 1= HSR, Line 2= FTH, Line 3= SRS, Line 4 = DBW, Line 5= SWN, Line 6 = BWL, Line 7 = MHR, Line 8 = BHR, Line 9 = ALW, Line 10 = BKN, Line 11= GNG, Line 12 = JLN, Line 13= LDN, Line 14 = MRN

Characterization of the population structure of fungal pathogens is important for understanding the biology of the organism and for development of disease control strategies (Malvick and Percich, 1998), and for molecular studies among individuals, which is one of the components of population structure (Leung *et al*., 1993). However, the classification system and identifications based on morphology has not provided an accurate tool for the identification of *S. sclerotiorum*, neither has morphological classification system resolved the relationship of isolates within *S. sclerotiorum*. So, a molecular approach is promising in establishing the objective of pathogen diversity (Zhang *et al*., 2006; O'Donnell *et al*., 2008). Among the methods rDNA-ITS regions have often been chosen in many fungi for taxonomy and phylogenetics, because sequence data are available and they contain both variable and conserved regions, allowing discrimination at the genus, species, or intra-specific level through ITS-RFLP studies. Several features make it a convenient target for molecular identification of fungi: (i) the entire ITS region is often between 600 to 800 bp and can be readily amplified with 'universal primers' that are complimentary to sequences within the rRNA genes (White *et al*., 1990), (ii) the multicopy nature of the rDNA repeat makes the ITS region easy to amplify from small, dilute, or highly degraded DNA samples, and (iii) the ITS region is often highly variable among morphologically distinct fungal species (Gardes *et al*., 1991) but intraspecific variation is low (Gardes *et al*., 1991; Chen *et al*., 1992)

So, the variability and identification of the isolates of *S. sclerotiorum* in the present studies at the genetic level was confirmed on the basis of rDNA-ITS regions amplified with universal primers combinations. The species identification was confirmed by PCR amplification with specific ITS primer pair combinations and identified all the isolates under the species *Sclerotinia sclerotiorum*. ITS 1-F/ ITS4; ITS1/ ITS4; ITS5/ ITS4 primer pair amplified all the fourteen isolates, and the generated length of amplified fragments varied from 550 bp to 650 bp (Fig. 1). Similarly, Mandal and Dubey (2012) observed 550 bp size fragments with ITS1/ITS4 primer pair in all the isolates of *S. sclerotiorum* collected from various infected plants. Korabecna (2007) also studied polymerase chain reaction amplification and subsequent restriction analysis of the ribosomal region spanning the internal transcribed spacers and the 5.8S rRNA is accepted as a

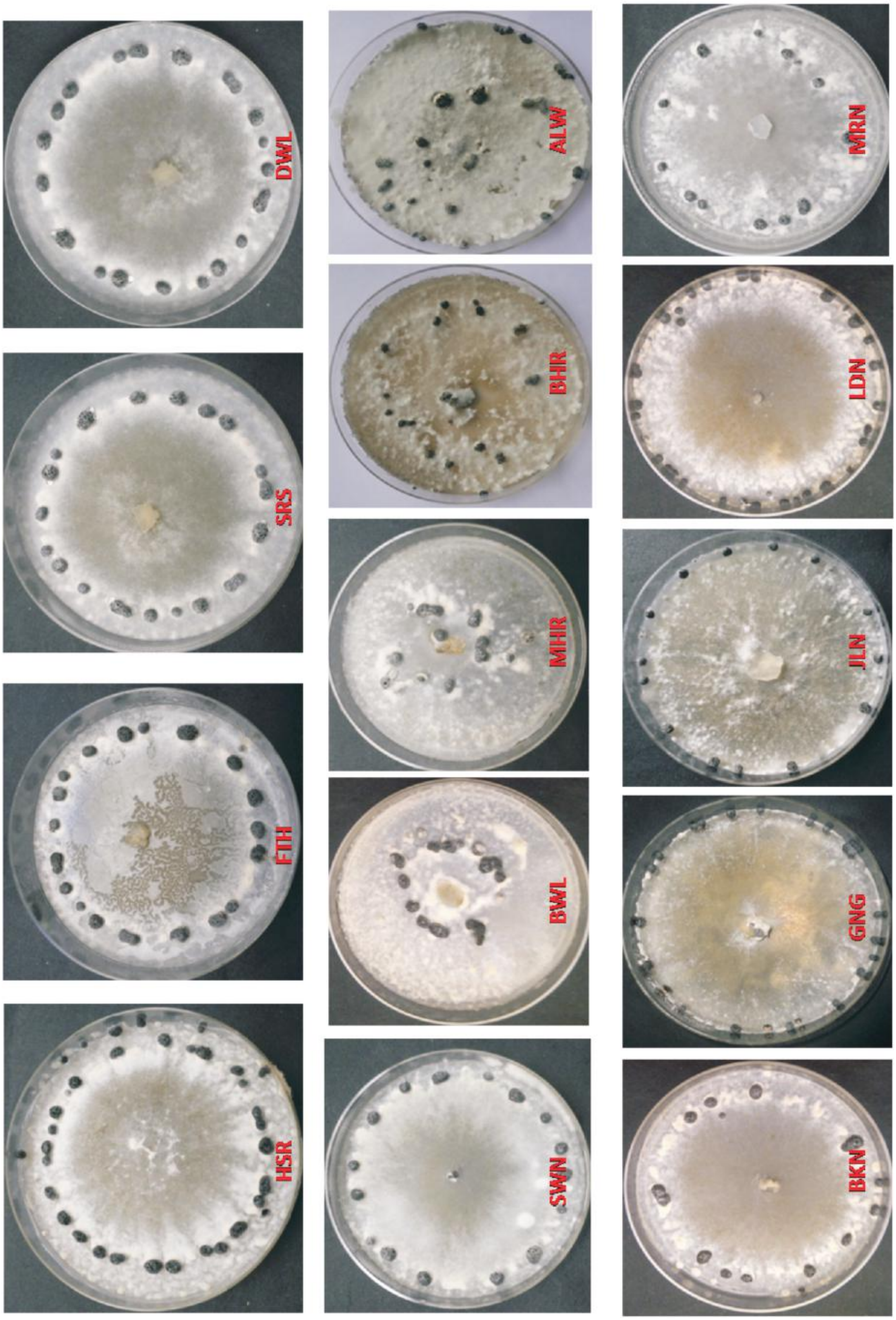

Plate 1. Morphological variability of *S. sclerotiorum* isolates collected from Indian mustard

powerful method for species identification.

In conclusion, no comprehensive study has been conducted for variability in this pathogen in Indian mustard. Isolates of *S. sclerotiorum* obtained from Indian mustard from different mustard growing locations of the country had shown existence of sufficient variations. Significant differences in pathogenicity among different isolates across genetically diverse rapeseed-mustard genotypes in the present study, suggest existence of a form of physiological specialization in *S. sclerotiorum* population in India. Furthermore, genotypes such as Varuna albino which has shown consistent moderate resistant reaction to all the isolates could be used as source of resistance in mustard breeding programmes in the country. In the future, more than one *S. sclerotiorum* isolates will be needed for germplasm screening programme particularly in coordinated disease nursery trials. Hence, our present study supports the results of several studies regarding presence of races or strains of this pathogen within *B. juncea* in various geographical regions of India. Sclerotinia pathogen has a wide host range and is reported to be homothallic in nature; hence it may be assumed that *S. sclerotiorum* survives as different clonal lineages in different mustard growing regions of India. There is a need to identify/designate standard set of host differentials for the identification of races of this pathogen within *B. juncea*, if standard differentials would have been available, the isolates could have been compared with other reports and be named as races of this pathogen within *B. juncea*. The genetic diversity study of the fungal population may be of major importance in accurate identification of the pathogens at genus, inter-specific and intra-specific level. So, the information about the morpho-cultural, pathogenic and genetic variability among the pathogen isolates can be taken in account in resistant breeding programmes for developing an elite resistant line for effective management of the pathogen.

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Evaluation of Botanicals, Antagonists and Fungicides against *Rhizoctonia solani* f. sp. *sasakii* causing Banded Leaf and Sheath Blight of Maize

Madan Lal, Rakesh Mehra[1], Pawan Kumar[*] and Jaywant Kumar Singh

Department of Plant Pathology and [1]Regional Research Centre, Karnal,
CCS Haryana Agricultural University, Hisar-125 004, India
[*]*E-mail:* pawankasniya@yahoo.co.in

***Abstract*:** The efficacy of different botanicals, antagonists and fungicides was tested against *Rhizoctonia solani* f. sp. *sasakii* causing banded leaf and sheath blight of maize. The botanicals and antagonists were effective under *in vitro* and *in vivo* conditions. Among the botanicals, garlic clove extract completely inhibited the mycelial growth (95.56%) at 15% concentration under *in vitro* condition followed by neem leaves extract (53.33%). The garlic cloves and neem leaves extracts were not effective only in the field condition in reducing disease severity as low as 50.6 and 38.8 per cent, respectively, but also were positively correlated with the significant increase in yield. The antagonist *Trichoderma viride* was superior to all other antagonists, *Trichoderma harzianum*, *Pseudomonas fluorescens, Pseudomonas maltophila* and *Bacillus subtilis* in inhibiting the mycelial growth of *Rhizoctonia solani* f. sp. *sasakii* and *Pseudomonas maltophila* was least effective. Although, the chemicals were more effective as compared to botanical and antagonists in controlling the disease, the maximum disease control was observed with spray of propiconazole (72.2%) followed by validamycine, hexaconazole, garlic cloves, carbendazim+flusilazole and moncern.

Key Words: Antagonists, Botanicals, Maize, *Rhizoctonia solani* f. sp. *sasakii*

Banded leaf and sheath blight disease of maize caused by *Rhizoctonia solani* f. sp. *sasakii* Exner [*Thanetophorus sasakii* (shirai) Tu & Kimbro] was first reported in 1966 as a minor disease in India (Payak and Renfro, 1966). This disease came in epidemic form and caused an unprecedented damage in foot hills of Mandi (Himachal Pradesh) in 1972 (Thakur *et al.,* 1973). Later, the disease was also recorded in north, north-western, central and north-eastern parts of the India. The disease is now wide spread and considered to be severe in Himachal Pradesh, Tarai area of Uttarkhand and across the length of Himalayas at the altitudes of 1100 to 1500 meters (Renfro and Ullstrup, 1976). The disease occurs both at pre- flowering and flowering stage causing direct losses and resulting in premature death, stalk breakage ear rot, and indirect losses by reducing the grain yield. The disease is more prevalent in humid weather with temperature around 28°C (Singh and Shahi, 2012). The banded leaf and sheath blight disease has been found to cause extensive losses not only in the total productivity of maize but also observed to cause considerable reduction in *per se* yield of high yielding varieties. However, the magnitude of grain loss may reach as high as 100 per cent if the ear rot phase of the disease predominates. Mehra *et al.* (2012) have also observed the disease in severe form in the last few years in Haryana and losses up to 100 per cent were recoded under continuous rainy conditions from July to August. Keeping in view the importance of the disease and lack of information available on this aspect, the present investigations were undertaken to evaluate the efficacy of fungicides and non-conventional chemicals for management of the disease.

MATERIAL AND METHODS

Collection, isolation and purification of *Rhizoctonia solani* f. sp. *sasakii:* The sclerotia of the soil-borne fungi *R. solani* f. sp. *sasakii* were collected from infected maize plants at the time of harvesting from Regional Research Station (RRS), Karnal and the sclerotia were preserved in Department of Plant Pathology, CCS Haryana Agricultural University, Hisar. Surface sterilization of the sclerotia were done with 0.1% mercuric chloride solution for 30 seconds, rinsed in sterile distilled water for 2-3 times, plated on potato dextrose agar medium (PDA) and incubated at 27±1°C for three days, purified by hyphal tip culture technique and finally used this pure culture for further experimental studies.

***In vitro* Conditions**

Evaluation of botanicals: Six plant species viz., neem (*Azadirachta indica*), eucalyptus (*Eucalyptus* spp.), aonla (*Emblica officinalis*), garlic (*Allium sativum*), onion (*Allium cepa*) and aak (*Ipomoea carnea*) were tested against *R. solani* f. sp. *sasakii* by poison food technique. The extracts of these botanicals were prepared in 1:1 ratio by crushing 100 g green leaves (garlic cloves, onion bulb, neem, aak and eucalyptus leaves) of each plant species in 100 ml distilled water using mixer and grinder. The supernatant was filtered through muslin cloth followed by Whatman filter paper no. 1.

The filtrates were then centrifuged at 5000 rpm for 10 minutes. Three concentrations *i.e.* 5, 10 and 15 per cent of the stock solution were prepared and were used in further experiment. The per cent inhibition of mycelium growth over control was calculated as

Per cent inhibition (%) =C-T/C×100

Where, C and T represent - radial growth of mycelia in control (mm) and in treatment (mm)

Evaluation of antagonists: *Trichoderma viride*, *T. harzianum*, *Pseudomonas fluorescens, P. maltophila* and *Bacillus subtilis* were obtained from department of Microbiology, CCS HAU, Hisar and tested for their efficacy in suppressing the mycelial growth of *R. solani* f. sp. *sasakii* by dual culture technique. Fungal antagonists were placed at same day, whereas, bacterial antagonists placed two days prior to pathogen inoculation. The per cent inhibition of mycelium growth over control was calculated by above formula.

***In vivo* Conditions**

Mass multiplication of *R. solani* f. sp. *sasakii*: Inoculum of *R. solani* f. sp. *sasakii* were prepared on barley grains for inoculation of pathogen under *in vivo* conditions. Barley grains were soaked in water for 24 hours after removing excess water and 100 g grain was added in each conical flask (500 ml) and autoclaved at pressure of 15 lb/sq. inch for 15-20 minutes. Each flask were inoculated with 2-3 day old pure culture of *R. solani* f. sp. s*asakii* and incubated at 27±1°C for 10 days for mycelial growth of pathogen on barley grains. These impregnated grains were used for inoculation of maize plants, both under pot and field conditions. Similarly, the mass culture of fungal antagonists was also prepared on barley grains, while the bacterial antagonists were prepared in water suspension which were used to inoculate in pot soils.

Evaluation of antagonists under screen house conditions: The experiment was conducted in earthen pots under screen house conductions. The pots were filled with mixture of sandy loam soil and FYM in 3:1 ratio and HM-4 hybrid cultivar of maize was sown in pots on last week of June, 2012. Four replications were maintained with three pots per replication and four plants per pot. When maize plants attained the height of 20-25 cm, the mass culture of antagonists was mixed @ 5 g kg^{-1} soil, while the bacterial antagonists were applied @ 5 ml kg^{-1} soil as soil drench. Inoculum of pathogen was inoculated in soil of pots after two weeks of antagonist inoculations and finally, the disease intensity was recorded using 1-5 scale by Ahuja and Payak (1983). The per cent disease intensity (PDI) was calculated by using following formula (Wheeler, 1969).

$$\text{PDI (\%)} = \frac{\text{Sum of numerical ratings}}{\text{No. of plants observed} \times \text{Maximum disease rating}} \text{X 100}$$

Evaluation of botanicals and fungicides under field conditions: HM-4 hybrid cultivar of maize was sown in 4 x 3m plot size with spacing 75 x 20 cm in three replicated sets using randomized block design under filed conditions during Kharif season 2011-12 and 2012-13 at Regional Research Station (RRS), Karnal. Different botanicals and fungicides were selected and tested against banded leaf and sheath blight disease for their efficacy against the pathogen *R. solani* f. sp. *sasakii*. Aqueous extracts of botanicals viz. neem leaves, eucalyptus leaves, aonla leaves, garlic clove, onion bulb and aak leaves were prepared at 15% concentration for foliar application and similarly, different fungicides *viz.,* moncern, validamycin, hexaconazole, carbendazim, carbendazim+flusilazole, propiconazole, copper oxychloride were also prepared for their foliar application. Carbendazim as seed treatment and stripping of lower two and three leaves along with sheath was also selected as treatments for the control of banded leaf and sheath blight disease in maize crop.

The plants were artificially inoculated with the pathogen at 40^{th} and 50^{th} day of planting followed by foliar sprays of fungicides after one week of inoculation. Two spray of each botanical and fungicide was applied, first application was done at the initiation of the disease (around one week after inoculation) followed by second at 15 days interval of the first spray. However, in case of stripping of leaves, lower two three leaves was removed along with sheath at the initiation of the disease. The observations of the disease and their symptoms were recorded on the basis of 1-5 scale and disease intensity was calculated. Data were analyzed statistically using online available statistical analysis tools (OPSTAT) (Sheoran, 2006).

RESULTS AND DISCUSSION

Evaluation of botanicals and antagonists *in vitro* conditions: The botanical were effective at all the concentration to suppress the mycelial growth of *R. solani* f. sp. *sasakii* under *in vitro* conditions. However, 15% concentration of botanicals was found most effective against mycelial growth of pathogen (Plate 1). *In vitro* study indicated that garlic cloves gave best results by suppressing 95.6% mycelial growth followed by neem leaves (53.3%), eucalyptus, aonla leaves, onion bulbs and aak leaves (Fig 1). Fruit pulp of *Azadirachta indica* and garlic leaf extract suppress the sclerotia formation and their mycelia formations reported by Meena *et al.* (2003). Kurucheve *et al.* (1997) observed that water extracts of *Eucalyptus globulus* completely inhibited the sclerotial production of *R. solani* at 2.5, 5 and 10 per cent concentrations.

Interesting growth inhibition patterns of *R. solani* f. sp. *sasakii* were observed with different fungal and bacterial antagonists in term of radial mycelial growth (Fig. 2) under *in vitro* conditions. A differential inhibition pattern was observed against the pathogen *R. solani* f. sp. *sasakii* with each antagonist, and among five potential antagonists, *Trichoderma viride* and *T. harzianum* proved to be the most potent bioagents against *R. solani* f. sp. *sasakii*. Initially very less effect was observed on the growth inhibition patterns of the pathogen by the antagonists, but after 4 days of incubation the rate of growth suppression was very high. A considerable reduction in radial mycelial growth of *R. solani* f. sp. *sasakii* was observed with fungal antagonists *T. viride* (23 mm) and *T. harzianum* (32 mm) after six days of incubation. The bacterial antagonist *P. fluorescens* and *B. subtilis* formed clear inhibition zones 8 mm and 5 mm, respectively, but no inhibition was formed with *P. maltophila* (Plate 2). However, *P. fluorescens* and *B. subtilis* inhibited mycelial growth more than 20 per cent. Rani *et al.* (2011) have observed that *T. harzianum* was superior to the bio-agents *T. viride, B. subtilis* and *P. fluorescens* with per cent growth inhibition of 67.02. Seema and Devaki (2012) reported the percentage inhibition of growth by *T. viride, T. harzianum, Aspergillus niger, B. subtilis* and *Penicillium* spp. on *R. solani* were 70, 67, 57, 50 and 44 per cent, respectively.

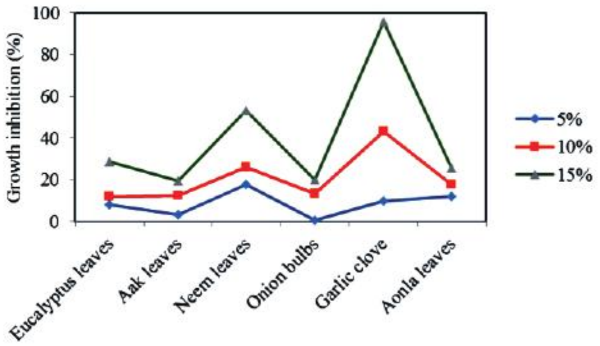

Fig. 1. Inhibition of mycelial growth of *R. solani* f. sp. *sasakii* at different concentration of botanicals under *in vitro* condition

Evaluation of antagonists under screen house conditions: The per cent disease inhibition was maximum with *T. viride* (32.2%) followed by *T. harzianum, P. fluorescens and B. subtilis*, however *P. maltophila* was found ineffective (Table 1). Similarly, Rani *et al*. (2013) also reported the effectiveness of *T. viride* used as seed treatment and soil application under field conditions. *P. fluorescens* effective against *R. solani* f. sp. *sasakii* in reduction of disease incidence was observed by Sharma and Saxena (2001) and Sharma *et al.* (2002). Some other workers have also reported the effectiveness of *B. subtilis* isolates against

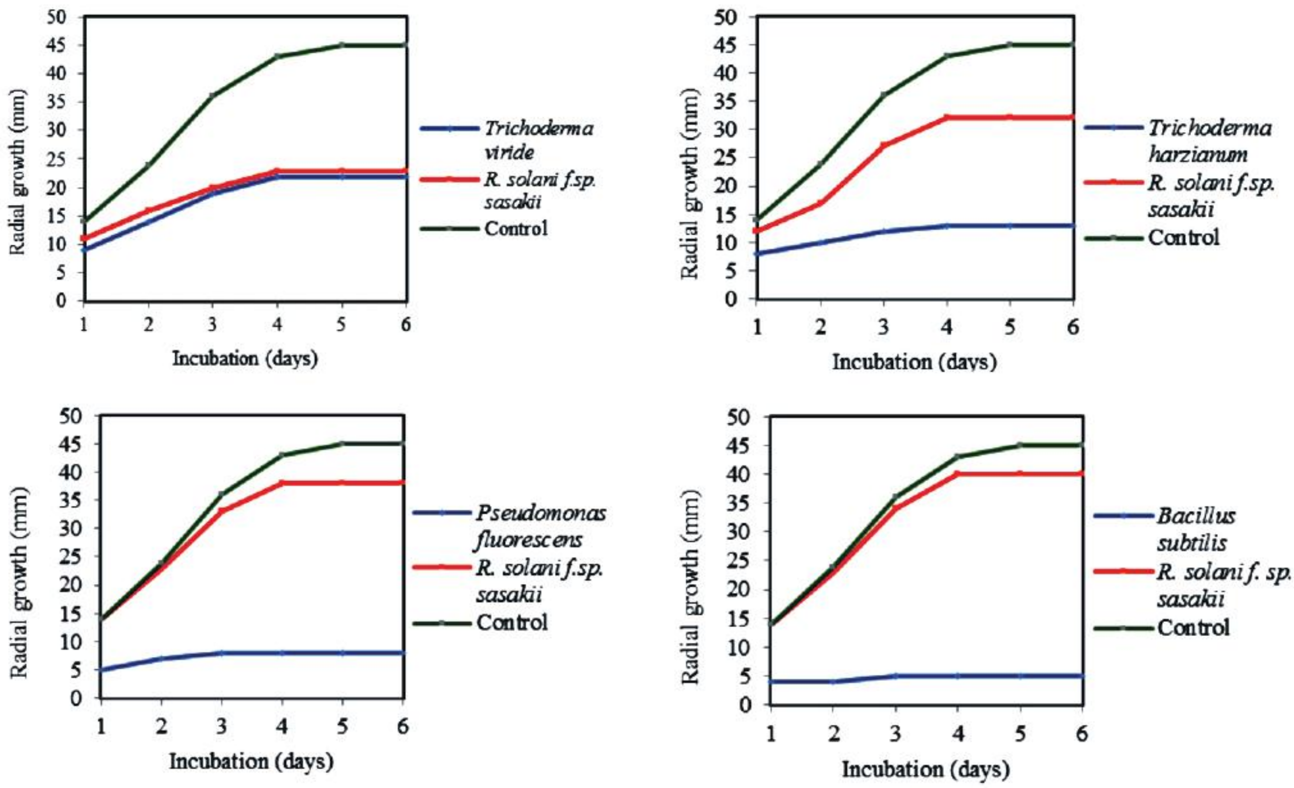

Fig. 2. Radial growth- patterns of *R. solani* f. sp. *sasakii* and different antagonistic agents under their mutual interaction conditions

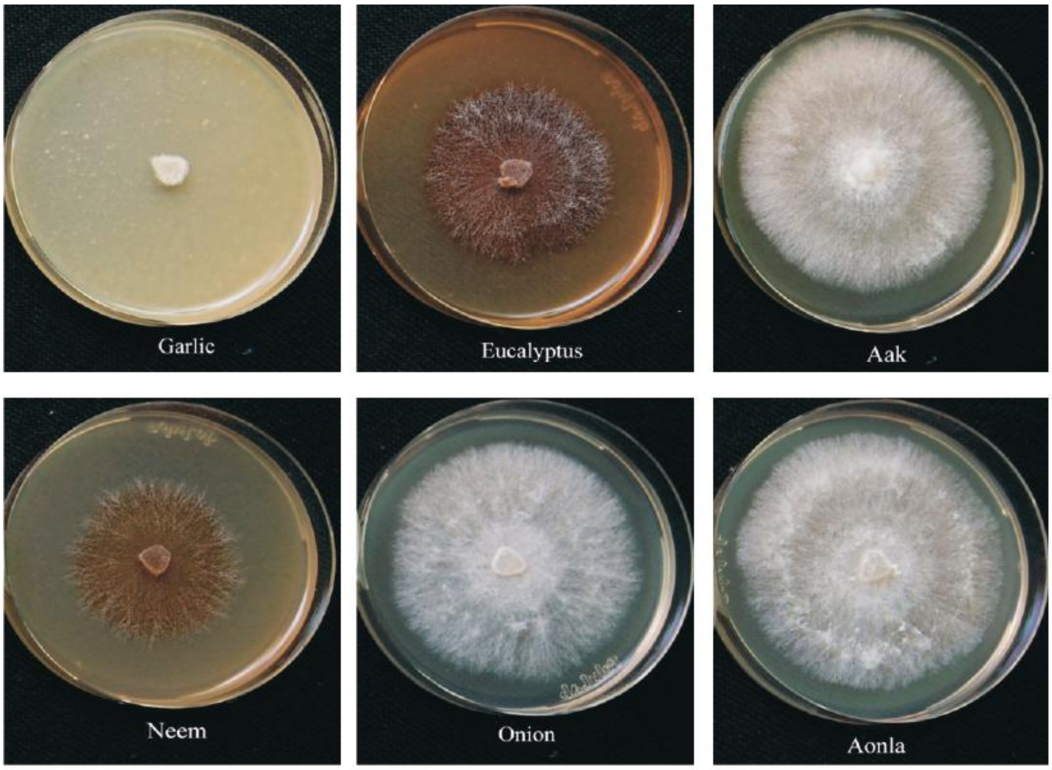

Plate 1: Efficacy of different botanicals at 15 per cent concentration on the mycelial growth of *R. solani* f. sp. *sasakii* under *in vitro* condition

the pathogen *R. solani* f. sp. *sasakii* (Gu-Zhen Rong *et al*, 2005; Muis and Quimio, 2006; Ugoji and Laing, 2008).

Evaluation of botanicals and fungicides under field conditions: The disease intensity with application of different botanicals (Table 2) was least with the foliar spray of garlic clove (45.0%) followed by neem leaves, onion bulb, eucalyptus, aonla and aak leaves under field conditions. However, among the botanicals, garlic cloves and neem leaves were most effective in control of disease by 50.6 and 38.8 per cent, respectively. The maximum yield (33.9 q ha^{-1}) was recorded with foliar application of garlic clove followed by neem leaves, onion bulbs, eucalyptus, aak and aonla leaves.

Table 1. Efficacy of various antagonists against *R. solani* f. sp. *sasakii* under screen house conditions

Antagonists	Per cent disease intensity (%)	Per cent disease control (%)
Trichoderma viride	56.8 (48.87)	32.2
Trichoderma harzianum	61.1 (51.39)	27.1
Pseudomonas fluorescens	69.5 (56.48)	17.1
Bacillus subtilis	73.6 (59.08)	12.2
Pseudomonas maltophila	82.2 (65.06)	1.90
Control	83.8 (66.24)	----
CD (P=0.05)	1.42	----
C.V.	1.36	----

Figures in parentheses are arcsine transformed values

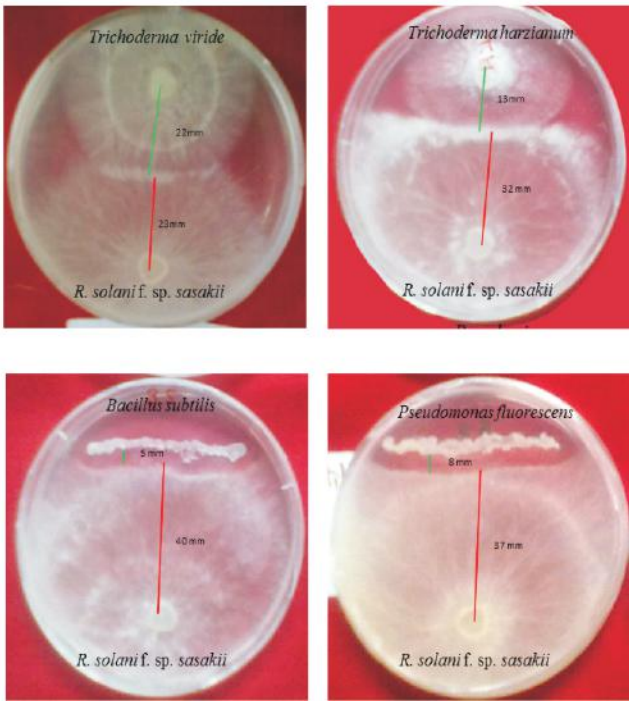

Plate 2. Growth patterns and inhibition of *R. solani* f. sp. *sasakii* through different antagonistic agents under *in vitro* condition

Garlic clove statistically differed to other botanicals. Meena *et al.* (2003) found plant extracts of garlic (5% w/v) as promising both in pot culture and field trials as soil drench or foliar spray in reduction of the disease intensity.

Different fungicides were tested under field condition as foliar spray after one week of artificial inoculation of *R. solani* f. sp. *sasakii.* The disease intensity recorded was minimum with foliar spray of propiconazole (24.3%) followed by validamycin. The disease intensity was more than 50 per cent even after applicalion of carbendazim (51.9%), copper oxychloride (69.95%) and carbendazim as seed treatment (64.9%). Significant difference was observed among the fungicides against banded leaf and sheath blight of maize. Stripping of lower leaves was also observed least effective with 51.1 per cent disease intensity (Table 3). Saxena (2002) tested efficacy of chemicals (propiconazole 0.1% and carbendazim 0.05%), by applying as foliar sprays at 30, 40 and 50th day of planting, alone or in combinations. Effectiveness of propiconazole was markedly observed, when the chemical was applied at initial stages at 30th or 40th day after planting and the second spray at 10 days after first. Rani *et al*. (2013) have used benomyl, carbendazim and thiram as seed treatment and soil application against banded leaf and sheath blight of maize, but carbendazim only was most effective. However, Rajput and Harlapur (2015) observed the minimum percentage disease intensity (20.40%) with two sprays of propiconazole (0.1%) at 30 and 40 days after sowing of maize. In China, the antibiotic Jinggangmycin (validamycin) was best in controlling the sheath blight of maize (Xue-Teng *et al.,* 2007). Singh and Singh (2011) observed that validamycin as foliar spray was more effective than propiconazole and carbendazim and correlated their effect with higher grain yield. Laster (carbendazim+ flusilazole) has been found effective and recommended against sheath blight of rice in Haryana (Anonymous, 2013). Stripping of lower leaves in 30-45 days old crop, removing infected maize leaves at the whorl stage or stripping of the lower 2-3 leaves along with sheath during rainy season considerably reduce the disease (Mehra *et al*., 2012). Among the fungicides, maximum disease was controlled by application of propiconazole (72.2%) followed by validamycin, hexaconazole, carbendazim+ flusilazole and moncern. The propiconazole gave maximum yield (47.8 q ha^{-1}) followed by validamycin (45.8 q ha^{-1}), hexaconazole (41.6 q ha^{-1}), carbendazim+flusilazole, moncern and carbendazim (Table 3). However, Devlash *et al.* (2011) and Rani *et al.* (2013) observed carbendazim highly effective as a seed treatment. Although, two sprays of propiconazole (0.1%) at 30 and 40 days after sowing of maize was found most effective by Rajput and Harlapur (2015).

In present investigation, garlic cloves, *T. viride,* propiconazole and validamycin were found effective against banded leaf and sheath blight of maize. These botanicals provide either certain toxic principles or strengthens the plant metabolic systems, whereas, the bio-agents uses different antagonistic as well as resistance inducing mechanisms,

Table 2. Efficacy of different botanicals against banded leaf and sheath blight of maize under field conditions

Botanicals	Per cent disease intensity (%)			Per cent disease control	Yield (q ha^{-1})		
	Season 2011-12	Season 2012-13	Mean		Season 2011-12	Season 2012-13	Mean
Eucalyptus leaves (*Eucalyptus* spp.)	67.5 (55.2)	64.5 (53.4)	66.0 $(54.3)^{c}$	27.5	20.8	18.2	19.5^{bc}
Aak leaves (*Ipomoea carnea*)	72.6 (58.5)	70.8 (57.3)	71.7 $(57.9)^{c}$	22.0	17.2	15.3	16.3^{bc}
Neem leaves (*Azadirachta indica*)	58.6 (49.9)	52.7 (46.5)	55.7 $(48.3)^{b}$	38.8	27.4	28.9	28.1^{d}
Onion bulbs (*Allium cepa*)	69.0 (56.2)	65.3 (53.9)	67.2 $(55.0)^{c}$	26.2	19.1	20.4	19.8^{c}
Garlic cloves (*Allium sativum*)	46.3 (42.8)	43.6 (41.3)	45.0 $(42.1)^{a}$	50.6	32.5	35.2	33.9^{e}
Aonla leaves (*Emblica officinalis*)	72.0 (58.1)	67.7 (55.3)	69.8 $(56.6)^{c}$	23.4	15.2	16.4	15.8^{b}
Control	94.2 (76.8)	87.9 (69.9)	91.1 $(72.7)^{d}$	---	10.3	11.7	11.0^{a}
CD (p=0.05)	4.55	4.4	3.86	---	4.11	2.33	3.80
C.V.	4.45	4.5	4.31	---	11.22	6.21	9.64

Figures in parentheses are arcsine transformed values
Values indicated by similar letters are statistically non-significant

Table 3. Efficacy of various fungicides against banded leaf and sheath blight of maize under field condition

Treatments	Per cent disease intensity (%)			Per cent disease control	Yield (q ha^{-1})		
	2011-12	2012-13	Pooled mean		2011-12	2012-13	Pooled mean
Moncern @ 0.1%	46.0 (42.7)	50.6 (45.3)	48.3 (44.0)^{cd}	44.7	38.6	35.3	37.0^{d}
Validamycin @ 0.2%	34.6 (35.9)	31.5 (34.1)	33.0 (35.1)^{b}	62.2	45.4	46.2	45.8^{f}
Hexaconazole @ 0.25%	44.3 (41.7)	41.2 (39.9)	42.8 (40.8)^{c}	51.0	40.8	42.5	41.6^{e}
Carbendazim @ 0.2%	50.0 (44.9)	53.8 (47.1)	51.9 (46.1)^{d}	40.5	36.4	35.2	35.8^{cd}
Carbendazim+flusilazole @ 0.2%	46.1 (42.7)	45.3 (42.3)	45.7 (42.5)^{cd}	47.6	38.1	37.8	38.0^{de}
Propiconazole @ 0.1%	26.3 (30.8)	22.3 (28.2)	24.3 (29.5)^{a}	72.2	47.4	48.2	47.8^{f}
Copper oxychloride @ 0.25%	66.0 (54.3)	73.9 (59.2)	69.9 (56.7)^{e}	19.9	24.4	22.7	23.6^{b}
Carbendazim seed treatment @ 2.5 g kg^{-1} seeds	61.7 (51.8)	68.1 (55.6)	64.9 (53.6)^{e}	25.6	25.5	23.5	24.5^{b}
Stripping of lower leaves	53.7 (47.1)	48.5 (44.1)	51.1 (45.6)^{d}	41.5	31.4	33.5	32.5^{c}
Control	94.2 (76.8)	87.9 (69.9)	91.1 (72.7)^{f}	---	10.3	11.7	11.0^{a}
CD (p=0.05)	5.28	3.34	4.25	---	3.33	3.74	3.21
CV	7.04	4.15	5.34	---	5.70	6.43	5.92

Figures in parentheses are arcsine transformed values
Values indicated by similar letters are statistically non-significant

competition and secretion of certain toxic principles/ antibiotics against the pathogen. The fungicide is superior to both the botanicals and bio-agents, as the pathogen is soil-borne and produces resting stages in sclerotial forms which can be easily overcome by the fungicides, whereas, botanicals and bio-agents require certain congenial conditions for their activity. So, for the management of the banded leaf and sheath blight of maize more effective and intensive trials need to be conducted for identification of stable sources of resistance and integration of cultural practices, chemical, plant extracts and bio-agents is also needed for effective management of this soil-borne pathogen in IDM strategies.

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Economic Analysis of Integrated Pest Management of Sugarcane in Haryana

Sumit, R. S. Pannu and Ajay Kumar

CCS, Haryana Agricultural University, Hisar-125 004, India
E-mail: athwal_sumit@yahoo.in

Abstract: The cost of cultivation for one hectare of sugarcane (Cost 'C_2') in IPM farmer's category was comparatively lower (Rs. 161830) than the non-IPM farmers category (Rs.164137). Human labour constituted the major share (19.03 and 17.85%) of the total cost of cultivation among the IPM and non-IPM farmer, respectively. The use of machine labour charges was higher non-IPM as compared to IPM. The fertilizer use in IPM was 3.37% and in non-IPM was 3.27 per cent of the total cost 'C_2'. Plant protection components accounted the highest share to the total cost in non-IPM farmers (3.19%), whereas, it was only (1.13%) in IPM farmers category. Total non-chemical pesticide used was 54.31% of the total cost on pest management and chemical pesticide used was 45.69% of the total cost on pest management. The per quintal cost of production on IPM sugarcane farm (Rs.190.39) was lower as compared to non-IPM sugarcane farms (Rs.209.54), mainly due to higher productivity per hectare on IPM farms (850 q) sugarcane than the Non- IPM farms (783.33 q). The gross returns on IPM and Non-IPM farms were estimated to Rs. 242317 and Rs. 223400 hectare^{-1}, respectively. The output-input ratio indicated of IPM (1:1.50) and for Non-IPM (1:1.36) that sugarcane cultivation was more profitable on IPM farms as compared to the Non-IPM sugarcane farms. The regression analysis showed that the plant protection chemicals have affected the yield of sugarcane on IPM farms significantly.

Key Words: Gross returns, IPM, Output-input ratio, Profitability, Sugarcane

Sugarcane (*Saccharum officinarum* L.) is an important commercial crop of the world and is cultivated in more than 100 countries. Out of total sugar production, 78% is made from sugarcane grown primarily in the tropical and sub-tropical zones of the southern hemisphere. Currently, 69 per cent of the world's sugar is consumed in the country of origin, while the balance is traded on world markets (Anonymous, 2007). Sugarcane crop is sensitive to the climate, soil type, irrigation, fertilizers, insects, disease control, varieties, and the harvest period. Over exploitation of natural resources and excessive chemicalization is main reason which led to poor sustainability of farm production. Though, the value of integrated pest management (IPM) in sustainable agriculture has been well recognized, it is being adopted very little at field level. The union agriculture ministry is concerned very much with the slow progress in IPM as there is increasing demand for chemical pesticide. In recent years, pesticides have come under sever criticisms due to resurgence and secondary outbreak of pest and potential hazards to ecology and human health. The resultant effects on farm economy have been escalation in the cost of production, increase in crop losses and reduction in farm profitability. These concerns have given rise to a demand for curtailing pesticide use in agriculture. In conventional non-IPM cultivation of sugarcane, cost of seed, chemical fertilizer and last but not the least chemical pesticides is considerably high as compared to other crops.

A number of non-chemical cultural practices form the core of IPM. Efforts should be made to minimize the expenditure and maximize the returns. The profitability is determined by the cost involves in the application of new technology, crop productivity and output price. In backdrop this, the study was undertaken to estimate the cost of production of sugarcane on IPM and non-IPM farms in Haryana and to determine the factors affecting productivity of sugarcane on IPM and non-IPM farms.

MATERIAL AND METHOD

Karnal district of Haryana was purposely selected for the study with 6 blocks in the district, out of which Indri and Karnal has been purposely selected for the present study due to highest area and production of sugarcane in the district. The study was based on farm level data pertaining to different aspect of economics of integrated pest management (IPM) of sugarcane. Two villages from each block were selected randomly. As such Bhadson and Khanpur villages from the Indri block, and Mahamudpur and Dakwala villages from the Karnal block formed the sample. A list of farmers who adopted IPM technology was prepared in consultation with the agricultural experts from the CCSHAU, Hisar and State Agriculture Department. From each selected village, 10 IPM and 10 non-IPM growers were selected randomly. The ultimate sample consisted of 40 IPM and 40 non-IPM farmers. The selected farmers were then divided into three categories according to their land holding by using cumulative cube root frequency method. The detail of which is provided in Table 1.

The primary data for the agricultural year 2012-13 were collected by survey method by through personal interviews of the selected farmers with the help of specially designed schedule. The data relating to various inputs used in the cultivation of sugarcane under IPM and non-IPM farms were collected. More specifically, the data were collected on yield, mechanical labour, human labour, seed cost, fertilizers, plant protection measures, etc.

Choice of production function: In order to determine the factors affecting sugarcane productivity, Cobb-Douglas Production Model was fitted of the following form:

Y = a x b x b x b x b x b5 e u

Where,

Y = Yield of sugarcane (Rs.)

X_1 = Total mechanical labour (Rs.)

X_2 = Total human labour (Rs.)

X_3 = Seed (Rs.)

X_4 = Fertilizer (Rs.)

X_5 = Plant protection charges (Rs.)

a = Constant

b_1- b_5 = Elasticity coefficients of respective inputs or regression coefficients.

eu = Error term with usual properties.

Also, the explanatory variables were tested for stochastic independence.

RESULTS AND DISCUSSION

IPM farmers used more of the human labour, fertilizers, whereas in case of non-IPM farmers, the use of machine labour and plant protection chemical was higher. The IPM farmers used on an average of small, medium, large and overall, 114.83, 121.52, 128.61 and 121.66 man days ha^{-1} of human labour as against 106.65, 119.83, 119.22 and 115.24 man days ha^{-1} by the non-IPM farmers, respectively. Similarly, the use of machine labour in small, medium, large and overall was 18.46, 19.35, 21.16 and 19.70 hours on IPM farm, while in case of non-IPM farms, its use was higher, *i.e.*, 19.95, 19.47, 21.54 and 20.28 hours, respectively. In case of seed and manures, small category farmers used equal quantity under both group, *i.e.*, 80 q ha^{-1} and 200 q ha^{-1} and in case of medium and large category, *i.e.*, 87.50 q ha^{-1} and 240 q ha^{-1} whereas, it was 85 and 226.67 q ha^{-1} seed and manures, respectively in IPM and non-IPM group. The total use of fertilizers by IPM farmers was found to be higher in all categories, *i.e.*, 261, 266, 271 and 266 kg ha^{-1} than those of non-IPM farmers in which it was 256, 261, 266 and 261 kg ha^{-1}, respectively. However, in case of plant protection chemicals, equal quantity of insecticides was used under small as well as medium farmers of non-IPM group. The overall insecticide used by non- IPM group was 6.04 litres/ha as compared to small, medium, large and overall categories in which equal quantity was used, *i.e.*, 5 litres ha^{-1} on the IPM farms. The use of biological agent *Trichogramma* cards plant products (Nimboli extract) and water soluble powder was equally used by all categories of IPM farmers, *i.e.*, 1.50 lac ha^{-1}, 1.50 litre ha^{-1} and 1.25 kg ha^{-1}, respectively. Small farmers obtained 800 q ha^{-1} yield, medium as well as large category farmers obtained equal quantity of yield, *i.e.*, 875 q ha^{-1}, whereas, overall average yield obtained was 850 q ha^{-1} as compared to non-IPM farmers in which equal quantity of yield was obtained in small and medium category, *i.e.,* 750 q ha^{-1}, 800 q ha^{-1} and in case of large category and overall average it was 783.33 q ha^{-1}, respectively. Similar findings were also reported by Kunnal *et al.* (2004).

Component-wise distribution of cost: The total cost on chemical pesticide used on non-IPM farms was same in the case of small and medium category farms (Rs. 5000). The corresponding figure for large category was estimated to be Rs. 5700 ha^{-1}. On the other hand in the case of IPM farms the same was estimated to be Rs. 800, 900 and 800 ha^{-1} in small, medium and large, respectively, which constituted 47.90, 48.65 and 41.02 per cent of the total cost incurred on plant protection measures, respectively. Of the total non-chemical pesticide materials used by IPM farms such as water soluble powder formed the major component. The respective figures for small, medium and large category were estimated to be 19.16, 18.93 and 23.08 per cent. This was followed by the expenses incurred on Trichogramma cards comprising of 17.96, 16.21 and 17.95 per cent for the above farm categories. The amount expended on plant product (*Nimboli extract*) was estimated to be 4.97, 16.21 and 17.95 per cent

Table 1. Classification of selected sugarcane growers of Haryana

Categories	Farm size group (in hectare)	No. of selected growers		Total
		IPM	Non-IPM	
Small	< 5.4	22	20	42
Medium	5.4-9.3	11	12	23
Large	> 9.3	0 7	08	15
		40	40	80

on small, medium and large IPM farms, respectively.

Total cost on chemical pesticide under non- IPM was Rs. 5233 ha^{-1} while in the case of IPM, it was Rs. 833 ha^{-1} which constituted 45.69 per cent percent of the total cost of IPM. of the total non-chemical pesticide materials used by IPM farms, the cost on water soluble powder formed the major component (20.48%) which was followed by the cost of Trichogramma cards (17.37%) and plant product (16.46%) in the total cost incurred on the plant protection. These results were inconsonance with the findings reported by Giri and Kapase (2007) and Naranjo et al. (2010)

Cost of cultivation: The cost of cultivation under IPM farms per hectare (Cost C_2) of small, medium and large category was Rs. 156924, Rs. 162836 and Rs. 165835, respectively. The corresponding figures for non-IPM farms came out to be Rs. 158929, Rs. 166005 and Rs.167572, for the above said farm categories, respectively. The per hectare Cost A_1 under the IPM farms on small, medium and large category were estimated to be Rs. 70910, Rs. 75783 and Rs. 77127, which accounted for 45.19, 46.50, 46.51 per cent of the total cost per hectare of Cost C_2. Similarly, under the non-IPM farms, the Cost A_1 were Rs. 73586, Rs. 77808 and Rs. 80102 per hectare on the above said farm categories, which accounted for 46.30, 46.87 and 47.45 per cent of the Cost C_2 by adding the value of imputed cost on account of the items such as rental value of land and interest in Cost A_1, respectively. The Cost B_2 were estimated to Rs. 145910, Rs. 150723 and Rs.

Table 2. Input use pattern of small, medium, large and overall growers (2012-13)

Items	Small growers		Medium growers		Large growers		Overall growers	
	IPM growers	Non - IPM growers	IPM growers	Non - IPM growers	IPM growers	Non - IPM growers	IPM growers	Non - IPM growers
Human labours (man days)								
Hired								
Male	38.17 (33.24)	36.75 (34.46)	39.46 (32.47)	37.14 (30.99)	39.27 (30.53)	38.26 (32.09)	38.97 (32.03)	37.38 (32.44)
Female	33.24 (28.95)	29.31 (27.48)	34.19 (28.14)	30.58 (25.52)	35.16 (27.54)	31.54 (26.46)	34.20 (28.11)	30.48 (26.45)
Sub-total	71.41 (62.19)	66.06 (61.94)	73.65 (60.60)	67.72 (56.51)	74.43 (57.87)	69.80 (58.55)	73.17 (60.14)	67.86 (58.89)
Family								
Male	23.30 (20.29)	22.25 (20.86)	25.39 (20.89)	27.71 (23.12)	28.72 (22.33)	25.86 (21.69)	25.80 (21.21)	25.27 (21.93)
Female	20.12 (17.52)	18.34 (17.20)	22.48 (18.50)	24.42 (20.38)	25.46 (19.80)	23.56 (19.76)	22.69 (18.65)	22.11 (19.19)
Sub-total	43.42 (37.81)	40.59 (38.06)	47.87 (39.39)	52.13 (43.50)	54.18 (42.13)	49.42 (41.45)	48.49 (39.86)	47.38 (41.12)
Total human labour	114.83 (100.00)	106.65 (100.00)	121.52 (100.00)	119.85 (100.00)	128.61 (100.00)	119.22 (100.00)	121.66 (100.00)	115.24 (100.00)
Machine (hrs)	18.46	19.95	19.35	19.47	21.16	21.54	19.70	20.28
Seed (q)	80	80	87.50	87.50	87.50	87.50	85	85
Manures (q)	200	200	240	240	240	240	226.67	226.67
Fertilizers (kg)								
Nitrogen	188.50	188.50	188.50	188.50	188.50	188.50	188.50	188.50
Phosphorus	57.50	57.50	57.50	57.50	57.50	57.50	57.50	57.50
Potash	15	10	20	15	25	20	20	15
Total fertilizers	261	256	266	261	271	266	266	261
Plant Protection								
Liquid insecticides (litres)	5	5.375	5	5.375	5	7.375	5	6.04
Water soluble powder (kg)	1.25	0	1.25	0	1.25	0	1.25	0
Trichograma chilonis (lakh ha^{-1})	1.50	0	1.50	0	1.50	0	1.50	0
Plant Products	1.50	0	1.50	0	1.50	0	1.50	0
Yield (q)	800	750	875	750	875	800	850	783.33

Figures in parentheses indicate the percentage to the total land holding

152127 hectare^{-1} on small, medium and large category on IPM farm while in the case of non-IPM farms it came out to be Rs. 148586, Rs. 152808 and Rs. 155102 on the above said farm categories, respectively. The major item of working capital on sugarcane farms under the IPM farm was hired labour which was estimated to be 11.54, 11.47 and 11.34 per cent in small, medium and large categories, respectively. The higher cost on labour may be due to the intensive cultivation and adoption of recommended package of practices by IPM farms. The other cost item such as machine labour expended by small, medium and large categories estimated to be 3.53, 3.59 and 3.83 per cent, respectively. The seed cost, fertilizer, manure cost, plant protection, repair charges and incidental charges were estimated to be 13.82, 3.43, 3.19, 1.06, 0.64 and 0.76 per cent of the Cost C_2 for small IPM farms, 14.56, 3.35, 3.68, 1.14, 0.61 and 0.74 per cent of the Cost C_2 for medium IPM farms and 14.30, 3.34, 3.62, 1.18, 0.60 and 0.90 per cent of the cost C_2 in the case of large IPM farm category, respectively. Under non-IPM group, the major items of working capital were hired human labour which came out to be 10.63, 10.39 and 10.61 per cent on small, medium and large farms, respectively. The respective figures for machine labour charges, seed, fertilizer, repair charges, manure and incidental charges were estimated to 3.76, 13.64, 3.33, 0.63, 3.15 and 0.72 per cent, 3.50, 14.28, 3.29, 0.60, 3.61 and 0.78 per cent and 3.86, 14.15, 3.26, 0.59, 3.58 and 0.84 per cent in the Cost C_2 for above said non-IPM farm categories, respectively. It was observed that the cost incurred on plant protection chemicals farms was higher for all non-IPM farm categories namely, as compared to IPM farms in the Cost C_2. The expensed incurred on human labour in the case of small, medium and large categories were estimated to Rs. 18099, Rs. 18676 and Rs. 18813 per ha on IPM farms. The respective figures for non-IPM farms were estimated to be Rs. 16887, Rs. 17258 and Rs. 17786 per ha for the above said farm categories, respectively. Similar findings were also reported by Singh and Singh (2005).

Overall analysis of cost of cultivation on IPM and non-IPM sugarcane farms: The cost of cultivation of sugarcane Cost C_2 was Rs. 2307 higher in non-IPM as compared to IPM. The Cost A_1 came out to be Rs. 74553 per hectare for IPM farms which accounted for 46.07 per cent of the Cost C_2. Similarly, in the case of non-IPM farms the Cost A_1 were estimated to Rs. 77134 ha^{-1}, which accounted for 46.99 per cent of the Cost C_2. The Cost B_2 was estimated to Rs. 149552 and Rs. 152135 per hectare in the case of IPM and non-IPM farms respectively. The major item of working capital on IPM sugarcane farms was hired labour (11.45%). The other cost items were machine labour (3.65%), seed (14.23%), fertilizer (3.37%), manure (3.50%), plant protection (1.13%), repairing charges (0.62%) and incidental charges (0.80%). The major items of working capital for non-IPM farms were hired human labour (10.54%), machine labour charges (3.71%), seed (14.03%), fertilizer (3.19%), repairing charges (0.61%), manure (3.45%) and incidental charges (0.78%). It was observed that the cost incurred on plant protection chemicals by the non-IPM was higher (3.19%) as compared to IPM farms (1.13%) as far as Cost C_2 was concerned. Similar findings were also reported by Tanveer (2006), Biradar (2007) and Kumar *et al*. (2008). It can be concluded from the above discussion that hectare^{-1} Cost C_2, Cost A_1 and Cost B_2 of sugarcane was higher for Non-IPM farms than IPM farms

Table 3. Component-wise cost incurred (*Rs*.ha^{-1}) by small, medium and large growers

Items	Small growers		Medium growers		Large growers		Overall	
	IPM growers	Non-IPM growers	IPM growers	Non-IPM growers	IPM growers	Non-IPM growers	IPM growers	Non-IPM growers
Trichogramma chilonis (lakh ha^{-1})	300 (17.96)	- -	300 (16.21)	- -	350 (17.95)	0 0	317 (17.37)	-
W.S.P. (kg) 1. *Beauvaria bassiana* 2.*Metarrzhium*	320 (19.16)	- -	350 (18.93)	- -	450 (23.08)	0 0	373 (20.48)	-
Plant product (Nimboli extract)	250 (14.97)	-	300 (16.21)	- -	350 (17.95)	0 0	300 (16.46)	-
Total non chemical Pesticides	870 (52.09)	- -	950 (51.35)	- -	1150 (58.98)	0 0	990 (54.31)	-
Chemical pesticides	800 (47.90)	5000 (100)	900 (48.65)	5000 (100)	800 (41.02)	5700 (100)	833 (45.69)	5233 (100)
Total cost on pest management	1670 (100)	5000 (100)	1850 (100)	5000 (100)	1950 (100)	5700 (100)	1823 (100)	5233 (100)

Figures in parentheses are percentage to total cost

Table 4. Cost of cultivation (Rs. ha^{-1}) of small, medium, large growers and overall averag

Particulars	Small growers		Medium growers		Large growers		Overall average	
	IPM Growers	Non-IPM growers	IPM growers	Non-IPM growers	IPM growers	Non-IPM growers	IPM growers	Non-IPM growers
				Hired human charges				
Male	11451	11025	11838	11142	11781	11478	11691	11214
	(7.30)	(6.94)	(7.27)	(6.71)	(7.10)	(6.84)	(7.22)	(6.83)
Female	6648	5862	6838	6116	7032	6308	6840	6096
	(4.24)	(3.69)	(4.20)	(3.68)	(4.24)	(3.76)	(4.23)	(3.71)
Total	18099	16887	18676	17258	18813	17786	18531	17310
	(11.54)	(10.63)	(11.47)	(10.39)	(11.34)	(10.61)	(11.45)	(10.54)
Machine labour charges	5538	5985	5841	5805	6348	6462	5910	6084
	(3.53)	(3.76)	(3.59)	(3.50)	(3.83)	(3.86)	(3.65)	(3.71)
Seeds	21680	21680	23712.5	23712.5	23712.5	23712.5	23035	23035
	(13.82)	(13.64)	(14.56)	(14.28)	(14.30)	(14.15)	(14.23)	(14.03)
Manures	5000	5000	6000	6000	6000	6000	5667	5667
	(3.19)	(3.15)	(3.6)8	(3.61)	(3.62)	(3.58)	(3.50)	(3.45)
				Fertilizers				
Nitrogen	2254.46	2254.46	2254.46	2254.46	2254.46	2254.46	2254.46	2254.46
	(1.44)	(1.42)	(1.38)	(1.36)	(1.36)	(1.35)	(1.39)	(1.37)
Phosphorus	2875	2875	2875	2875	2875	2875	2875	2875
	(1.83)	(1.81)	(1.77)	(1.73)	(1.73)	(1.71)	(1.78)	(1.75)
Potash	247.50	165	330	330	412.5	330	330	247.50
	(0.16)	(0.10)	(0.20)	(0.20)	(0.25)	(0.20)	(0.20)	(0.15)
Total	5376.96	5294.46	5459.46	5459.46	5541.96	5459.46	5459.46	5376.96
	(3.43)	(3.33)	(3.35)	(3.29)	(3.34)	(3.26)	(3.37)	(3.27)
Plant protection charges	1670	5000	1850	5000	1950	5700	1823	5233.33
	(1.06)	(3.15)	(1.14)	(3.01)	(1.18)	(3.40)	(1.13)	(3.19)
Repairing charges	1000	1000	1000	1000	1000	1000	1000	1000
	(0.64)	(0.63)	(0.61)	(0.60)	(0.60)	(0.59)	(0.62)	(0.61)
Irrigation charge	4800	4900	5100	5200	5250	5300	5050	5133.33
	(3.06)	(3.08)	(3.13)	(3.13)	(3.17)	(3.16)	(3.12)	(3.13)
Incidental charges	1200	1150	1200	1300	1500	1400	1300	1283.33
	(0.76)	(0.72)	(0.74)	(0.78)	(0.90)	(0.84)	(0.80)	(0.78)
Working capital	64463.96	66896.46	68838.96	70734.96	70115.46	72819.96	67775	70122.70
	(41.08)	(42.09)	(42.28)	(42.61)	(42.28)	(43.46)	(41.88)	(42.72)
Interest on working capital	6446.40	6689.65	6883.90	7073.50	7011.55	7282	6777	7012.27
	(4.11)	(4.21)	(4.23)	(4.26)	(4.23)	(4.35)	(4.19)	(4.27)
Cost ‘A_1’	70910	73586	75723	77808	77127	80102	74552	77135
	(45.19)	(46.30)	(46.50)	(46.87)	(46.51)	(47.80)	(46.07)	(46.99)
Rental value of land	75000	75000	75000	75000	75000	75000	75000	75000
	(47.79)	(47.19)	(46.06)	(45.18)	(45.23)	(44.76)	(46.34)	(45.69)
Cost ‘B_2’	145910	148586	150723	152808	152127	155102	149553	152135
	(92.98)	(93.49)	(92.56)	(92.05)	(91.74)	(92.56)	(92.41)	(92.68)
				Family labour charges				
Male	6990	6675	7617	8313	8616	7758	7740	7581
	(4.45)	(4.20)	(4.68)	(5.01)	(5.20)	(4.63)	(4.78)	(4.62)
Female	4024	3668	4496	4884	5092	4712	4538	4522
	(2.57)	(2.31)	(2.76)	(2.94)	(3.07)	(2.81)	(2.80)	(2.69)
Total	11014	10343	12113	13197	13708	12470	12278	12003
	(7.02)	(6.51)	(7.44)	(7.95)	(8.27)	(7.44)	(7.58)	(7.31)
Cost ‘C_2’	156924	158929	162836	166005	165835	167572	161831	164138
	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)
Main products	216800	203250	237125	216800	237125	216800	230350	212282
	-	-	-	-	-	-	-	-
By products	11400	10800	12000	11100	12000	11100	11800	11000

Figures in parentheses are percentage to Cost C2 for all the farm categories. This clearly showed that IPM technology not provided higher returns to the farms but also beneficial for the environment and human health.

Returns on IPM and non-IPM farms: In IPM farms, the cane yield was 800, 800 and 875 on small, medium and large farms, respectively. The overall figure came out to be 850 quintal ha^{-1}. An overall average value of main produce came out to be Rs. 230350 ha^{-1}. The overall average yield of by-product was 196.67 quintal ha^{-1}, which was estimated to be Rs. 11967 ha^{-1}. The gross returns were Rs. 228200, Rs. 249125, Rs. 249625 and Rs. 242317 ha^{-1}, whereas, net returns were estimated to be Rs. 71276, Rs. 86289, Rs. 83790 and Rs. 80486 ha^{-1} in the case of small, medium, large categories and overall average, respectively. The returns over Cost A_1 in the case of IPM farms were estimated to be Rs. 157289, Rs. 173402, Rs. 172498 and Rs. 167764 ha^{-1} in small, medium, large and overall average. The returns over Cost B_2 came out to be Rs. 82290, Rs. 98402, Rs. 97498 and Rs. 92764 on above said farm categories. The figures for returns over Cost C_2 were found to be Rs. 7126, Rs. 86289, Rs. 83790 and Rs. 80486 on small, medium, large and overall average, respectively. The output-input ratios were estimated at 1.45, 1.53, 1.51 and 1.50 on small, medium, large and overall average, respectively. The yield obtained by the non-IPM farms was 750, 800, 800 quintals ha^{-1} on small, medium and large non-IPM farms, respectively. An overall average yield of cane came out to be 783.33 quintal ha^{-1}. The value of the main produce was estimated to be Rs. 202350, Rs. 216800 and Rs. 216800 ha^{-1} in the small, medium and large farm categories with overall returns of Rs. 212282. The yield of by-product was 180, 185 and 185 quintal ha^{-1} on small, medium and large category growers. The value of by product was estimated to be Rs. 10800, Rs. 11100 and Rs. 11100 small, medium and large and overall figure came out to be Rs. 1167. The gross returns were estimated to be Rs. 214050, Rs. 227900, Rs. 228100 and Rs. 223400 on small, medium, large and overall average respectively. The corresponding figure net returns were estimated to be Rs. 55121, Rs. 61895, Rs. 60528 and Rs. 59261 for the above said farm categories. The returns over Cost A_1 in the case of non-IPM farms were Rs. 140464, Rs. 150092, Rs. 147998 and Rs. 146214 ha^{-1} on small, medium, large and overall average farm size, respectively. The corresponding figure for returns over Cost B_2 were came out to be Rs. 65464, Rs. 75092, Rs. 72998 and Rs. 71214 and returns over Cost C_2 were estimated to be Rs. 55121, Rs. 61895, Rs. 60528 and Rs. 59261 in the case above said farm categories, respectively. The output-input ratios were found to be 1.35,

Table 5. Cost and returns (*Rs.*ha^{-1}) of small, medium, large and overall growers from sugarcane

Particular	Small growers		Medium growers		Large growers		Overall	
	IPM growers	Non-IPM growers	IPM growers	Non-IPM growers	IPM growers	Non-IPM growers	IPM growers	Non-IPM growers
Yield (q ha^{-1})	800	750	875	800	875	800	850	783.33
Value of the main produce @271 q^{-1}	216800	203250	237125	216800	237125	216800	230350	212282
Yield (by-product)	190	180	200	185	200	185	196.67	183.33
Value of the by-product @60 q^{-1}	11400	10800	12000	11100	12000	11000	11967	11067
Gross returns (Rs.)	228200	214050	249125	227900	249625	228100	242317	223400
Net returns (Rs.)	71276	55121	86289	61895	83790	60528	80486	59261
Cost of cultivation at								
Cost ‘A’	70910	73586	75723	77808	77127	80102	74553	77135
Cost ‘B’	145910	148586	150723	152808	152127	155102	149553	152135
Cost ‘C’	156924	158929	162836	166005	165835	167572	161831	164138
Returns at (Rs.)								
Cost ‘A’	157290	140464	173402	150092	172498	147998	167764	146214
Cost ‘B’	82290	65464	98402	75092	97498	72998	92764	71214
Cost ‘C’	71275	551201	86289	61895	83790	60528	80486	59261
Cost of production (Rs. q^{-1})	196.16	211.90	186.10	207.51	189.53	209.46	190.39	209.54
Output-input ratio at cost ‘C’	1.45	1.35	1.53	1.37	1.51	1.36	1.50	1.36

Table 6. Functional analysis of IPM vis-à-vis non-IPM farms with respect to yield (monetary terms) of sugarcane crop

Variables		IPM growers N= 40	t-value	Non-IPM growers N= 40	t – value
Constant	a	210,842.921		216,358.467	
Total machine labour (Rs.)	X_1	3.726	3.271*	-1.308	-0.545
Total human labour (Rs.)	X_2	1.165	4.216*	0.478	0.778
Seeds (Rs.)	X_3	0.426	2.152*	0.722	1.702
Fertilizers (Rs.)	X_4	0.385	0.262	2.369	0.549
Plant protection charges (Rs.)	X_5	11.880	13.473*	-7.599	-3.685*
R^2		0.9843		0.5613	

1.37, 1.36 and 1.36 on small, medium, large and overall average farm size, respectively.

Functional analysis: All the five resource variables included in the production function under IPM have explained jointly as high as 98.43% of the total variation in the yield of sugarcane in monetary terms. In the case of non-IPM farms, the corresponding variables explained only 56.13 per cent variation in the yield. In the case of IPM farms, the regression coefficient of variables relating to plant protection charges and human labour were turned out to be significant statistically indicating that these were the important inputs to which the output was highly responsive. Similarly, the inputs of machine labour and plant protection charges were turned out to be significant statistically while under non- IPM farms, the regression coefficients of the variables such as plant protection charges were significant statistically worth mentioning that the influence of total machine labour, human labour, seed and fertilizers was turned out to be non-significant on non-IPM farms while it was significant in IPM farms. This revealed that the IPM components have contributed significantly to yield of sugarcane.

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Impact of Better Management Practices in Cotton on the Selected Biodiversity in Warangal, Telangana, India

R. Deepak[1], Vamshi Krishna, Murli Dhar, Farida Tampal and Ampilli Sridhar

World Wide Fund for Nature-India (WWF-India), Hyderabad-500 073, India
World Wide Fund for Nature-India (WWF-India), New Delhi-110 003, India
E-mail: deepak@rediffmail.com

Abstract: The impact of cotton production on freshwater ecosystems through activities such as excessive water withdrawal for irrigation, runoff from fields, drainage, pesticide application, dam construction and land reclamation has already been established. There has been hardly any study to determine the impact on biodiversity because of cotton production. The impact of better management practices (BMP), which can use resources effectively and reduce the negative environment foot print of cotton on the selected biodiversity is studied to validate the practices and to understand the potential impact of various cotton cultivation practices on biodiversity. The frequency, abundance of the vertebrates were more in BMP areas, in comparison to conventional area. A large population of Indian bull frog *Hoplobatrachus tigerinus* was found in the tank silt collected as manure for the BMP cotton crop fields. Indian bull frogs were recorded more in BMP (70 in numbers), when compare to non-BMP fields (32 in conventional cotton fields). Lepidopterans, Odonates, Arachnids and other invertebrates were studied for their frequency of visit to the BMP and non BMP cotton area. The frequency of visit is 26% more in the BMP area. Six bird species were recorded regularly in the cotton. Out of which, ashy prinia was selected to study for its detail interaction with cotton. Ashy prinia has spent an average of 54% of time feeding, 23% scanning, 14% flying, and 4% resting activities. The time spent on scanning the whole plant, flying in search of prey also adds to the feeding behaviour of the bird. This shows the potential of biological control of cotton pests by ashy prinia. The impact of agriculture practices on biodiversity has to be studied in detail to validate and recommend BMP. This could help in protecting the local biodiversity, which in turn can support the ecosystem to sustain productivity in an agriculture system.

Key Words: Ashy prinia, Biodiversity, Better management practices, Cotton

Agriculture has dominant role as a driver of change in biodiversity (Liu *et al.,* 2002). Biodiversity is negatively affected not only due to the transformation of natural habitat into agriculture lands, but also with the intensification of crop production. Cotton crop production systems use half of the agrichemicals in the world, which in turn affect the associated biodiversity. WWF has selected cotton as thirsty crop, as it uses considerable (7000-29000l) water to produce 1 kg of fibre, and it is considered as a threat to the ecosystem and biodiversity. WWF has been working with cotton farmers to reduce water and chemical use in cotton cultivation by introducing Better Management Practices (BMP). A comparative analysis of the biodiversity of cotton fields cultivated with BMP and with fields growing conventional cotton is necessary in order to determine the factors responsible for greater presence of biodiversity in BMP cotton fields. Salivaagu micro-basin in Godavari river basin was selected to implement BMP and efficiency was studied for their potential to reduce chemical use at farm level. The programme has reached out to 20214 farmers in 17095 ha of cotton growing fields with a positive transformation in the cotton cultivation practices. The farm level results have shown that there is significant reduction in the pesticide, fertiliser and water use at micro basin level. BMP can reduce the use of chemicals and water in crop management and encourage farmers to maintain farm diversity with recommended agriculture practices (Van der Werf, 1996). As per the monitoring and evaluation report prepared with the support of Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad for the season 2014-15, the BMP cotton fields have sprayed with 2.8ai kg ha^{-1}, compared to 3.91ai kg ha^{-1} in conventional cotton fields. The pesticide usage was reduced to 39.61% ha^{-1} in sample cotton fields with wide implementation of Integrated Pest Management (IPM) practices as part of BMP. The fertilizer use (NPK in Kgs ha^{-1}) is also reduced to 67.6% in BMP cotton fields, compared to conventional fields. The water use is reduced to 40.66% in BMP fields, compared to conventional fields by using drip, alternative furrow irrigation as part of BMP. Hence, the regular and large level adoption of BMP may support the habitat and improve associated biodiversity. WWF –India has initiated studies to understand the impact of the BMP on the biodiversity. The study was conducted to assess and to understand the potential impact of various cotton cultivation practices on biodiversity.

MATERIAL AND METHODS

The comparative analytical study on the impact of the selected biodiversity of BMP and Non-BMP cotton fields of Warangal was conducted by following the standard procedure.

Status of biodiversity in the study area through aninventory: The detailed inventory of the biodiversity in the project location was studied in the complete Salivaagu micro basin villages of Shyampet and Regonda Mandals, (Warangal District, Telangana). A total of 5.6 ha each of BMP and non-BMP crop fields were selected for sampling in both mandals. The flora and fauna of the area were recorded in detail. The study was conducted for a period of 3 years in different seasons.

Fig. 1. Map of Shayampet Mandal

Fig. 2. Map of Regonda Mandal

A pilot survey was conducted for selection and familiarization of the BMP and non-BMP sites. During the survey the sampling area and sites were selected with specific criteria. The control area (non-BMP sites), which are adjacent to project area was selected with similar soil characteristics to the BMP area and with similar wetland structure.

Selection of cotton cultivation practices and identification of key species: The detail list of BMP and conventional cotton cultivation practices was collected from the Programme staff. BMP were carefully analysed for their potential positive and negative impact on various species. The practices were grouped in to pre sowing soil management practices (tank silt application), water management practices (drip irrigation techniques, flooding and water logging), and pesticide management practices (botanical and safe pesticides and chemical pesticides). The pilot survey was also used to identify the important species, which are directly and indirectly influenced by the cultivation practices.

Lepidopterans (butterflies), Odonates (dragon and damsel flies), other invertebrates, arachnids, amphibians, reptilians, avian and mammalians were sampled both diurnally and nocturnally by using both opportunistic and standard methods like line transact, point survey, opportunistic sighting records and road flushing (at night). Terrestrial faunal diversity was studied through direct sighting and through collecting indirect evidences such as observing vocalizations, fecal observation, footprints and pugmarks and road kills. Identification of species was done using field guides of different fauna (Kunte, 2000; Coddington *et al.,* 2002; Das, 2002; Menon, 2003).

Seasonal sampling: The detail sampling studies were conducted during the cotton season and standard

Table 1. Sampling methods for different taxa with parameters estimated

Taxa	Sampling methods		Parameters estimated
Mammals	(a)	Belt transects	Species composition
(based on droppings and sighting)	(b)	Transects on trails (night & day)	Encounter rates of droppings
	(c)	Local information	Encounter rates of sightings
Birds	(a)	Belt transect – point samples	Species composition
	(b)	Transects on trails – point samples	Density
	(c)	Block counts for galliformes	
	(d)	Local information	
Reptiles & Amphibians	(a)	Transects on trails	Species composition
(including road kills)	(b)	Quadrat	Abundance
Lepidopterans (butterflies), Odonates and	(a)	Belt transects	Species composition
other Invertebrates, Arachnids	(b)	Transects on trails	Relative abundance

techniques were used to calculate the presence of the species, abundance of the species, and to analyse the behaviour of the species. The seasonal samplings were conducted thrice in the cotton season, including the preparatory cultivation period. Identification of species was done through field guides of different fauna. The focus of the study during different seasons was listed below:

Pre monsoon (pre sowing): Birds and other biodiversity observed in both non-BMP and BMP crop fields, and observations were made in tanks with special reference to the tank silt.

Onset of monsoon season (sowing): Insects, Arachnids and pollinators were observed.

Monsoon and post-monsoon seasons [vegetative (growing)-flowering-harvesting]: Observations made on pollinators/pests and insects. Also observations were made on feeding and nesting behaviours of birds.

The study was conducted for a period of 3 years. The surveys were conducted according to the growth of the cotton pattern (sowing, and growing-flowering-harvest, post-harvest and pre-sowing) in order to record and monitor the seasonal changes in the floral and faunal species. The species which were frequent and abundant in their interaction with the cotton crop were also listed down to study further in the cotton growing period. The study narrowed down to bird species, amphibian and invertebrates species which showed significant difference in their interaction with cotton crop, based on the cultivation practices followed in the field.

The data on pesticide and the fertiliser use was collected from the project during the study period. The farmers were interviewed for their observations in the farms for the change in the biodiversity, especially soil arthropods, visit of birds, earthworms, frogs in the fields etc. This information has supported in designing the sample studies and verifying the field observations.

RESULTS AND DISCUSSION

Warangal, Telangana has significant number of wetlands, which serve as percolation and irrigation tanks. Salivaagu micro basin is selected for the promotion of BMP in cotton. The initial study on the status of biodiversity in this region recorded that a total number of 335 plant species and 332 faunal species belonging to 77 families from the environs of the study sites. It indicates the potential for rich biodiversity in the study location, in spite of the larger area being used for agriculture.

The impact of agriculture practices on biodiversity can be at different level, from ecosystems to genetic/farm level micro-diversity. The biophysical processes relating to agriculture and biodiversity are so numerous and interacting that it is difficult to ascribe a particular biodiversity response to an individual agricultural cause. Rather, most biodiversity changes are responses to a suite of agricultural changes that can be regarded together as agricultural intensification. Hence, the study is limited to understand and explain the potential impact of the BMP on the selected biodiversity, which have direct interaction with the cotton crop during its production cycle.

Birds and other biodiversity observed in both non-BMP and BMP crop fields: Total of 58 bird species were recorded during the pre-monsoon survey. Since, this was the breeding season for birds; it was observed that many insectivorous birds visiting the BMP cotton fields. The birds were in search of the prey for themselves as well as for constructing nest. It was observed that many insectivorous bird species such as Ashy prinia (*Prinia socialis)*, Plain prinia (*Prinia inornata)*, Common myna (*Acridotheres tristis)*, Brahminy starling (*Sturnia pagodarum)*, Black drongo (*Dicrurus macrocercus)*, Cattle egret (*Bubulcus ibis)*, Scaly-breasted munia (*Lonchura punctulata)*, Green bee-eater (*Merop sorientalis)*, and White breasted kingfisher (*Halcyon smyrnensis)* in search of prey during the ploughing period (Fig. 3). A close observation was made on the soils of the BMP and non-BMP fields. The prey availability for the birds such as soil arthropods such as Amazon centipede (*Scolopendra amazonica)*, Tiger centipede (*Scolopendra hardwickei)*, and Termite (*Odontotermes formosanus),* House cricket (*Acheta domesticus)* was richer in the BMP fields.

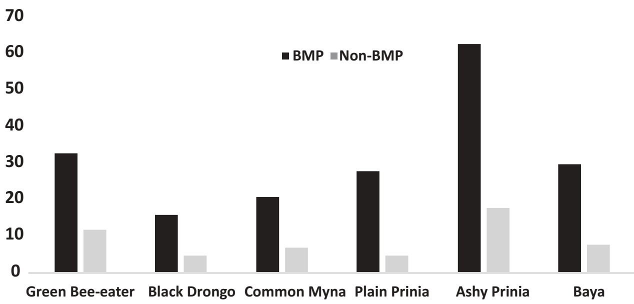

Fig. 3. Visit of insectivorous birds for prey

The insectivorous and predatory birds play a very useful role in controlling insect and rodent pests of agricultural crops (Asokan *et al.,* 2009). Presence of huge number of these birds in cotton crop fields is useful for controlling the pests on the crop. Unequal growth in height, poor water management and high pesticide applications can be the reasons for less count of these birds in Non-BMP fields. The more diversity of birds in BMP fields gives more choice for the food preference of the bird species.

Among all the six species, ashy prinia (*Prinia*

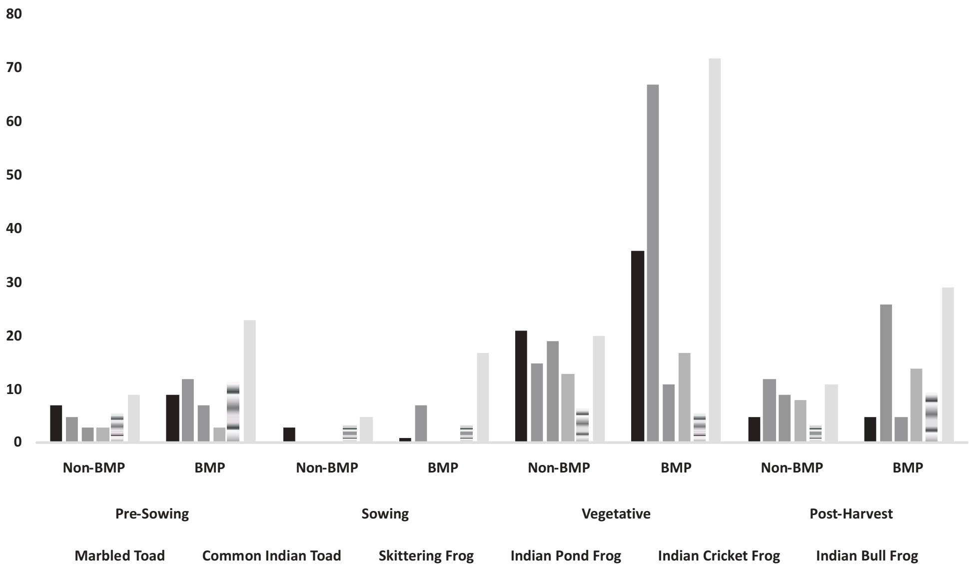

Fig. 4. Amphibians recorded in BMP and Non-BMP fields

socialis) most frequently visits the BMP and non-BMP fields (Table 2). Though it visits both the BMP and non-BMP cotton crop fields for food, the frequency in its visiting to the BMP field was higher. Their food mainly comprised of diverse agriculturally valuable insect pests and was also seen to feed on crustaceans. A detailed behavioural study of this species was conducted using "Time Activity Budget" - a quantitative description of how animals apportion their time for feeding and other activities (Altman, 1974; Rodway, 1998; Ramachandran, 1998).

Ashy prinia has spent an average of 54, 22, 14 and 4 percent of time in feeding, scanning, flying, and resting activities. The time spent on scanning the whole plant, flying in search of prey also adds to the feeding behaviour of the bird. This shows that there is a chance of biological control of cotton pests (aphids and others) by ashy prinia. Common Bird Monitoring of India (CBMI) has selected ashy prinia as bird of the Month in August 2012 and reported that ashy prinia is an insectivorous bird and it feeds on a diversity of insects like Coccids, aphids, earwigs, leafhoppers, caterpillars, grasshoppers and butterflies, spiders and also flower nectar.

Being an upright plant with evergreen foliage, ashy prinia builds its nest during breeding season in cotton. Also cotton being an all season feeding ground or food resource, the bird has selected cotton shrubs in BMP fields for nesting and breeding. The bird chooses shrubby plant within the field. The ashy prinia builds its nest close to the ground in the shrub and lays 3–5 eggs. Breeding has been recorded after the monsoons. A total of 12 nests were recorded during the study. Hence, ashy prinia can be considered as one of the most important species impacted by BMP and also supporting cotton in pest control.

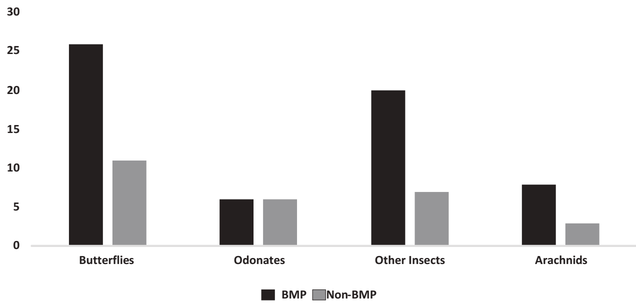

Fig. 5. Number of arthropods observed in sample plots during a visit

Observations made in tanks with special reference to the tank silt: The interactions between humans, land and water is the greatest in wetlands, i.e., tanks. Tanks also have the highest productivity both in agriculture and ecosystem uses

Table 2. Mean percentage of diurnal time spent in various activities by ashy prinia

Activity	Pre-Sowing	Sowing	Vegetative	Post-Harvest	Overall
Scanning	18.9	21.3	27.1	22.6	22.4
Feeding	47.3	52.8	57.4	56.7	53.5
Resting	4.1	5.1	2.6	2.7	3.7
Flying	11.6	14	15.6	15.3	14.1

Table 3. Butterfly diversity in the study area

Scientific name	Common name	Abundance
Family : Hesperiidae		
Hasora chromus	Common banded awl	C
Spialia galba	Indian skipper	C
Family : Lycaenidae		
Castalius rosimon	Common pierrot	VC
Catochrysops Strabo	Forget-me-not	C
Freyeria trochylus	Grass jewel	VC
Jamides celeno	Common cerulean	C
Leptotes plinius	Zebra blue	C
Family : Nymphalidae		
Acraea violae	Tawny coster	VC
Ariadne ariadne	Angled coster	UC
Byblia ilithyia	Joker	VC
Danaus chrysippus	Plain tiger	VC
Danaus genutia	Striped tiger	VC
Euploea core core	Common crow	C
Euthalia nais	Baronet	UC
Hypolimnas bolina	Great eggfly	C
Hypolimnas misippus	Danaid eggfly	C
Junonia altites	Grey pansy	VC
Junonia hierta	Yellow pansy	C
Junonia lemonias	Lemon pansy	VC
Junonia orithya	Blue pansy	C
Melanitis leda	Common evening brown	VC
Moduza procis	Commander	UC
Phalanta phalantha	Common leopard	C
Polyura athamas	Common nawab	UC
Precis almana	Peacock pansy	VC
Precis iphita	Chocolate pansy	C
Tirumala limniace	Blue tiger	C
Family : Papilionidae		
Graphium agamemnon	Tailed jay	R
Pachliopta aristolochiae	Common rose	VC
Pachliopta hector	Crimson rose	VC
Papilio demoleus	Lime butterfly	VC
Papilio polytes	Common mormon	C
Family : Pieridae		
Catopsilia pomona	Common emigrant	C
Cepora nerissa	Common gull	C
Colotis danae	Crimson tip	C
Colotis etrida	Small /little orange tip	C
Delias eucharis	Common jezebel	C
Eurema hecabe	Common grass yellow	C
Ixias marianne	White orange tip	C
Leptosia nina	Psyche	C
Pareronia valeria	Common wanderer	C

Abundance: C = Common; UC = Uncommon; VC = Very common; R = Rare

(Canet *et al.,*2003; Amarnath and Karthik, 2006; Binitha, 2006; Ramanagowda *et al.,*2009). Tanks in Shyampet and Regonda Mandals, where tank silt is collected for nourishing the soil during land preparation in the BMP cotton fields were visited for observation. Many significant changes in the biodiversity were recorded. A large population of Indian bull frog *Hoplobatrachus tigerinus* was found in the tank silt collected as manure for the BMP cotton crop fields (Fig. 4). This results in translocation of frogs from the pond to the cotton crop field. Frogs also attract snakes- the bio-control for rodents. Tank silt usage can improve the water retention capacity. This results in reduced water usage and could lead to favourable temperatures for the growth of soil arthropods that play a vital role in fixing soil nutrients for better cotton growth.

Insects, arachnids and pollinators: Insects are seen as harmful for the devastation they cause on cotton crops (Table 3, 4, 5 and 6). But, we have recorded their presence during the survey in both the BMP and non-BMP fields and have also studied and analysed their benefits using existing literatures. Insects and pest population and the pest management activities play a vital role in the local biodiversity. During the survey, a total 35 species of

Table 4. Odonata diversity in the study area

Scientific name	Common name	Abundance
Family : Gomphidae		
Ictinogomphus rapax	Common clubtail	UC
Family : Aeshnidae		
Anax guttatus	Blue-tailed green darner	R
Family : Cordulidae		
Aethriamanta brevipennis	Scarlet marsh hawk	R
Family : Libellulidae		
Brachythemis contaminata	Ditch jewel	C
Crocothemis servilia	Rudy marsh skimmer	C
Diplacodes trivialis	Ground skimmer	VC
Orthetrum luzonicum	Tricoloured marsh hawk	VC
Orthetrum sabina	Green marsh hawk	C
Orthetrum taeniolatum	Little skimmer	VC
Rhodothemis rufa	Rufous marsh glider	VC
Rhyothemis variegata	Common picture wing	VC
Tramea basilaris	Red marsh trotter	VC
Trithemis pallidinervis	Long-legged marsh glider	VC
Family : Coenagrionidae		
Ceriagrion coromandelianum	Coromandel marsh dart	C
Ischnura aurora	Golden dartlet	VC
Ischnura senegalensis	Senegal golden dartlet	VC
Pseudagrion microcephalum	Blue grass dartlet	C
Pseudagrion rubriceps	Saffron-faced blue dart	UC

Abundance: C = Common; UC = Uncommon; VC = Very common; R = Rare butterflies are recorded commonly in both the BMP and Non-BMP fields. The presence of pollinators like butterflies (mud-puddling), dragonflies and other insects in BMP area during the sowing season is higher compare to the non BMP fields. This may be due to the water management practices and pest management. The frequent flooding of cotton crop results in the change of micro climate and soil moisture, which is harmful to the soil arthropods and other insects. The frequent spraying of pesticides in non BMP fields also resulted in lower count of the invertebrate species. Pesticide use in BMP cotton fields are reduced by 39.61% compare to non-BMP cotton fields and the average sprays in non-BMP cotton fields are 6, whereas, 4 in BMP cotton fields.

CONCLUSION

This 3-year study had provided an insight into the impact of BMP on biodiversity. The findings can be further corroborated through a long term study and indicator species for BMP can be arrived at. Preparation of biodiversity monitoring plan will help in validating the recommended agriculture practices, which in turn will improve ecosystem productivity. The methodology used for this study is first of its

Table 5. Other invertebrates' diversity in the study area

Scientific name	Common name	Abundance
Order : Orthoptera Family : Gryllidae		
Acheta domesticus	House cricket	VC
NEMOBIUS S YLVESTRIS	Wood cricket	C
Family : Acrididae		
Chortophaga viridifasciata	Green-striped grasshopper	C
Melanoplus sanguinipes	Brown grasshopper	VC
Family : Pyrgomorphidae		
Poekilocerus pictus	Painted grasshopper	R
Order: Hymenoptera Family : Formicidae		
Componatus compressus	Common godzilla ant	VC
Componatusirritans	Giant honey ant	C
Crematogaster subnuda	Common board acrobat ant	C
Diacamma ceylonense	Greater striated bispinous ant	C
Leptogenys processionalis	Procession ant	C
Monomorium criniceps	Spineless harvester ant	C
Monomorium pharaonis	Pharaonis ant	VC
Occophylla smaragdina	Weaver ant	VC
Pachycondyla tesseronoda	Rare sausage huntress ant	VC
Solenopsis geminata	Common red fire ant	C
Tetraponera rufonigra	Arboreal bicolored ant	VC
Family : Apidae		
Apis cerana	Asiatic honey bee	C
Apis dorsata	Giant honey bee	VC
Order : ColeopteraFamily : Carabidae		
Anthia sexguttata	Six-spot ground beetle	UC
Cicindela sp.	Green tiger beetle	UC
Family : Scarabaeidae		
Oryctes nasicornis	Palm rhinoceros beetle	C
Family : Scolopendridae		
Scolopendra amazonica	Amazon centipede	C
Scolopendra hardwickei	Tiger centipede	R
Family : Termitidae		
Odontotermes formosanus	Termite	VC

Abundance: C = Common; UC = Uncommon; VC = Very common; R = Rare

Table 6. Arachnid diversity in the study area

Scientific name	Common name	Abundance
Family : Buthidae		
Hottentotta tamulus	Brown scorpion	VC
Lyhcas scaber	-	R
Lychas tricarinatus	-	C
Isometrus corbeti	-	C
Family : Scorpionidae		
Heterometrus swammerdami	Giant forest scorpion	VC
Family : Araneidae		
Argiope anasuja	Signature spider	VC
Argiope pulchella	Garden cross spider	UC
Neoscona bengalensis	Spotted orb spider	VC
Neoscona mukerjei	Common garden spider	C
Family : Eresidae		
Stegodyphus sarasinorum	Social spider	VC
Family : Hersiliidae		
Hersilia savignyi	Common two tail	VC
Murricia sp.	Spotted orb spider	UC
Family : Lycosidae		
Lycosa sp.	-	C
Hippasa agelenoides	Wolf spider	UC
Pardosa birmanica	Wolf spider	C
Pardosa sumatrana	Wolf spider	C
Family : Oxyopidae		
Oxyopes pawani	Pawan's green lynx spider	UC
Peucetia yogeshi	Yogesh's green lynx spider	UC
Family : Pholcidae		
Artema atlanta	Atlanta spider	UC
Crossopriza lyoni	Daddy long legs	UC
Pholcus phalangioides	Pholcus spider	VC
Family : Tetragnathidae		
Leucauge decoratus	Decorated spider	C
Tetragnatha mandibulata	Spike orb spider	UC
Family : Salticidae		
Marpissa mandali	Jumping spider	C
Myrmarachne plataleoides	Ant mimic spider	C

Abundance: C = Common; UC = Uncommon; VC = Very common; R = Rare

kind and can be tested on other crops and other geographical locations for refinement and wider replication.

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Life Table Studies of *Pieris brassicae* L. on Different Hosts Plants

Praveen Vaishnav, V. Kaul, R. M. Bhagat and Devinder Sharma*

Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu
Jammu-180 009, India
**E-mail: devskuastj@gmail.com*

Abstract: Age and stage specific life table and life table parameters of *Pieris brassicae* were studied under laboratory conditions on cabbage, cauliflower, broccoli, toria and yellow sarson in 2014-15 .*P. brassicae* required 43 days to complete generation on toria and 35-39 days on remaining hosts. The highest values of net reproductive rate (44.75 females/female/generation), Intrinsic rate of increase (0.0504 females/female/day), Finite rate of increase (1.0517 females/female/day), weekly multiplication of population [1.4229 times], Annual Rate of Increase (97191147.07 times), hypothetical F_2 females (2002.2) were recorded on cabbage. The cabbage was highly preferred while toria was the least preferred crop by the *P. brassicae.* The survivorship decreased gradually from an initial stage of development till culmination of the generation on each host plant. The total generation mortality, 'K' of *P. brassicae* was recorded maximum (0.6576) on toria followed by minimum (0.3098) on cabbage. The life-table parameters revealed that cabbage is the most preferred food of *P. brassicae* than other crucifer crops.

Key Words: Age stage specific, Crucifers, Life table, *Pieris brassicae*

The damage caused by insect herbivory alone causes 40 per cent of yield loss annually on different vegetable crops (Hasan and Ansari, 2010). Hasan (2008) listed 38 insect pest species that feed on the cole crops; among these the cabbage butterfly, *Pieris brassicae* (L.) (Lepidoptera: Pieridae), is one of the most destructive pests, causing damage at all host plant growth stages from seedling to vegetative and flowering stages. In India, it is distributed in Himalayas while in plains, it has been reported as major pest from Punjab, Haryana, West Bengal, Bihar, Andhra, Orissa and Meghalaya (Hemchandra and Singh, 2005). The strategies to control any insect pest generally need a detailed study of the life history parameters (Hasan and Ansari, 2010). There is a considerable interest to explore alternative methods, including host plant resistance to efficiently control the large white butterfly and diminish its damages on the crops. Life tables are powerful tools for analyzing and understanding the impact that an external factor has upon the growth, survival, reproduction, and rate of increase of an insect population (Soleimannejad *et al*., 2010). Life table is an appropriate tool to study the dynamics of animal populations, especially arthropods, because this tool can provide very important demographic parameters (Maia *et al*., 2000). Demographic studies have several applications: analyzing population stability and structure, estimating extinction probabilities, predicting life history evolution, predicting outbreak in pest species, and examining the dynamics of colonizing or invading species (Haghani *et al*., 2006). Demographic information may also be useful in constructing population models and understanding interactions with other insect pests and natural enemies. Knowledge of the biology and life table parameters of *P. brassicae* on different cole crops could be effective in detecting and monitoring the pest infestation, variety selection and crop breeding. The present investigation was therefore undertaken to construct the life table of *P. brassicae* and identify the key mortality factors responsible for fluctuation in its population.

MATERIAL AND METHODS

Five hosts i.e. cabbage (*Brassica oleracea* var*. capitata*), cauliflower (*B. oleracea* var*. botrytis*), broccoli (*B. oleracea* var*. italica*), *toria (B. oleracea var*. *toria) and yellow* sarson (*B. campestris* var*. yellw sarson*) were used. A cohort, comprising 100 eggs were collected from the field and after hatching, the cluster of 10 caterpillars (zero day old) in 10 replications, making a cohort of 100, were reared in plastic vial (6x10 cm) on leaves of respective host plant. When the caterpillars reached in to second larval instar, they were reared individually in separately till formation of adult and their subsequent mortality was also recorded. On adult emergence, the male and female reared in nylon mesh cage on respective host plant. A sugar soaked cotton swab along with flowers of respective host plant were also provided in the cage for feeding of adults. Age specific data on the survival and mortality of the larvae was recorded at every 24 hrs interval. The different vital statistics of age and stage specific life-tables were calculated as per suggestions of Birch (1948) and Southwood (1978).

RESULTS AND DISCUSSION

Age specific life table : The present study indicated that host plants affected biological aspects including life history and life table parameters of *P. brassicae* (Fig. 1-5 and Table 1, 2). The highest values (female/female) of net reproductive rate (R_o) 44.75 per generation, Intrinsic rate of increase (r_m) 0.0504 day^{-1}, finite rate of increase (ë) 1.0517 day^{-1}, weekly multiplication of population 1.4229 times, Annual Rate of Increase (ARI) 97191147.07 times, hypothetical F_2 females 2002.20 were on cabbage with lowest mean length of generation (T_c) 32.7598 days and doubling time (DT) 5.9740 days as compared to other crucifers (Table 3). These results depicted that cabbage was highly preferred by the *Pieris brassicae* as compared to other crucifer crops.

The lowest values of net reproductive rate (R_o) 1.40 females/female/generation, Intrinsic rate of increase (r_m) 0.0036 females/female/day, Finite rate of increase (ë) 1.00357 females/female/day, weekly multiplication of population 1.0253 times, Annual Rate of Increase (ARI) 3.68 times, hypothetical F_2 females 1.96 were found on toria with highest mean length of generation (T_c) 40.9286 days and Doubling Time (DT) 84.3146 days as compared to other crucifers (Table 2). These results depicted that toria was not preferred by the *P. brassicae* as compared to other crucifer crops.

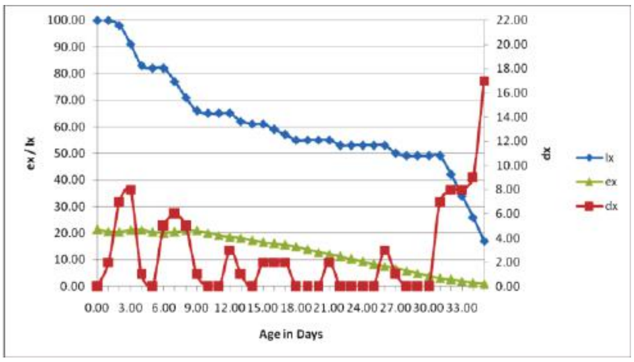

Fig. 1. Age specific suvivorship (l_x), death (d_x) and life expectancy (e_x) of *P. brassicae* on cabbage

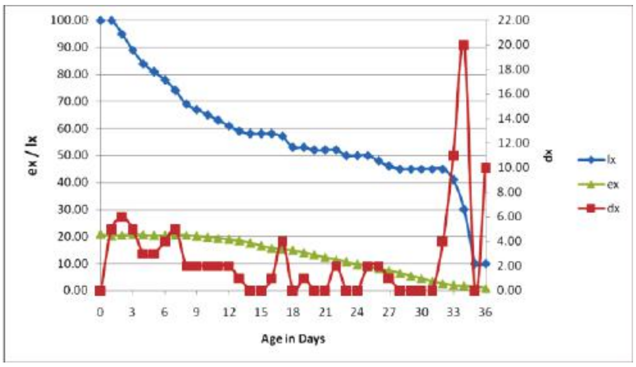

Fig. 2. Age specific suvivorship (l_x), death (d_x) and life expectancy (e_x) of *P. brassicae* on cauliflower

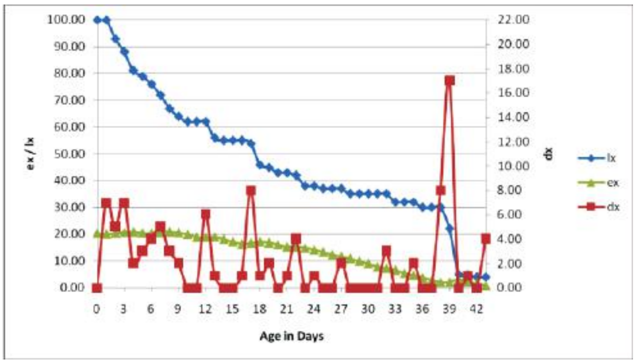

Fig. 3. Age specific suvivorship (l_x), death (d_x) and life expectancy (e_x) of *P. brassicae* on broccoli

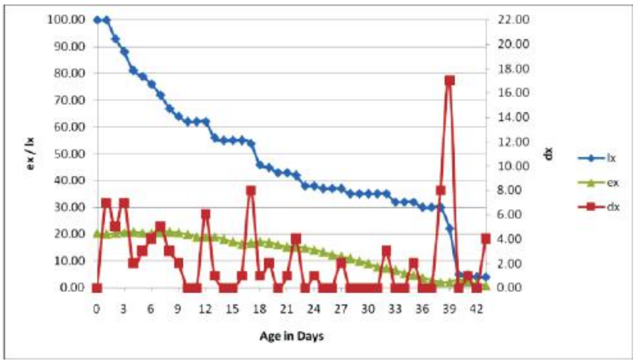

Fig. 4. Age specific suvivorship (l_x), death (d_x) and life expectancy (e_x) of *P. brassicae* on toria

Similar observations on different insects were also reported by Hemchandra and Singh (2005); Jeyakumar *et al*. (2005); Mohapatra and Sahu (2005); Dabhi and Patel (2007); Sonawane *et al.* (2007); Acharya *et al*. (2007); Bisane and Katole (2008); James and Khan (2008); Mohana; Sundaram and Dhandapani (2008); Singh and Yadav (2009) ; Choudhury *et al*. (2013); Kumar *et al*. (2014) and Dhurgude *et al.* (2015). This information can aid in detecting and monitoring pest infestations, cultivar selection, and crop breeding programme showing that the toria was highly resistant crop against the attack of *P. brassicae*.

Stage specific life table; The survival of *Pieris brassicae* decreased continuously from day one, till the end of generations on each crucifer host plant (Table 3). At egg stage, the apparent mortality was recorded maximum (24.00%) on toria and minimum (17.00%) on cabbage and broccoli. At larval instars, the highest mortality (19.51%) was noticed at second instar on cabbage and lowest (1.20%) at first instar on cabbage. Similarly, at pre-pupal the maximum mortality (5.41) was f on toria and minimum (zero) on cabbage. At pupal stages, the maximum mortality (37.14%) was on toria and minimum (10.00%) on cauliflower. The highest fraction (S_x) was obtained (0.99) at first instar on

Table 1. Age specific fecundity of *P. brassicae* on host plants

Pivotal age in days (x)	Survival at different age interval (l_x)	Age schedule for birth at age x (m_x)	$l_x.m_x$	$x.l_x.m_x$
		Cabbage		
0-29	0.49	-	-	Immature
30	0.49	-	0.49	14.7
31	0.49	-	0.49	15.19
32	0.42	43.4	18.228	583.296
33	0.34	45.9	15.606	514.998
34	0.26	38.2	9.932	337.688
35	0.17	-	-	-
			$\Sigma l_x m_x$ = 44.746	$\Sigma x l_x m_x$=1465.87
		Cauliflower		
0-31	0.45	-	-	Immature
32	0.45	-	0.45	14.4
33	0.41	-	0.41	13.53
34	0.30	38.5	11.55	392.7
35	0.10	60.9	6.09	213.15
36	0.10	-	-	-
			Σlxmx = 18.5	Σxlxmx=633.78
		Broccoli		
0-32	0.34	-	-	Immature
33	0.34	-	0.34	11.22
34	0.31	-	0.31	10.54
35	0.26	29.3	7.618	266.63
36	0.19	31.1	5.909	212.724
37	0.12	-	-	-
			$\Sigma l_x m_x$ = 14.177	$\Sigma x l_x m_x$=501.114
		Toria		
0-39	0.22	-	-	Immature
40	0.5	-	0.50	20
41	0.5	-	0.50	20.5
42	0.4	-	0.40	16.8
43	0.4	-	-	-
			$\Sigma l_x m_x$ = 1.40	$\Sigma x l_x m_x$=57.3
		Yellow sarson		
0-35	0.35	-	-	Immature
36	0.35	-	0.35	12.6
37	0.28	-	0.28	10.36
38	0.20	28.5	5.7	216.6
39	0.11	-	-	-
			$\Sigma l_x m_x$ = 6.33	$\Sigma x l_x m_x$=239.56

Table 2 . Age specific life table parameters for *P. brassicae* on host plants

Population growth statistics	Formula	Cabbage	Cauliflower	Broccoli	Toria	Yellow saraon
Net reproductive rate (R_O) (females/female)	$R_O = \Sigma l_x m_x$	44.75	18.50	14.17	1.40	6.33 e
Mean length of generation (T_C) (days)	$T_C = \Sigma l_x m_x / R_O$	32.7598	34.25838	35.3469	40.9286	37.8451
Intrinsic rate of increase (r_m) females/females/day	$r_m = Log_e R_O / T_C$	0.0504	0.0369	0.0326	0.0036	0.0212
Finite rate of increase (ë) (females/females/day)	ë =antilog$_e r_m$	1.0517	1.0377	1.0331	1.00357	1.0214
Doubling Time (DT)-days	DT = Log_e 2/r	5.9740	8.1384	9.2399	84.3146	14.2157
weekly multiplication of population	$(ë)^7$	1.4229	1.2955	1.2562	1.0253	1.1598
Annual Rate of Increase (ARI)	ARI = e^{365r}	97191147.07	730046.29	146019.27	3.68	2273.74
Hypothetical F_2 females	$(R_o)^2$	2002.20	342.25	200.9873	1.96	40.07

cabbage, whereas, lowest (0.80) at second instar on cabbage. The highest survival fraction at prepupal stage was on cabbage (1.00), and minimum) on toria and yellow sarson. Similarly, at pupal stage high S_x was (0.90) on cauliflower and low (0.63) on toria. The highest indispensable mortality (10.56) at egg stage was recorded on cauliflower and lowest (6.95) on toria. At larval stages, indispensable mortality (IM) was noticed maximum (11.88) at second instar on cabbage and minimum (0.60) at first instar on cabbage. At prepupal stage, it remained highest (1.80) on cauliflower followed by lowest (zero) on cabbage. However, at pupal stage, maximum IM (15.00) was obtained on broccoli and minimum (5.00) on cauliflower. At egg stage, the highest k-value was recorded (0.1192) on toria and lowest (0.0809) on cabbage and broccoli. The maximum 'k' (0.0943) was obtained at second instar on cabbage. At prepupal and pupal stage, the highest k-value (0.0241 and 0.2016, respectively) was on toria and lowest (zero and 0.0458) on cabbage and cauliflower respectively. Similarly, the total generation mortality, 'K' of *P. brassicae* was recorded maximum (0.6576) on toria followed by minimum (0.3098) on cabbage (Table 4). The mortality of the larvae was high during initial days due to high mortality of early instars. Ahmad *et al*. (2007) found that the death rate of *P. brassicae* was superior during the initial days due to high mortality of early instars. However, the death rate was found relative low on cabbage than other cole crops, may be due to the soft tissue texture (Gupta, 2002). Whereas, other cole crops have hard tissue texture and spine-like appendages (trichomes) on leaves that was the reason of high mortality at early larval instars (Ahmad *et al.,* 2007). Furthermore, the production of chemicals, such as toxins and digestibility reducers, may interfere with the physiology of the herbivore and reduce growth and survival (Schoonhoven *et al*., 2005). When larvae entered in third instar the mortality decreased automatically on each crucifer host plant, because the maxillae and mandibles of mouth parts get modified in these stages and larvae were able to eat plant leaves easily. A little mortality of larvae was also found at later stage of development, may be due to the variation in nutritional value of crucifers. Several studies supported the nutritional value of these crops are Newkirk *et al.* (1997), Font *et al.* (2005), Padilla *et al*. (2007), Scalzo *et al*. (2008). Whereas, the decline in survival and expectation of life was coincided with the continuous death of insects and a sharp decline was found at later stage of development attributed to the death of adults (Sharma *et al.,* 1999).

Among different host plants, lowest death rate was found on cabbage possibly due to choice of food. Whereas, the high mortality was observed on toria followed by yellow sarson, broccoli and cauliflower (Ali and Rizvi, 2007). The survival fractions of *P. brassicae* shown reverse order that of mortality. The maximum survival was recorded at later stage of development on cabbage as compared to other crucifer host plants (Thapa, 1987; Melspalu *et al* . 2003; Ali and Rizvi, 2007). Despite the facts, minimum mortality and maximum survival of cabbage butterfly was recorded on cabbage leaves as compared other crucifer host plants. Therefore, it could be accomplished that *P. brassicae* prefers cabbage for their fast growth and healthy development than other crucifer host plants.

The intrinsic rate of natural increase (r_m) is the most important parameters for describing the growth potential of a population under given climatic and food conditions because, r_m reflects an overall effect on development, reproduction, and survival (Southwood and Handerson, 2000; Kafil *et al*., 2007). Therefore, *P. brassicae* population that fed cabbage, cauliflower, and broccoli showed a higher intrinsic rate of increase resulting from faster development, higher survivorship, and oviposition rates. These three species are presumably more suitable hosts for this pest.

Table 3. Stage specific life table of *P. brassicae* on host plants

Stages (x)	Number surviving at the beginning of the stage (lx)	Number dying in each stage (dx)	Apparent mortality (100qx)	Survival fraction (Sx)	Mortality/ survivor ratio of the stage (MSR)	Indispensable mortality (IM)	Log lx	k-values
				Cabbage				
Egg	100.00	17.00	17.00	0.83	0.20	10.04	2.00	0.0809
L 1	83.00	1.00	1.20	0.99	0.01	0.60	1.92	0.0053
L 2	82.00	16.00	19.51	0.80	0.24	11.88	1.91	0.0943
L 3	66.00	1.00	1.52	0.98	0.02	0.75	1.82	0.0066
L 4	65.00	4.00	6.15	0.94	0.07	3.21	1.81	0.0276
L 5	61.00	6.00	9.84	0.90	0.11	5.35	1.79	0.0450
Pre-pupa	55.00	0.00	0.00	1.00	0.00	0.00	1.74	0.0000
Pupa	55.00	6.00	10.91	0.89	0.12	6.00	1.74	0.0502
Adult	49.00	49.00	100.00	0.00			1.69	
								0.3098
				Cauliflower				
Egg	100.00	19.00	19.00	0.81	0.23	10.56	2.00	0.0915
L 1	81.00	7.00	8.64	0.91	0.09	4.26	1.91	0.0393
L 2	74.00	11.00	14.86	0.85	0.17	7.86	1.87	0.0699
L 3	63.00	5.00	7.94	0.92	0.09	3.88	1.80	0.0359
L 4	58.00	1.00	1.72	0.98	0.02	0.79	1.76	0.0076
L 5	57.00	5.00	8.77	0.91	0.10	4.33	1.76	0.0399
Pre-pupa	52.00	2.00	3.85	0.96	0.04	1.80	1.72	0.0170
Pupa	50.00	5.00	10.00	0.90	0.11	5.00	1.70	0.0458
Adult	45.00	45.00	100.00	0.00			1.65	
								0.3468
				Broccoli				
Egg	100.00	17.00	17.00	0.83	0.20	6.96	2.00	0.0809
L 1	83.00	11.00	13.25	0.87	0.15	5.19	1.92	0.0617
L 2	72.00	5.00	6.94	0.93	0.07	2.54	1.86	0.0313
L 3	67.00	5.00	7.46	0.93	0.08	2.74	1.83	0.0337
L 4	62.00	11.00	17.74	0.82	0.22	7.33	1.79	0.0848
L 5	51.00	1.00	1.96	0.98	0.02	0.68	1.71	0.0086
Pre-pupa	50.00	1.00	2.00	0.98	0.02	0.69	1.70	0.0088
Pupa	49.00	15.00	30.61	0.69	0.44	15.00	1.69	0.1587
Adult	34.00	34.00	100.00	0.00			1.53	
								0.4685
				Toria				
Egg	100.00	24.00	24.00	0.76	0.32	6.95	2.00	0.1192
L 1	76.00	14.00	18.42	0.82	0.23	4.97	1.88	0.0884
L 2	62.00	7.00	11.29	0.89	0.13	2.80	1.79	0.0520
L 3	55.00	9.00	16.36	0.84	0.20	4.30	1.74	0.0776
L 4	46.00	4.00	8.70	0.91	0.10	2.10	1.66	0.0395
L 5	42.00	5.00	11.90	0.88	0.14	2.97	1.62	0.0550
Pre-pupa	37.00	2.00	5.41	0.95	0.06	1.26	1.57	0.0241
Pupa	35.00	13.00	37.14	0.63	0.59	13.00	1.54	0.2016
Adult	22.00	22.00	100.00	0.00			1.34	
								0.6576
				Yellow sarson				
Egg	100.00	20.00	20.00	0.80	0.25	8.75	2.00	0.0969
L 1	80.00	10.00	12.50	0.88	0.14	5.00	1.90	0.0580
L 2	70.00	6.00	8.57	0.91	0.09	3.28	1.85	0.0389
L 3	64.00	6.00	9.38	0.91	0.10	3.62	1.81	0.0428
L 4	58.00	11.00	18.97	0.81	0.23	8.19	1.76	0.0913
L 5	47.00	4.00	8.51	0.91	0.09	3.26	1.67	0.0386
Pre-pupa	43.00	2.00	4.65	0.95	0.05	1.71	1.63	0.0207
Pupa	41.00	6.00	14.63	0.85	0.17	6.00	1.61	0.0687
Adult	35.00	35.00	100.00	0.00			1.54	
								0.4559

L : Larva

Therefore, it can be concluded from the present study that *P. brassicae* prefers cabbage and cauliflower for speedy and healthy development with low larval mortality and highest number of adult yield than other cole crops.

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Biophysical and Biochemical Constituents Influencing Thrips and Jassid Resistance in Groundnut Germplasm

E. Chandrayudu, K. Vemena, B. Santhoshkumar Naik and C. Prathyusha
Acharya N.G.Ranga Agricultural University, Agricultural Research Station, Kadiri-515 591, India
E-mail: ecrayudu@gmail.com

Abstract: Field screening of 39 groundnut genotypes revealed that none was highly resistant to thrips and jassid. Screened 30 genotypes were recorded resistant and 2 moderately susceptible to thrips and jassid. Leaf thickness, laminar hairs and phenols showed significant and negative relationship with number (r = -0.750, -0.864) and damage (r = -0.641, -0.784) of thrips and jassid. Total sugar (r= 0.313. 0.38) showed positive relationship with number of thrips, jassid and their percent leaf damage. Linear regression analysis revealed that more leaf thickness, laminar hairs, high amount of phenols contributed for thrips and jassid resistance in groundnut.

Key Words: Biophysical and biochemical constituents, Thrips and jassid in groundnut

Groundnut (*Arachis hypogaea* L.) (Fabaceae) is a valuable cash crop for millions of small farmers in the semi-arid tropics and it is the principle oilseed crops in India. Among different pests infesting groundnut crop, thrips and jassid are important sucking pests. Among the thrips four genera commenly infest groundnut namely *Scirtothrips dorsalis* Distant, *Frankliniella schultzei* Trybom, *Thrips palmi* Karny*, Caliothrips indicus* Bagnall and Jassid, *Empoasca kerri*. Thrips are also known to transmit bud necrosis disease caused by tomato spotted wilt virus in groundnut and other several crops (Nagaraja *et al*., 2005). No single measure can currently provide adequate control of spotted wilt where severe epidemics occur. However, interdisciplinary investigations have resulted in development of integrated management systems that make use of moderately resistant cultivars, chemical and culinary practices, each of which helps to suppress spotted wilt epidemics (Culbreath *et al*., 2003). Early season moisture stress associated with thrips and jassid injury intensifies the groundnut yield and quality loss (Funderburk *et al*., 1998). Groundnut crop contains different types of plants that exhibit variability in phenotype (morphological and anatomical differences) and or genotype (genetically different from one another). One of the means by which thrips and jassid damage on groundnut crop can be curtailed by breeding varieties which can genetically or physically resist the feeding by thrips and jassid (Krishnaiah *et al*., 2012). So, the first step is to screen groundnut genotypes to thrips and jassid damage in order to identify resistant genotype. The screening the groundnut genotypes showing wide variations are generally selected and host plant resistance provides an additional measure to integrate with other management tactics to reduce yield loss in groundnut. Considering the above facts, a study was undertaken to screen biophysical and biochemical constituents influencing thrips and jassid damage on groundnut.

MATERIAL AND METHODS

Screening groundnut genotypes against thrips and jassid: Experiment was conducted during *kharif* 2012 to 2014 at Agriculture research station, Kadiri, Anantapuramu, Andhra Pradesh, India. Different genotypes of groundnut obtained from different centers were screened in the field under natural infestation to identify the resistant ones. Groundnut genotypes were sown in three replications at 30 cm x 10cm between rows and plants, respectively. The crop was raised following recommended package of practices except for plant protection measures. The reaction of groundnut genotypes was assessed by visual grading of damage and absolute insect counts on each test entry. Visual observations were recorded on leaf yellowing and curling of leaves due to jassid and thrips feeding during peek infestation following standard scale 1–9 (Ranga Rao and Wightman, 1997). Categorization of genotypes was based on damage score. Absolute jassid and thrips population counts were recorded as number of jassid on each plant and thrips per terminal bud leaves. At weekly intervals from 10 days after sowing to harvest per cent foliage damage was calculated.

Biophysical analysis: Fresh uniformly developed leaves were collected from randomly selected plants and leaf thickness, laminar hairs were measured in accordance with Jackai and Oghikhe (1989). The groundnut leaves was cut into bits of 9 mm^2 (3x3 mm) and hairs present on the laminar portion of these leaves were counted under a binocular microscope (10x,100x). Similarly, leaves thickness were measured under a compound microscope using stage and ocular micrometer.

Biochemical analysis: Fresh tender shoot and leaves of 10 groundnut genotypes were collected, which included resistant, moderately resistant and susceptible group, and dried at 32°C in a hot air oven for 48 hr. The samples were powdered using mixer for 3 min. The powdered samples were sieved through a 100 mesh screen and stored in sealed plastic containers (0.5m diameter) at 4°C, for further analysis.

Sugars: Total sugar was hydrolyzed in 1.0 ml of 1.0 N H_2SO_4 to 0.5ml of aliquot and heated over boiling water bath for 30 min. After cooling under running water, one to two drops of phenophthalein indicator was added. Later 1.0 N NaOH was added drop by drop to neutralize the acid in the hydrolysate till it developed pink colour. Further, 1.0 N $H_2SO_4$was added to make it colourless, finally the volume was made up to 10ml with distilled water and absorbance was read at 510 nm using spectrophotometer (Nelson,1944).

Total phenol content: 100 mg of oven dried powdered sample was extracted in 10ml of warm 80% ethanol for one hour at room temperature. The extract was centrifuged at 6000 rpm for 15min.The supernatant was evaporated to dryness on a water bath and the residue was dissolved in 5 ml water. Alcohol free extract was used for estimation of total phenols (Malick and Singh, 1980). An aliquot sample of 0.1ml was diluted to 3ml with water and 0.5ml of Folin-ciocalteau reagent (FCR) was added and mixed. Exactly after 3min, 2ml of 20% sodium carbonate solution was added and kept in boiling water bath for one min. After cooling under running tap water, the absorbance was read at 650 nm, against the reagent blank in a photo spectrometer. A standard graph was constructed with Catechol as a standard. The total phenol content was expressed as mg g^{-1} d.wt.

RESULTS AND DISCUSSION

Thrips and jassid were active throughout the cropping season from July – October. Among 39 genotypes screened against thrips and jassid damage, 30 were categorized as resistant, 07 as moderately resistant, 2 as susceptible. However, none of the genotypes reacted as a completely resistant to thrips and jassid damage (Table 1). There was a significant and positive correlation between thrips, jassid density and foliage damage (r = 0.363 and 0.205) indicating that this parameter can be used to asses thrips and jassid resistance in ground nut genotypes.

The numbers of thrips and jassid on groundnut genotypes varied from 2.1 and 1.0 (K-1535 {IPR}and K-1564{IPR}) to 6.4 and 3.5 (DRT43 and K-1463), moderately resistant category 2.4 and 1.2 (K-1482{FDR}VG and K-1563{IPR}) to 5.4 and 4.1 (TAG-24 and K-1578{LS}). Susceptible genotypes harboured numbers ranging from 6.3 and 2.1(TIR-9) to 8.6 and 5.4(JL-24) thrips/ terminal bud, jassid per plant and none of the variety showed high level of susceptibility (Table 1). The relationship between thrips, jassid population and percent foliage damage was significant ($p < 0.05$) and positively correlated at five percent level (r =0.363 and 0.205). The significant lowest foliage damage by thrips, jassid and high pod yield in resistant genotypes (ranges from 13.00 to 19.45 and 13.10 to 18.65 %) were recorded when compared to susceptible genotypes (38.00 to 49.15 and 35.50 to 38.00 %). This is in confirmation with Anonymous (2002) who recorded 47.33% leaf damage. The variation in damage may be due to differential load of thrips and jassid population on different genotypes based on the morphological/ biochemical variations in plants. Groundnut genotype screening work against thrips and jassid damage was conducted and reported by several workers.

Biophysical parameters: Among the genotypes leaf thickness and laminar hairs varied from 19.58 to 24.80 mm and 19.58 to 29.58 no's. The resistant genotypes had higher leaf thickness and laminar hairs ranging from 21.48 to 24.80 mm and 23.74 to 29.58 no's compared to lower leaf thicknesses and laminar hairs in susceptible genotypes *viz.*, JL-24 (18.35 mm and 19.58 no's). The data showed a significant negative relationship between leaf thickness, laminar hairs and thrips, jassid population (r = -0.923,-0.908 and -0.807,-0.855). A similar trend was observed between leaf thickness, laminar hairs and percent foliage damage (r = -0.876, -0.843 and -0.828,-0.782) at 5% level of significance (Table 4). The leaf thickness and trichomes of different cotton varieties/hybrid showed significant negative relationship with the incidence of thrips and jassid (Balakrishnan, 2006).

Biochemical parameters: Total sugar content of different groundnut genotypes varied from 1.6 mg (K-1535{IPR}) to 6.8 mg (JL-24) per gram of leaf. The highest quantities were in susceptible genotypes. These contents were positively correlated with thrips and jassid population and foliage damage (r = 0.942, 0.949 and 0.952, 0.929). Phenol of different genotypes varied from 0.18 mg (JL-24) to 0.79 mg (K-1604{HY}) per gram of leaf sample among the susceptible and resistance group, respectively. The highest quantities were noticed in resistant and group. However, lower quantities of phenols were noticed in susceptible groundnut genotypes. These results showed significant difference at 5% level of significant. There was a negative correlation between phenols and thrips, jassid population (r = -0.866 and -0.919). A similar trend was observed between phenols content and per cent foliage damage (r = -0.858 and -0.820). The phenol content showed significant negative correlation with thrips and jassid numbers. These results are in

Table 1. Reaction of groundnut genotypes against thrips and jassid damage, *kharif* 2012-2014

Genotype	Thrips		Jassid		Pod yield ($kg\ ha^{-1}$)
	Population / top bud leaf	Leaf damage (%)	Population $plant^{-1}$	Leaf damage (%)	
DRT40	4.2	14.70 (22.90)	1.8	13.95(22.30)	2020
K-1274	3.5	18.80(25.65)	2.1	14.50(22.20)	1818
K-1282	3.0	18.70(25.55)	2.8	14.85(22.40)	1428
K-1320	2.9	16.60(24.00)	3.1	15.45(22.80)	1260
K-1392	3.8	19.45(24.95)	3.3	15.15(22.75)	1822
K-1463	3.4	29.35(26.05)	3.5	24.85(22.45)	2009
K-1470(FDR)	4.1	15.35(23.05)	2.8	14.80(22.20)	1299
K-1535(IPR)	2.1	14.25(22.10)	1.1	13.65(22.10)	1613
ICGV-888	5.6	25.40(23.10)	2.5	26.80(23.95)	1529
ICGV-00350	3.9	16.10(23.60)	1.9	13.95(21.80)	1678
TCGS-750	6.2	16.05(23.65)	2.6	14.10(21.90)	1697
TIR-9	6.3	38.00(26.55)	2.1	35.50(23.05)	1770
ICGV-91114	4.5	18.35(25.35)	2.0	16.50(21.20)	1840
TAG24	5.8	22.25(28.10)	2.0	23.50(22.80)	1903
DRT43	6.4	16.20(23.70)	2.8	14.65(20.90)	1633
K-1451(DT)VG	3.0	16.60(26.15)	2.0	14.40(21.35)	1376
K-1452(DT)VG	3.1	18.00(25.10)	2.1	13.60(21.40)	1303
K-1454(DT)VG	2.5	18.35(25.35)	3.4	14.00(21.70)	1649
K-1468(FDR)VG	2.8	16.00(23.35)	3.0	15.50(21.20)	1809
K-1482(FDR)VG	2.4	25.50(26.20)	2.4	24.65(22.20)	1546
K-1501(LS)	2.5	16.40(23.85)	2.0	14.30(22.00)	1386
K-1504S(LS)	3.8	15.35(23.05)	1.9	13.95(21.70)	1859
K-1504T(LS)	4.1	16.25(23.75)	2.4	15.40(22.90)	1631
K-1563(IPR)	2.8	13.00(22.45)	1.2	13.25(22.20)	2110
K-1564(IPR)	2.5	13.25(22.15)	1.0	13.30(22.90)	2041
K-1569(HY)	5.2	14.25(21.85)	2.6	15.40(21.70)	1639
K-1570(TAF)	3.5	13.90(21.30)	2.1	13.40(20.55)	2111
K-1571(TAF)	3.2	13.75(21.75)	2.4	13.40(21.25)	2104
K-1574(LS)	5.3	14.95(22.75)	3.2	14.85(22.50)	1049
K-1576(LS)	4.2	21.75(27.80)	2.6	23.65(21.35)	1964
K-1577(LS)	3.8	15.80(23.40)	3.5	14.90(22.55)	1761
K-1578(LS)	3.3	23.10(28.75)	4.1	24.60(22.25)	1591
K-1581(LS)	4.0	17.90(25.00)	2.8	18.65(25.40)	1752
K-1604(HY)	3.5	13.00(21.10)	1.8	13.10(26.05)	2055
K-1609(HY)	4.0	15.70(23.30)	3.3	18.30(25.10)	1933
K-1520(HY)	4.1	17.10(24.40)	3.4	18.30(25.00)	1702
K-1621(HY)	5.2	20.90(27.15)	3.3	23.80(25.40)	1859
K-1622(HY)	3.6	16.95(24.25)	3.2	17.80(24.80)	1943
JL-24(Check)	8.6	49.15(35.10)	5.4	38.00(34.30)	698
CD (p=0.005)	--	1.65	--	2.15	181.0

Table 2. Reaction of selected groundnut varieties and germplasms to thrips and jassid damage under field condition, *kharif* 2012-14

Damage score	Genotypes	Damage (%)	Reaction
1	-None-	--	Immune
2	DRT40, K-1274, K-1282, K-1320, K-1392, K-1463, K-1470 (FDR), K-1535(IPR), ICGV-00350, TCGS-750, ICGV-91114, DRT43, K-1451(DT)VG, K- 1454 (DT) VG, K-1468 (FDR) VG, K-1501(LS), K-1504S (LS), K-1504 T(LS),K-1563(IPR), K-1564(IPR),K-1569 (HY), K-1570 (TAF), K-1571 (TAF), K-1574(LS), K-1577 (LS), K-1581 (LS),K-1604 (HY), K-1609 (HY),K-1520 (HY) and K-1622 (HY).	13-19.45	Resistant
3	K-1463, ICGV-888, TAG24, K-1482(FDR)VG, K-1576(LS), K-1578 (LS) and K-1621(HY).	20.9-29.0	Moderately resistant
4	TIR-9 and JL-24 (Check).	31-40	Moderately susceptible
5	-None-	41-50	Susceptible
6-7	-None-	--	Highly susceptible
8	-None-	--	--
9	-None-	--	--

Table 3. Relationship between biophysical and biochemical constituents on thrips, jassid number and foliage damage, *kharif* 2012-2014

Varieties	Thrips		Jassid		Leaf thickness (mm)	Laminar hairs (No.s/ 3 mm^2)	Phenols (mg g^{-1})	Total sugars (mg g^{-1})
	Population/top bud leaf	Foliage damage (%)	Population $plant^{-1}$	Foliage damage (%)				
K-1604(HY)	3.5	13.00	1.8	13.10	24.48	29.58	0.79	2.1
K-1563(IPR)	2.8	13.00	1.2	13.25	24.45	28.63	0.75	1.8
K-1564(IPR)	2.5	13.25	1.0	13.30	24.55	28.32	0.73	1.7
K-1535(IPR)	2.1	14.25	1.1	13.65	24.80	27.03	0.77	1.6
K-1570(TAF)	3.5	13.90	2.1	13.40	23.68	26.90	0.60	2.3
K-1571(TAF)	3.2	13.75	2.4	13.40	23.64	24.70	0.53	2.8
K-1451(DT)VG	3.0	16.60	2.0	14.65	22.72	24.97	0.51	3.2
DRT40	4.2	14.70	2.4	13.95	21.48	24.70	0.53	2.5
ICGV-00350	3.9	15.40	1.9	13.95	21.84	23.74	0.53	3.5
JL-24(Check)	8.6	33.15	5.4	32.00	18.35	19.58	0.18	6.8

Table 4. Correlation of biophysical and biochemical constituents of groundnut varieties with thrips, jassid number and per cent foliage damage by thrips, jassid during *kharif* 2012-2014

Host plant characters	Thrips ("r" value)		Jassid ("r" value)	
	Population /top bud leaf	Foliage damage (%)	Population $plant^{-1}$	Foliage damage (%)
Leaf thickness	-0.923**	-0.876**	-0.908**	-0.843**
Laminar hairs	-0.807**	-0.828**	-0.855**	-0.782**
Phenols	-0.866**	-0.858**	-0.919**	-0.820**
Total sugars	0.942**	0.952**	0.949**	0.929**

** Significant at p=0.01

Table 5. Regression equations for biophysical and biochemical constituents and number of thrips, jassid

Particulars	Regression equation	R^2
Thrips population	Y_1= 6.774-0.661X_1+0.318X_2-2.571X_3-28.349X_4	0.947
Foliage damage (%)	Y_2 = 1.915-0.312X_1-1.327X_2-14.042X_3-307.185X_4	0.918
Jassid population	Y_3 = 0.131-0.104X_1+0.265X_2-15.076X_3-13.132X_4	0.923
Foliage damage (%)	Y_4 = 5.727-0.332X_1+1.482X_2-9.946X_3-271.544X_4	0.942

Y1=Thrips (No. per top bud leaf) ; Y2= Foliage damage (%) ; Y3= Jassid Population (No. per plant); Y4= Foliage damage (%) ; X1= Leaf thickness (mm); X2=Laminar hairs (No./3 mm2); X3= Phenols (mg) X4=Total sugars (mg)

Table 6. Step wise regression analysis showing the significant variables in genotypes reaction against thrips and jassid in relation with biochemical characters

Variables	Regression coefficient	Standard error	't' value	'F' value	'R' value
			Thrips population (per top terminal bud leaf)		
	-2.120	0.561	-6.088	22.543	0.973
			Thrips foliage damage (%)		
Phenols	-15.841	2.339	-3.777	14.042	0.958
			Jassid population plant^{-1}		
	-4.974	0.467	-4.130	15.076	0.961
			Jassid foliage damage (%)		
	-16.201	2.613	-3.730	9.946	0.942

**Significant at p=0.01

confirmation with the findings of Somasekhar *et al.* (2003) where thrips and jassid resistant groundnut varieties had highest leaf thickness, laminar hairs and higher quantities of phenols compared with the susceptible varieties. Rohini *et al.* (2011) reported that the presence of high quantities of morphological and biochemical components like trichomes and tannins, phenols conferred resistance against thrips and jassid. Significant negative correlations were obtained between polyphenols and damage indices (r = -0.57), mean adult counts (r = -0.56) and mean larval counts (r = -0.64) of resistant cowpea cultivars, indicating that polyphenols play a significant role in cowpea thrips and jassid resistance (Alabi *et al*., 2011). Multiple linear regression equation was fitted to foliage damage due to thrips and jassid population. According to regression equation, thrips and jassid population influenced foliage damage to an extent of 91.8 % and 94.2 % (R^2 = 0.918 and 0.942), respectively (Table 5). Stepwise regression analysis with biophysical and biochemical constituents, thrips and jassid number and percent foliage damage revealed that leaf thickness, laminar hairs and phenols had significant relationship with thrips, jassid numbers and percent foliage damage.

In the current investigation, 39 groundnut genotypes screened in field experiment, 30 genotypes were found significantly resistant. These genotypes may prove promising in breeding programme concerning with thrips and jassid resistance. Leaf thickness, laminar hairs and phenols conferred the groundnut genotypes resistant to thrips and jassid damage. This suggests that groundnut varieties with more leaf thickness, laminar hairs and high concentration of phenols play a major role against thrips and jassid damage.

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Analysis of Technology Gap and Relative Importance of Banana Pseudostem Borer, *Odoiporus longicollis*, Olivier in Tamil Nadu

Nikita S. Awasthi, S. Sridharan and B. Padmanaban[1]
Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore-641 003, India
[1]ICAR-National Research Centre for Banana, Tiruchirapalli-620 120, India
E-mail: nikita.agri19@gmail.com

***Abstract*:** A survey was conducted during 2014-2015, in major banana growing districts of Tamil Nadu, for assessing the distribution, infestation level and the relative importance of banana pseudostem borer *Odoiporus longicollis* Olivier. The common susceptible cultivar was Nendran with 43.90% infestation in Kanyakumari, followed by Coimbatore and Tiruchirapalli. Matti and Red Matti specifically grown in Kanyakumari were susceptible with 19.62 and 18% infestation, respectively. Rasthali was the least susceptible variety (0.16 %), followed by Singan (0.18 %). 50. 83 % respondents ranked pseudostem borer as the most important pest with 1st rank. The technological gap index (TGI) was high in use of pseudostem traps (76.23 %), biological control agent (82.79 %) and the use of pseudostem injector (79.51 %), which are the effective management practices for the management of pseudostem borer. A majority of the respondents (54.10 %) belonged to the high technological gap category, whereas, only 7.38 % were in low level of technology gap. Thus, efforts should be taken to create awareness in the banana growers for the use of eco-friendly bio-control methods against pseudostem borer as well as other pests of banana.

***Key Words*:** IPM, Mattock, Pseudostem injector, Pseudostem borer, Technological gap index

Banana is ravaged by number of insect pests, diseases and nematodes, of them, insect pests play a major role in reducing yield and quality. More than 180 species of insect pests have been recorded on banana world over (Simmonds, 1966). In India, nineteen species infest banana (Padmanaban *et al*., 2002), which includes major pests such as corm weevil (*Cosmopolites sordidus, Germar)*, pseudostem borer (*Odoiporus longicollis, Olivier)*, banana aphid (*Pentalonia nigronervosa f. typica Coquerel)*, tingid or lace wing bug (*Stephanitis typicus, Distant),* fruit rust thrips (*Chaetanaphothrips signipennis, Bagnall)*, castor hairy caterpillar (*Pericallia ricini, Fabricius),* cut worm (*Spodoptera litura Fabricius)* etc. In recent years, banana industry is facing problem due to several other emerging pests such as banana skipper (*Erionota thrax, Linnaeus*), spiralling whitefly (*Aleurodicus disperses, Russell*) and different species of mealybugs. Among these pests, the pseudostem weevil (banana pseudostem borer) [*Odoiporus longicollis* (Olivier) (Coleoptera: Curculionidae)] is one of the serious monophagous pest limiting the production and productivity of bananas. In recent years, severe incidence of banana pseudostem weevil has been reported from different parts of India and it is becoming very serious in southern India particularly in Tamil Nadu and Kerala (Justin *et al.,* 2008). It has been estimated that the stem weevil causes 10-90% yield loss depending on the infestation stage and management efficiency (Prasuna *et al.,* 2008). Because of long life span of the adults and endophytic behaviour of the grubs, conventional methods of control, especially chemical control using the insecticides proved to be less effective. But farmers mainly rely on the use of chemical insecticides for the management. Integrated Pest Management (IPM) techniques comprising physical, chemical and biological measures are essential for effective and eco-friendly management of pests. As the farmers are end users and the final decision-makers for the adoption of any technology, it is essential to know their knowledge about the pests and practices recommended for pest management. However, not much attention has been paid to assessing the farmer's perception. Hence, considering the economic losses caused by this pest, the study was undertaken to assess the incidence of pseudostem borer in major banana growing districts in Tamil Nadu and to assess the farmer's perception on the awareness about this pest and its relative importance over other key pests of banana.

MATERIAL AND METHODS

For assessing the distribution of pseudostem borer in Tamil Nadu, a survey was conducted during 2014-2015 in ten major banana growing districts (Fig. 1) to know the distribution of the pseudostem weevil. In each district, 5-10 banana gardens were randomly selected and the number of damaged plants in each garden was recorded.

For assessing the awareness about the pest and to know its relative importance over other key pests of banana, face-to-face interviews of banana growers were carried. Although expensive, this method provides the highest response rates and is better suited to collecting complex information. The study areas were selected based on the extent of cultivation of the crop. From each selected village, 5

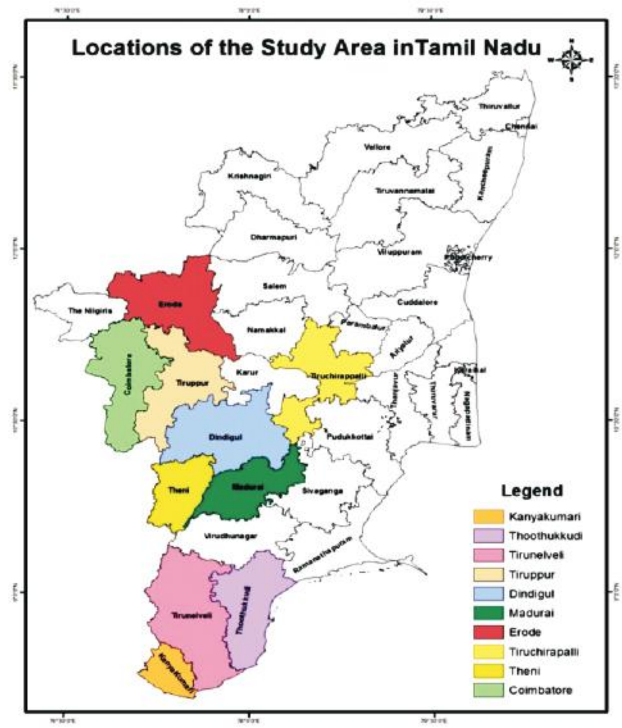

Fig.1. Map showing the study site

to 10 banana growing farmers were randomly selected and the data collected by means of a structured questionnaire prepared in local language administered via personal interviews (Pinyupa *et al.,* 2009). The questionnaire composed of the list of different pests in banana and the pest which ranks first. Information was collected on awareness of respondents about the susceptible stage of crop to pest attack, months of severity of pest incidence and the management practices carried out by them. The data sets compiled and tabulated before subjecting to statistical analysis. Technological Gap Index (TGI) was computed to analyze the extent of adoption of various recommended practices related to pseudostem borer management. The following formula was used to compute the technological gap (%) for management of pseudostem borer (Sakthivel *et al*., 2012).

$$\text{Technological Gap Index (TGI)} = \frac{R-A}{R} \times 100$$

Where, R = Recommended practice

A = Adopted practice

On account of a wide range of technological gap, the banana growers were categorized as 'High' for those having TGI of 70 and above, 'Medium' and 'Low' having TGI between 40 and 70 and below 40 respectively.

RESULTS AND DISCUSSION

Incidence of pseudostem borer in different districts in Tamil Nadu: Pseudostem borer was the major pest in Kanyakumari, Coimbatore and Dindigul. In Kanyakumari, the common susceptible cultivar Nendran recorded 43.90 % infestation, followed by Coimbatore (13.70 %) and Tiruchirapalli (10.24 %). In Dindigul, the hill banana varieties such as Virupakshi and Sirumalai were susceptible with 18.84 % infestation. Matti and Red Matti were specifically grown in Kanyakumari were also susceptible with 19.62 and 18 % infestation, respectively. Matti was the most susceptible banana variety and Rasthali was the least susceptible variety (0.16 %), followed by Singan (0.18 %). The tissue culture banana variety, Grand Naine was less susceptible with 0.49 % infestation. Observations on weevil distribution pattern district-wise revealed that infestation was maximum (43.90 %) on Nendran in Kanyakumari and least in Theni (1.46 %) (Table1). The variety Red banana which is popular among banana growers in Tamil Nadu was infested with pseudostem borer in Kanyakumari (23.91 %), Thoothukudi (13.60 %) and Dindigul (9.22 %). Our results are in accordance with Padmanaban and Sundaraju (1999) and Anitha (2004), where the highest level of infestation on Nendran followed by Red banana had been reported. Thippaiah *et al*. (2010) reported that susceptibility of Nendran to pseudostem weevil in south Karnataka. In Kanyakumari, the incidence of this pest was high due to preference of the most susceptible varieties such as Nendran, Red banana, Matti and Red Matti. The weevil also attacked Karapooravalli and Poovan but the level of infestation was intermediate. Thus, it can be inferred that pseudostem weevil density was high in southern districts of Tamil Nadu and also in Coimbatore.

Relative importance of pseudostem borer and perception among banana growers: Majority of respondents (84.58%) know about pseudostem borer and among them 50. 83% ranked it as the most important pest with rank one. The respondents who ranked corm weevil as the most important pest were 14.58%, whereas 13.75% found the lepidopteran leaf feeders as major problem. More than half of the respondents (66.25%) responded that the susceptible stage at which the pest attacked is above 8 months whereas 19.58% felt it during 5-8 months (Fig. 3). Nearly half of the respondents (48.75%) feel that the incidence of the pseudostem weevil is severe in October to January, medium (35.83%) in June to September, while the incidence reported by farmer during February to May was 15.54 % (Fig. 4). Similar results were found by Tiwari *et al*. (2006) in Nepal.

Technology gap index on management practices of pseudostem borer among banana growers: Pseudostem borer was ranked 1st most important pest. Cultural control measures like clean cultivation (91.80%) and removal of

Table 1. Incidence of pseudostem weevil in different banana varieties in Tamil Nadu

District	Varieties (% Incidence)*													
	Nendran	Karpooravalli	Poovan	Robusta	Rasthali	Red Banana	Hill Banana	Grand Naine	Matti	Red Matti	Singan	Monthan	Kanthali	Others
Coimbatore	13.70 (6250)	7.96 (4625)	2.21 (950)	0.43 (3750)	-	1.73 (750)	-	0.87 (1725)	-	-	-	0.24 (2125)	0.09 (2190)	0.32 (1550)
Theni	1.46 (2125)	0.67 (900)	0.59 (3235)	-	-	5.80 (1880)	-	0.56 (9650)	-	-	-	1.36 (1250)	0.00 (1300)	-
Tiruchirapalli	10.24 (4375)	8.67 (2250)	0.69 (2450)	0.72 (1800)	0 (2775)	2.91 (825)	-	0.59 (5400)	-	-	-	1.06 (1320)	0.00 (3175)	0.25 (1590)
Erode	2.53 (1225)	-	-	0.62 (1290)	0.25 (1200)	-	-	0.47 (3225)	-	-	-	0.77 (3230)	0.27 (750)	-
Dindigul	-	-	-	-	-	9.22 (1800)	18.84 (7065)	-	-	-	-	-	0.00 (925)	-
Madurai	-	-	1.29 (850)	-	0 (825)	-	-	-	-	-	-	-	-	0.72 (6275)
Thoothukudi	8.19 (2185)	1.97 (1875)	-	-	0.16 (2540)	13.60 (2235)	-	0.00 (900)	-	-	-	-	-	1.20 (4660)
Tirunelveli	3.52 (2500)	-	0.71 (425)	0.82 (490)	0 (1235)	7.54 (3275)	-	-	5 (900)	-	-	-	-	1.64 (2323)
Kanyakumari	43.90 (6250)	0.48 (1880)	-	-	0.11 (2775)	23.91 (7700)	-	-	34.25 (3025)	18 (250)	0.18 (2275)	-	-	-
Tiruppur	6.08 (1250)	1.58 (1390)	-	0.65 (1850)	0.625 (800)	-	-	0.47 (3025)	-	-	-	0.00 (2140)	-	-
Mean	11.20*	3.55	1.10	0.65	0.16	9.25*	18.84*	0.49	19.62*	18*	0.18	0.69	0.072	0.83

Based on number of plants infested * statistically significant at 5% by t. test.
Figures in parentheses indicate number of plants observed/variety/district

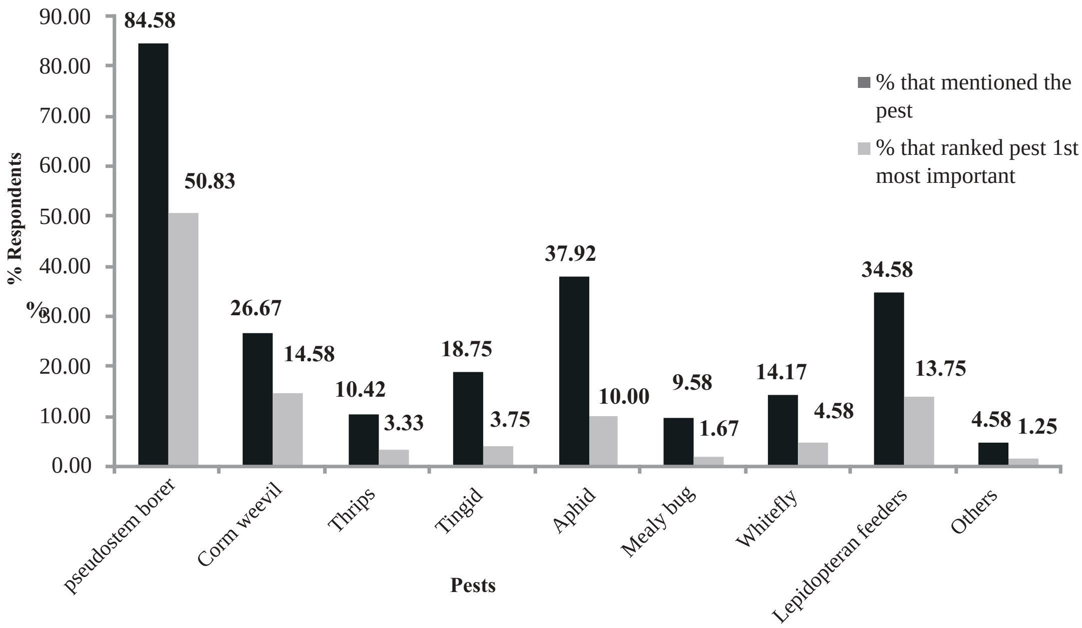

Fig. 2. Ranking of banana pests by banana growers (n=240)

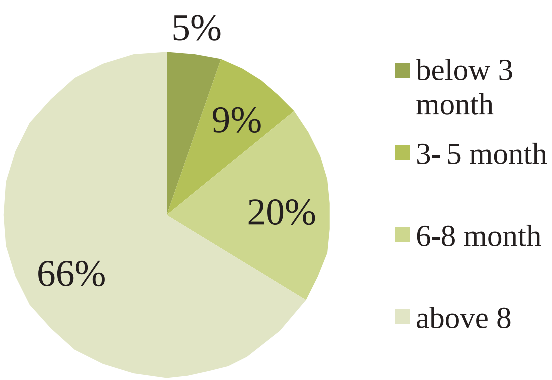

Fig.3. Perception of respondents on susceptible stage of the crop for attack of pseudostem borer (n=240)

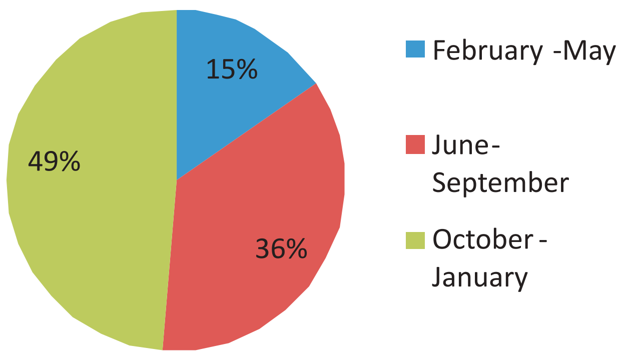

Fig. 4. Perception of respondents on months of severe incidence of pseudostem borer (n=240)

dried and old leaves (93.44) were followed by majority of banana growers, thus recorded less technological gap. This is due to the ease of the practice, which can be done while doing day to day field works. The technological gap was found high in other cultural/mechanical practices viz., use of pseudostem traps (76.23%) and destruction of mattock (87.70%). The operation of placing pseudostem trap is labor intensive, thus not commonly followed by the farmers. After harvesting of the bunch, farmers are leaving the stem without cutting with the intention that nutrition from the main stem will be supplied to side suckers. Only 17.21% used the bio-control agents such as entomopathogenic fungi and entomopathogenic nematodes, with technology gap of 82.69% (Table 2.)

The main reason was the lack of awareness about biological control, less and slow relief on biocontrol agents and the unavailability. In case of chemical control with spraying, comparatively medium technology gap (58.20%) was observed, which is due to the ease of application and availability of chemicals. Most of the farmers are applying chemicals as spray as a preventive measure. Very few farmers were aware about the pseudostem injection of chemicals (20.49 %) and proper handling of pseudostem injector (18.03 %), which can be attributed to the wide technology gap. Only 13.11 % farmers were following the chemical treatment of the harvested stem which is the major source of survival of pseudostem borer.

Distribution of respondents: Majority of the respondents (54.10 %) belonged to the high technological gap category

Table 2. Technological gap at farmer's level in adopting recommended management practices for banana pseudostem borer (n= 122)

Sr. No.		Particulars of practices*	Respondents %	Technological gap (%)
A		Cultural /Mechanical practices		
	1.	Follow clean cultivation practices	91.80	8.20
	2.	Remove old and dried leaves and pruning side suckers	93.44	6.56
	3.	Use of longitudinally split and disc on stump pseudostem traps @ 10-15 ha^{-1}	23.77	76.23
	4.	Avoid Matocking. Cutting the plant from the base after harvest	12.30	87.70
B		Biological control		
	5.	Use of 20 g Entomopathogenic fungi (*Beauveria bassiana, Metarhizium anisopliae*) and entomopathogenic nematodes on pseudostem trap	17.21	82.79
C		Chemical control		
	6.	Spray of Chlorpyriphos 20 EC 2.5 ml l^{-1} + 1 ml wetting agent or Azadirachtin (5 ml $litre^{-1}$) for two or three times at three weekly intervals	41.80	58.20
	7.	Stem injections of Monocrotophos (150 ml 350 ml $water^{-1}$) solution @ 2ml $plant^{-1}$ after 7^{th} month of planting	27.05	72.95
	8.	Use of stem injector	20.49	79.51
	9.	Correct use and handling of pseudostem injector	18.03	81.97
	10.	Application of carbaryl at base of harvested stem	13.11	86.89

* The common and effective management practices are selected based on Tamil Nadu Agricultural University, National Horticultural Board and ICAR-National Research centre for Banana.

whereas, 38.52% of the respondents were found under medium technology gap category. Only 7.38% of the respondents were found in low level of technology gap. The adoption gap analysis clearly indicates that among the various practices recommended for the management of pseudostem borer, like the spraying of chemical and few cultural/mechanical practices with less complexity were more feasible and adopted. Several constraints viz., unavailability of labors for carrying out cultural practices, lack of awareness about the use of pseudostem injector and lack of technical help leads to widening of technology gap. More or less similar findings were reported by Verma *et al*. (2003) and Bhagwan Singh *et al*. (2007).

It is therefore suggested that extension agencies should intensify their efforts to organize extension educational programmes like trainings, demonstrations, field days, etc., to motivate the farmers to accept and adopt the IPM practices. In the extension programmes, a special emphasis should be given to promote eco-friendly bio-control methods against pseudostem borer as well as other pests of banana by conducting skilled demonstrations and specialized participatory trainings.

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Dose Mortality Response of *Panonychus ulmi* Koch (Acari: Tetranychidae) to Various Acaricides

Shifa, Asma Sherwani, Malik Mukhtar, Deelak Amin and Asmat Ara[1]
Division of Entomology, [1]Division of Genetics and Plant Breeding
Sher-e-Kashmir University of Agricultural Sciences and Technology, Shalimar- 190 025, India
E-mail: shifamuneer2@yahoo.com

Abstract: Four acaricides viz, Propargite, Hexythiazox, Bifenthrin and Spiromesifen were studied for mortality response under leaf spray and leaf dip method wherein the underside of leaves were sprayed and whole leaf dipped in acaricides of different concentrations. The lowest LC_{50} value was recorded in Hexythiazox, which entitled it to be the most toxic of all the acaricides, followed by Propargite, Bifenthrin and Spiromesifen. Leaf dip proved to be toxic than leaf spray method owing to full coverage of the leaf surface.

Key Words: Acaricides, Bioassay, LC_{50}, Mortality, Toxicity, *Panonychus ulmi*

Apple (*Malus x domestica* Borkh) , a member of Rosaceae, is the fourth most widely produced fruit in the world after bananas, oranges and grapes (World Apple Review, Belrose, 2006). Jammu and Kashmir offers a share of around 70.39 per cent in the national market (National Horticulture Board, 2013). However, the quality and production of apple is quite low in the state of Jammu and Kashmir, because of some major constraints in its production. European red mite (*Panonychus ulmi* Koch) has become the most common pest of apple in recent years. In spite, of occurrence of several species of mites on fruits in Kashmir, none of the mite spp. was considered a major pest of apple till 1993, when European red mite (*P. ulmi* Koch) and two spotted spider mite (*Tetranychus urticae* Koch) broke out as pests in epidemic form on apple in entire Kashmir valley (Sheikh, 1993).

Control of *P.ulmi* is based largely on the use of acaricidal sprays. As generations overlap, sprays may become less effective and a regular schedule of miticide application is necessary. A major problem with chemical control of tetranychid mites is the continued development of resistance to a wide range of chemical groups (Davies *et al*., 2007 and Sherwani *et al*.. 2011). This has necessitated the development of further chemical groups with novel modes of action. Efficacies of various preparations for control of the mites have been investigated by many workers (Maciesiak and Olszak, 2001; Kimura *et al*., 2005; Singh and Choudhary, 2008; Wnag *et al*., 2010; Tomar and Singh, 2011).

The acaricides, propargite, hexythiazox, bifenthrin and spiromesifen have recently been introduced in the spray schedule for horticultural crops in Kashmir valley. The response of the *P.ulmi* to these newly introduced acaricides has not been fully studied in vitro. Use of these acaricides can be advocated in the main field only if they are tested for their toxicity and response in the laboratory.

MATERIAL AND METHODS

The study on dose-mortality response, of some new acaricides against natural populations of *P. ulmi* Koch on apple in Kashmir was carried out in Sher-e-Kashmir University of Agriculture Sciences and Technology of Kashmir at Shalimar campus, Srinagar during the year 2014.

Budded apple seedlings (cv. Red Delicious) of one year age were raised in plastic pots (20 x 15 cm) with pot-mix made from sand, fine clay and farm-yard manure in equal proportions. Field survey was carried out to identify *P.ulmi* infested trees. Different leaf samples and spur branches were collected which showed symptoms of infestation or mite eggs and adult populations on it. Samples collected from such trees were brought to Entomological laboratory and observed under the microscope to ascertain the presence of adult mites. Adults of *P. ulmi* were then transferred on apple saplings for raising culture.

Four acaricides were evaluated at different concentrations against the motile adult forms of *P. ulmi* on apple (Table 1)

Graded response bioassay: Bioassay was performed by two methods viz. leaf spray bioassay and leaf dip bioassay.

Apple leaves were excised from the potted plants. In case of leaf spray, underside of the leaf was sprayed with different concentrations of the acaricides while in case of leaf dip method leaves were dipped in different concentrations of acaricides for 10 seconds. The procedure for both the bioassay methods was same thereafter. Leaves were dried in shade for one hour, before placing them upside down on petriplates (100 mm diameter) over a wet blotting paper.

Table 1. Acaricides, trade names and concentrations used in the present study

Acaricide	Trade name	Concentrations (%)	Treatment codes
Water	-	-	T_0
Propargite	Mitex 57 EC	0.025	T_1
		0.050	T_2
		0.100	T_3
Hexythiazox	K-aradite 5 EC	0.001	T_4
		0.002	T_5
		0.004	T_6
Bifenthrin	Brigade 8% SC	0.003	T_7
		0.006	T_8
		0.012	T_9
Spiromesifen	Oberon 240 SC	0.012	T_{10}
		0.024	T_{11}
		0.048	T_{12}

Thirty adult mites irrespective of sex were transferred on each leaf with the fine camel hairbrush. The petriplates were then kept in B.O.D incubator at controlled conditions of 27+/-1^{0}C and 70% RH. Mortality counts were recorded 24 hours after the transfer of mites to petriplates. Mites incapable of coordinated movements when prodded were considered dead (Koskela and Fisher, 1998).

The mortality of both the bioassay methods was subjected to probit-regression analysis (Finney, 1971) (Table 2) after percentage mortality for each concentration was corrected by Abbott's formula (Abbott, 1925).

RESULTS AND DISCUSSIONS

Hexythiazox: The findings revealed that for leaf spray, the LC_{50} value of 0.0036 per cent for *P. ulmi* population was obtained (Table 2). The lower and upper fiducial limits at 95 per cent confidence were found to be 0.0025 and 0.0078 respectively. From this data, the correlation coefficient (r) of 0.980 was obtained and thus depicted a positive correlation between dose and mortality of *P. ulmi*. Consequently, the coefficient of determination (R^2) was computed to be 0.960. From the data, a ÷2 value of 0.3514 was worked out which indicated that the data was significantly homogeneous at $p \leq 0.05$.

Similarly, for leaf dip bioassay, the LC_{50} value of 0.0019 per cent for *P. ulmi* population was obtained (Table 3). The lower and upper fiducial limits at 95 per cent confidence were found to be 0.0018 and 0.0069 respectively. From this data, the correlation coefficient (r) of 0.980 was calculated which indicated a positive correlation between the dose and mortality of *P. ulmi*. Consequently, the coefficient of determination (R^2) was computed to be 0.960. From the data, a ÷2 value of 0.3424 was worked out which indicated that the

Table 2. Quantitative assessment of the relationship between doses and response of European Red Mite, *Panonychus ulmi* to acaricides by leaf spray method

Acaricide	LC_{50}	95% C.I.		r	Y=a+bx	R^2	?2
		Lower limit	Upper limit				
Hexythiazox	0.0036*	0.0025	0.0078	0.980	Y=4.24+1.15x	0.960	0.3514
Propargite	0.00827	0.00518	0.1412	0.993	Y=3.86+1.21x	0.986	0.2347
Bifenthrin	0.0093	0.0001	0.0121	0.990	Y=5.05+0.855x	0.980	2.22
Spiromesifen	0.0312**	0.0268	0.1218	0.989	Y=2.35+1.50x	0.978	0.0627

*Most toxic; **Least toxic

Table 3. Quantitative assessment of the relationship between doses and response of European Red Mite, *Panonychus ulmi* to acaricides by leaf dip method

Acaricide	LC_{50}	95% C.I.		r	Y=a+bx	R^2	÷2
		Lower limit	Upper limit				
Hexythiazox	0.0019*	0.001849	0.00696	0.980	Y=4.35+1.13x	0.960	0.3424
Propargite	0.00482	0.000077	0.1339	0.982	Y=4.54+0.89x	0.964	0.1168
Bifenthrin	0.0057	0.00042	0.0059	0.961	Y=5.12+1.35x	0.923	0.0180
Spiromesifen	0.0202**	0.00222	0.0541	0.974	Y=2.47+1.63x	0.948	0.8643

* Most toxic; **Least toxic

All tables represent data based on the study done under graded response bioassay
C.I. represents confidence interval, r- correlation coefficient, Y- dependant variable, x- independent variable, a and b-coefficients, R^2- Coefficient of determination and ÷2 represents chi-square test value
Data is significantly homogeneous at $P \leq 0.05$

data was significantly homogeneous at $p \leq 0.05$.

Propargite: The findings for leaf spray revealed the LC_{50} value of 0.0082 per cent for *P.ulmi* population (Table 2). The lower and upper fiducial limits at 95 per cent confidence were found to be 0.0051 and 0.1412, respectively. From this data, the correlation coefficient (r) of 0.9930 was obtained and thus depicted a positive correlation between dose and mortality of *P.ulmi*. Consequently, the coefficient of determination (R^2) was computed to be 0.9860. From the data, a ÷2 value of 0.2347 was worked out, which indicated that the data was significantly homogeneous at $p \leq 0.05$.

Similarly, for leaf dip bioassay, the LC_{50} value of 0.0048 per cent for *P.ulmi* population was obtained (Table 3). The lower and upper fiducial limits at 95 per cent confidence were found to be 0.00007 and 0.13390 respectively. From this data, the correlation coefficient (r) of 0.9820 was calculated which indicated a positive correlation between the dose and mortality of *P.ulmi*. Consequently, the coefficient of determination (R^2) was computed to be 0.9640. From the data, a ÷2 value of 0.1168 was worked out which indicated that the data was significantly homogeneous at $p \leq 0.05$.

Bifenthrin: The data (Table 2) revealed that for leaf spray, the LC_{50} value of 0.0093 per cent for *P. ulmi* population was obtained. The lower and upper fiducial limits at 95 per cent confidence were found to be 0.0001 and 0.0121 respectively. From this data, the correlation coefficient (r) of 0.990 was obtained and thus depicted a positive correlation between dose and mortality of *P. ulmi*. Consequently, the coefficient of determination (R^2) was computed to be 0.980. From the data, a ÷2 value of 2.220 was worked out which indicated that the data was significantly homogeneous at $p \leq 0.05$.

Similarly, for leaf dip bioassay, the LC_{50} value of 0.0057 per cent for *P.ulmi* population was obtained (Table 3). The lower and upper fiducial limits at 95 per cent confidence were found to be 0.0004 and 0.0059 respectively. From this data, the correlation coefficient (r) of 0.961 was calculated which indicated a positive correlation between the dose and mortality of *P.ulmi*. Consequently, the coefficient of determination (R^2) was computed to be 0.923. From the data, a ÷2 value of 0.0180 was worked out which indicated that the data was significantly homogeneous at $p \leq 0.05$.

Spiromesifen: The data in table 2 revealed that for leaf spray, the LC_{50} value of 0.0312 per cent for *P.ulmi* population was obtained. The lower and upper fiducial limits at 95 per cent confidence were found to be 0.0268 and 0.1218 respectively. From this data, the correlation coefficient (r) of 0.989 was obtained and thus depicted a positive correlation between dose and mortality of *P. ulmi*. Consequently, the coefficient of determination (R^2) was computed to be 0.978. From the data, a ÷2 value of 0.0627 was worked out which indicated that the data was significantly homogeneous at $p \leq 0.05$.

Similarly, for leaf dip bioassay, the LC_{50} value of 0.0202 per cent for *P.ulmi* population was obtained (Table 3). The lower and upper fiducial limits at 95 per cent confidence were found to be 0.0022 and 0.0540 respectively. From this data, the correlation coefficient (r) of 0.974 was calculated which indicated a positive correlation between the dose and mortality of *P.ulmi*. Consequently, the coefficient of determination (R^2) was computed to be 0.948. From the data, a ÷2 value of 0.8643 was worked out which indicated that the data was significantly homogeneous at $p \leq 0.05$. Relative toxicity was also evaluated while comparing the toxicity of two bioassay techniques (Table 4). Highest toxicity fold was found in case of hexythiazox as it was found to be 8.6 times more toxic to spiromesifen. Similarly, propargite was 3.7 times and bifenthrin 3.3 times more toxic than spiromesifen in case of leaf spray bioassay. In case of leaf dip bioassay the highest toxicity fold was found again in case of hexythiazox as it was found to be 10.6 times more toxic to spiromesifen. Similarly, propargite was 4.1 times and bifenthrin 3.5 times more toxic than spiromesifen.

The comparison of LC_{50} values and relative toxicity fold was also done (Table 5) In case of propargite, leaf dip

Table 4. Relative toxicity of various acaricides based on LC_{50}

Bioassay method	Acaricide	LC_{50}	Relative toxicity	Relative toxicity fold
Leaf spray	Propargite	0.00827	3	3.7
	Hexythiazox	0.00360	4	8.6
	Bifenthrin	0.00930	2	3.3
	Spiromesifen	0.03120	1	1.00
Leaf dip	Propargite	0.00482	3	4.1
	Hexythiazox	0.00190	4	10.6
	Bifenthrin	0.00570	2	3.5
	Spiromesifen	0.02020	1	1.00

Study done under graded response bioassay, LC_{50} of spiromesifen taken as unity

Table 5. Comparison of toxicity of various acaricides based on two different bioassay methods

Acaricides	Bioassay method	LC_{50} value	Relative toxicity fold	Percentage toxicity fold*
Propargite	Leaf spray	0.00827	3.7	58.28
	Leaf dip	0.00482	4.1	
Hexythiazox	Leaf spray	0.0036	8.6	52.78
	Leaf dip	0.0019	10.6	
Bifenthrin	Leaf spray	0.0093	3.3	61.29
	Leaf dip	0.0057	3.5	
Spiromesifen	Leaf spray	0.0312	1.00	64.74
	Leaf dip	0.0202	1.00	

*based on LC_{50}

method showed 58.28 per cent toxic fold than leaf spray method. Similarly, leaf dip methods of hexythiazox, bifenthrin and spiromesifen showed 52.78, 61.29 and 64.74 per cent toxic folds respectively than leaf spray method. Leaf dip bioassay was found to be more toxic than leaf spray.

Based on LC_{50} values, hexythiazox was most toxic followed by propargite, bifenthrin and spiromesifen in both the methods- leaf spray and leaf dip. Leaf dip was found to be a better method in comparison to leaf spray. This was due to the fact that in case of leaf spray method, only the underside of the leaf was sprayed and only such acaricides could prove to be efficient which had translaminar action due to which even if the mite would escape on the other side of leaf (unsprayed) it would still be killed. On the contrary, in leaf dip method, whole of the leaf was dipped in the acaricide solution ensuring its full coverage. However, leaf spray is a realistic approach of spraying in main field.

The most toxic nature of hexythiazox and propargite to mites can be explained by the finding of Wnag *et al*. (2010) who carried out field trials of different insecticides against vegetable spider mites and concluded that, propargite and hexythiazox showed that hexythiazox and propargite provided good control, but hexythiazox caused quick mortality. This verifies and validates our findings of hexythiazox providing good control in 24 hours.

Propargite in terms of order of high toxicity stands second after hexythiazox. It was found more toxic as compared to bifenthrin and spiromesifen. Very less development of resistance can be one possible reasons of efficacy of propargite. Propargite successfully controlled *P. ulmi* species and these observations draw their support from the findings of Kimura *et al*. (2005) who evaluated some acaricides against *T. urticae* and *P. ulmi*. This enhanced activity of propargite can be attributed to the fact that it works by two modes of action, and till now has no confirmed case of resistance. Propargite rapidly suppresses the mite population. This is in line with the findings of Angeli *et al.* (2008) who tested the susceptibility of two strains of two-spotted spider mite, *Tetranychus urticae* collected from different host plants (apple, grape, tomato and aubergine) for propargite. Propargite provided excellent control on all strains and appeared to be rapid in suppressing the *T. urticae*. Propargite controls mites effectively in different crops other than apple as well.

However, bifenthrin appears not to effectively control *P.ulmi*. Synthetic pyrethroids can have good chronic toxicity but poor acute toxicity. There may also be the reason of development of resistance. DDT, pyrethrins and synthetic pyrethroids act on the voltage-gated sodium channel proteins found in insect nerve cell membranes. Some insect pest populations have evolved modifications of the sodium channel protein which prevent the binding of the insecticide and result in the insect developing resistance. This was reported by Davies *et al.* (2007).

According to the *datasheet of pesticide* (2013) spiromesifen is not expected to persist in the environment because it readily undergoes both biotic and abiotic degradation. So, these reasons might possibly contribute to least toxicity of spiromesifen.

The leaf dip method was found to be toxic than leaf spray method as indicated by the percentage toxicity fold. However, in field conditions a much realistic estimate can be made by leaf spray method and therefore, spray method can be designated as a much important method than dip method. Jeon *et al.* (2010) reported that application method of spraying (direct contact) bioassay was more effective than other method.

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Aprostocetus purpureus, a Major Parasitoid of Indian Lac Insect, *Kerria lacca* (Coccoidea: Tachardiidae)

A. Mohanasundaram, Mohammad Monobrullah, K. K. Sharma, S. C. Meena, Sweta Verma and R. Ramani

ICAR-Indian Institute of Natural Resins and Gums, Namkum, Ranchi-834 010, India
E-mail: mohaniinrg@gmail.com

Abstract: Relative abundance of lac associated fauna was analyzed during summer season (*baisakhi*) crops for two consecutive years, which revealed that, parasitoids alone constitute 93 and 89 per cent population among lac associated fauna, followed by predators and hyper parasitoid on *ber*, respectively during 2011-12 and 2012-13. Similar trend was observed on *palas* for both the years. Among them, *Aprostocetus purpureus* was significantly more abundant which constitute 71.56 per cent on *ber* and 74.47 per cent on *palas*, respectively during 2011-12 and 2012-13. In recent years, 538 per cent increase in *A. purpureus* population over the four decade. The per cent population of *A. purpureus* was mainly observed more during the critical period *i.e.*, 17 to 22 week after inoculation. Interestingly, male lac insect was more vulnerable towards parasitization than female. A significant negative correlation with relative humidity was observed during critical period of *baisakhi* crop. The observations indicate the resurgence of *A. purpureus* as the most serious pest of lac insect causing huge economic losses.

***Key Words*:** *Aprostocetus purpureus, Kerria lacca,* Lac associated fauna, Relative abundance

India is the largest producer of lac in the world and is a major source of livelihood to millions of economically backward population especially tribals in Jharkhand, Madhya Pradesh, Chhattisgarh, Maharashtra, West Bengal, etc. National lac production trends in India during 1980-81 to 2012-13 have shown an inconsistence and fluctuating production. The lac production of the country can be viewed as summation of the contribution of four crops, contributed by two crops each of these strains. The contribution of rangeeni strain has shown a sharp decline in total production (151.5 t annum^{-1}), whereas, kusmi strain has shown the increasing production (214.5 t annum^{-1}). This change could be attributed to promoting *kusmi* lac production, especially on ber during winter (aghani) crop and drastic decline in the production of summer (baisakhi) *rangeeni* lac crop (180 t annum^{-1}), which used to be the major lac crop (Anonymous, 2014).

Lac is the only natural resin of insect origin derived mostly from a few species of *Kerria* (Coccoidea: Tachardiidae) belonging to a specialized group of scale insects, that are phytosuccivorous and thrive well only on specific plants called lac-hosts. The Indian lac insect, *Kerria lacca* is represented by two strains rangeeni and kusmi. Both the strains complete two cycles in a year, thus each producing two crops. But their life cycle patterns differ due to genetic differences in their developmental response to temperature. Thus, these two forms exhibit differences in their vulnerability to deviations from the normal climatic conditions.

K. lacca is associated with a large pest complex comprising mainly of predatory and parasitic insects. The parasitoids and predators of the Indian lac insect have been held responsible for causing about 50 per cent loss in normal crop. There are several parasites and predators of lac insects and another set of parasites of lac predators which are intimately associated with each other in the biotic complex (Varshney, 1976). Thirty five species of primary and 45 species of secondary parasitoids have been reported in lac insect ecosystem, which are highly responsive to climate changes in view of their relatively shorter life cycle. Among primary parasitoids, *Aprostocetus purpureus* as the most dominant inimical parasitoids among the composition of lac associated fauna particularly in Baisakhi (summer) crop and causes major damage to the lac crop during critical crop growth period. *A. purpureus* is an endoparasitoid and completes 10-12 generation in a year. Sharma *et al.* (2010) reported that 58 per cent of the living lac insects were parasitized with *A. purpureus*. The present investigation was aimed to study the emergence profile of *A. purpureus* and its correlation with weather parameters at Ranchi, Jharkhand on ber and palas.

MATERIAL AND METHODS

The *rangeeni* strain broodlac was cultured on *ber* (*Ziziphus mauritiana*) and *palas* (*Butea monosperma*) during summer season (Baisakhi) crop 2011-12, 2012-13 and 2013-14 at Institute Research Farm, Ranchi (Jharkhand). Lac insect samples (one meter length of encrustation) were collected randomly from inoculated trees one month after inoculation at every 15 days interval till harvest under three replications. The samples were caged in parasitoid emergence cage (20×20×30cm), fitted with glass tubes to collect parasitoids by exploiting their phototropic behaviour. Lac associated fauna (parasitoids and predators) were collected from cage every day continuously upto one month. Among lac associated fauna, *A. purpureus* were morphologically identified and population abundance was recorded and correlated with weather parameters. Per cent lac insect (male and female) parasitization was observed through microscope by pricking method in the month of March 2014 during summer crop 2013-14.

RESULTS AND DISCUSSION

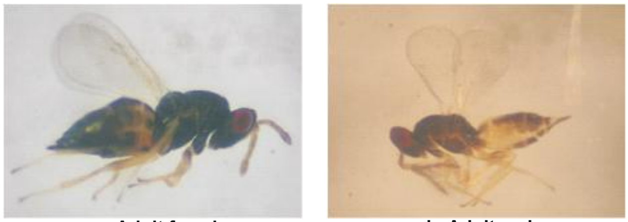
A brief morphological description of *A. purpureus* and symptom of infestation (Fig. 1-3) are given below.

Adult female measures 1.5-1.8 mm in length, is black coloured, shining, very slightly punctulate with rounded head. Eye is pink in colour; antennae are brown, elongate, scape reaching a little beyond ocelli; 8 funicle joints and the pedicellus nearly all of equal length, the club 3-jointed, the last joint short and pointed. Mesonotum and scutellum slightly reticulate, the median groove of the mesonotum and the two longitudinal grooves of the scutellum are well marked. Wings are large hyaline, reaching beyond the end of the abdomen. Marginal nerve longer than submarginal; pterostigma as long as a third of the marginal nerve and pubescence not in rows. Legs yellow, the base of the coxae stripes above and below the femora and the end of tarsi brownish with 4 segments, a shortened, straight fore tibial spur, marginal and stigma nerves light yellow Abdomen a little longer than the thorax, slightly broadened until beyond the middle then sharply pointed, ovipositor slightly protruding, black with purplish and greenish reflection, base of abdomen more or less yellow (Fig. 1a).

Adult male measures 1.2 mm in length with other morphological features almost similar to female except in few cases *viz.*, antennae with long bristles arranged in half-circles, abdomen shorter than the thorax with male genetalia, with the 1st segment yellow, legs clear yellow; coxae, part of femora, and of tarsi brown (Fig. 1b) (Ferriere, 1928).

Grub is apodus pink colour with outer white cover, yellowish body with pink colour eye of immature adult stage and black colour body with pink colour eye before emergence**.** The symptom of parasitized lac insect has been depicted in figure 2.

Relative abundance of lac associated fauna during rangeeni crops: During baisakhi crops, the parasitoids alone constitute (93 and 89 per cent) population among lac associated fauna followed by predators (4 and 7 per cent) and hyper parasitoid (3 and 4 per cent) on ber, respectively during 2011-12 and 2012-13. Among them, *A. purpureus* was



a. Adult female b. Adult male

Fig. 1. *Aprostocetus purpureus*

Fig. 2. Holes showing symptom of parasitization

significantly the most abundant and constituted 71 and 56 per cent population, followed by *Tachardiaephagus tachardiae* (21 and 14 per cent) and *P. clavicornis* (1 and 18 per cent), respectively during 2011-12 and 2012-13. The major predators *viz*., *Eublemma amabillis* and *Pseudohypatopa pulverea* and hyperparasitoid, *Bracon greeni* populations were at par with each other during baisakhi 2011-12. In addition, *Marietta javensis* and *Apanteles tachardiae* were also recorded on ber during baisakhi 2012-13. Similar trend was observed on palas, wherein *A. purpureus* was the most abundant and constituted 74 and 47 per cent population, followed by *T. tachardiae* (16 and 26 per cent), respectively during 2011-12 and 2012-13. *P. clavicornis, Marietta javensis*, *E. amabillis, Bracon greeni* and Coleopteran beetles were at par with each other during baisakhi 2011-12. In addition to that, *Erencyrtus dewitzi*, *Eupelmus tachardiae*, *P. pulverea* and *A. tachardiae* were also recorded on palas during baisakhi 2012-13 (Table 1). The per cent increase in lac associated parasitoids was compared between the recent years (2011-12 and 2012-13) with four decade backs (1972-73 and 1973-74). There was 361 per cent increase in total parasitoids population, among them the population of *A. purpureus* increased very high (538 %) followed by *T. tachardiae* (120 %) and *P. clavicornis* (5 %) while other parasitoids (*Coccophagus tschirchi*, *E. dewitzi, E. tachardiae, M. javensis*) decreased 4.71 per cent (Table 2). It clearly reveals that the parasitoids populations increased many fold over a period, *A. purpureus* being the most abundant. Srivastava *et al.* (1984) found that among the parasitoids of lac insect, *Aprostocetus* (*Tetrastichus) purpureus* and *T. tachardiae* were of regular occurrence and were recorded in large numbers in all the four lac crops (baisakhi, katki, jethwi and aghani). Sharma *et al.* (1997) also reported higher abundance of *A. purpureus* and *T. tachardiae,* constituting 55.82 and 28.37%, respectively of the total population of parasitoids.

Emergence profile of *A. purpureus* during summer season crops: The weekly emergence profile of *A. purpureus* revealed significant differences in *A. purpureus* population on week and host plant basis. The maximum *A. purpureus* population per meter lac encrustation in samples collected 21 WAI on ber (37) and 22 WAI on palas (28) during baisakhi 2011-12, whereas, during 2012-13 the maximum emergence was 20 WAI on ber (57) and 21 WAI on palas (41) (Table 3). In baisakhi 2013-14, maximum *A. purpureus* population was 17 WAI on *ber* (64) and 20 WAI on *palas* (17) (Table 3). Further per cent lac insect parasitization was more in male lac insect (64 %) as compared to female (36 %) during baisakhi 2013-14. The longer duration of crop period (8 months in baisakhi) with more parasitization at initial stage lead to more adverse effect on the crop. This is one of the major reasons for summer crop mortality.

***A. purpureus* population during critical period of *rangeeni* summer crops:** Among the lac associated fauna, 78 and 66 per cent population of *A. purpureus* on *ber* were recorded only during crtical crop period (17 to 22 WAI before sexual maturity) for baisakhi 2011-12 and 2012-13, respectively. Similarly in palas, 62 and 49 per cent population of *A. purpureus* were recorded only during crtical period (17 to 22 WAI before sexual maturity) for baisakhi 2011-12 and 2012-13, respectively. However, in baisakhi 2013-14, *A. purpureus* alone constitut 100 per cent population during crtical period causing complete lac insect mortality on ber and palas. Yield ratio of 1.13 and 2.08 was on ber and 1.79 and 3.39 on palas of mature lac crop during baisakhi 2011-12 and 2012-13, respectively. Lesser broodlac ratio during 2011-12 was due to higher parasitization during critical period compared to 2012-13. However, no havest could be made during baisakhi 2013-14 due to hundred per cent mortality during critical crop growth period. Monobrullah (2010) analyzed the samples from four different locations and average parasitization 54 per cent. The parasitoid emergence was 248-364 in January and 416-573 in March from 10 cm length of lac encrustations during critical periods, which was indicative of very high level of parasitization leading to the collapse of lac insect populations.

Impact of abiotic factors on insect pest of lac insect: Emerging population of *A. purpureus* during critical crop growth period (17 to 22 WAI) and weather parameters *viz.,* temperature, relative humidity and rainfall were correlated during baisakhi 2011-12 and 2012-13. Positive correlation

Table 1. Per cent composition of lac associated fauna summer *rangeeni* (*baisakhi*) *crops*

Lac associated fauna	Ber		Palas	
	2011-12	2012-13	2011-12	2012-13
Tachardiaephagus tachardiae	20.61	13.73	15.54	25.91
Aprostocetus purpureus	71.47	55.71	73.86	46.92
Parechthrodryinus clavicornis	1.06	17.99	1.65	2.54
Eupelmus tachardiae	-	-	0.00	0.18
Erencyrtus dewitzi	-	-	0.00	0.18
Marietta javensis	0.00	1.16	0.37	0.36
Eublemma amabilis	3.17	3.09	2.74	16.30
Pseudohypatopa pulverea	1.06	4.45	0.00	3.80
Coleopteran	-	-	0.55	0.36
Bracon greeni	2.64	0.19	5.30	0.18
Apanteles tachardiae	0.00	3.68	0.00	3.26
CD (p= 0.05)	14.79	9.00	7.83	7.64

Table 2. Comparative analysis of lac associated parasitoids population (Number kg^{-1} broodlac sample)

Year	Total parasitoid population	*A. purpureus*	*T. tachardiae*	*P. clavicornis*	Other parasitoids
1972-73 to 1973-74*	28.4	17.0	9.1	1.7	0.56
2011-12 to 2012-13	130.7 (361.0)	108.4 (537.7)	19.9 (119.9)	1.8 (5.2)	0.53 (-4.71)

*Mean of two crop seasons adopted from Srivastava *et al.* (1976)
Figures in parentheses is per cent increase over initial population

Table 3. Weekly emergence profile of *Aprostocetus purpureus* during summer rangeeni (baisakhi) crops

Period	2011-12			2012-13			2013-14		
	Ber	*Palas*	Mean	*Ber*	*Palas*	Mean	*Ber*	*Palas*	Mean
8 WAI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9 WAI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 WAI	0.00	0.25	0.13	0.00	0.00	0.00	0.00	0.00	0.00
11 WAI	1.00	0.50	0.75	0.00	0.00	0.00	0.00	0.00	0.00
12 WAI	3.50	0.25	1.88	0.00	0.67	0.33	0.00	0.00	0.00
13 WAI	2.25	0.25	1.25	0.00	9.00	4.50	0.00	0.00	0.00
14 WAI	6.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
15 WAI	0.00	0.25	0.13	0.00	0.67	0.33	0.00	0.00	0.00
16 WAI	0.00	0.00	0.00	0.67	0.00	0.33	0.00	1.67	0.83
17 WAI	1.25	14.50	7.88	0.67	0.00	0.33	63.67	9.00	36.33
18 WAI	0.50	10.50	5.50	0.00	0.00	0.00	12.00	0.00	6.00
19 WAI	21.25	5.00	13.13	0.67	0.00	0.33	2.00	4.33	3.17
20 WAI	22.75	1.50	12.13	57.33	0.00	28.67	3.33	16.67	10.00
21 WAI	37.25	3.00	20.13	3.67	40.67	22.17	1.67	10.00	5.83
22 WAI	22.00	27.75	24.88	1.00	1.67	1.33	0.00	7.00	3.50
23 WAI	0.75	5.50	3.13	0.67	2.67	1.67	0.00	0.00	0.00
24 WAI	1.00	2.50	1.75	0.67	0.00	0.33	0.00	0.00	0.00
25 WAI	1.25	0.75	1.00	0.33	0.67	0.50	0.00	0.00	0.00
26 WAI	0.50	0.00	0.25	0.00	0.33	0.17	0.00	0.00	0.00
27 WAI	0.00	0.50	0.25	0.00	0.00	0.00	0.00	0.00	0.00
28 WAI	0.00	0.50	0.25	0.00	0.00	0.00	-	-	-
29 WAI	0.00	0.50	0.25	1.33	0.00	0.67	-	-	-
30 WAI	0.00	0.00	0.00	0.33	0.33	0.33	-	-	-
31 WAI	0.00	0.00	0.00	1.33	10.33	5.83	-	-	-
32 WAI	0.00	0.00	0.00	7.33	1.00	4.17	-	-	-
33 WAI	0.00	0.00	0.00	0.00	1.67	0.83	-	-	-
34 WAI	0.00	0.00	0.00	16.67	13.67	15.17	-	-	-
35 WAI	0.00	0.00	0.00	3.00	2.33	2.67	-	-	-
36 WAI	0.00	0.00	0.00	0.33	0.67	0.50	-	-	-
37 WAI	0.00	2.25	1.13	0.00	0.00	0.00	-	-	-
38 WAI	0.00	0.50	0.25	0.00	0.00	0.00	-	-	-
39 WAI	1.00	2.00	1.50	0.00	0.00	0.00	-	-	-
40 WAI	0.00	5.25	2.63	0.00	0.00	0.00	-	-	-
41 WAI	6.75	13.75	10.25	0.00	0.00	0.00	-	-	-
42 WAI	3.25	3.25	3.25	0.00	0.00	0.00	-	-	-
43 WAI	3.00	0.00	1.50	-	-	-	-	-	-
44 WAI	0.00	0.00	0.00	-	-	-	-	-	-
45 WAI	0.00	0.00	0.00	-	-	-	-	-	-
Mean	3.56	2.66		2.74	2.47		4.13	2.43	
CD (p= 0.05)									
Week		2.05			2.00			2.11	
Host plant		0.47			0.48			0.67	
Week × Host plant		2.89			2.83			2.99	

WAI: week after inoculation

Table 4. Correlation between abiotic factors and population of *Aprostocetus purpureus* at Ranchi

Crop/critical period (Week After Inoculation)	Host plant	Temperature (^{0}C)		Relative humidity (%)		Total rainfall (mm)
		Maximum	Minimum	Maximum	Minimum	
Summer (baisakhi) crop 2011-12						
(17 to 22)	Ber	0.215	0.059	-0.329(*)	-0.292(*)	-0.017
	Palas	0.219	0.088	0.002	-.040	-0.146
Summer (baisakhi) crop 2012-13						
(17 to 22)	Ber	0.088	0.196	0.095	0.079	0.079
	Palas	0.129	0.267	-0.020	-0.023	-0.031

*Significant

with temperature and significant negative correlation with relative humidity was on ber in baisakhi (2011-12) during the critical periods. In baisakhi (2012-13), positive correlation with temperature and negative correlation with relative humidity during critical period on *palas* (Table 4) indicated that the summer crop is vulnerable to weather parameters. Ramani (2009) analyzed the critical weather data recorded at Ranchi during past ten years in comparison to the previous decade and revealed clear deviations from the normal weather pattern; changed rainfall pattern; reduced post monsoon and winter rain spells; overall fall in relative humidity and deviations in maximum and minimum temperature pattern over seasons coupled with heavy incidence of *A. purpureus* resulting in lac crop mortality. A very high incidence of, *A. purpureus* (108 nos. kg^{-1} broodlac) was recorded in summer rangeeni lac insect populations during 2011-12 and 2012-13, whereas, it was less than 17 nos. per kg during 1972-73 and 1973-74 (Srivastava *et al.,* 1976) showing 538 per cent periodical increase in 2011-12 and 2012-13 as compared to 1972-73 and 1973-74.

The observations indicate the resurgence of *A. purpureus* as the most serious pest of lac insect causing huge economic losses. *A. purpureus* was earlier considered as minor pest of lac insect but nowadays, has acquired the status of most dreaded pest of the lac insect. Parasitization at an early development stage of lac insect by *A. purpureus* leads to complete failure of the lac crop, so it has assumed the status of key pest in the lac ecosystem in the changing scenario of climate change.

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Integrated Weed Management in Turmeric (*Curcuma longa* L.)

S. Bharty, S. Barla, R. R. Upasani and R. Faruque

Birsa Agricultural University, Ranchi -834 006, India
E-mail: shruti06bharty@gmail.com

Abstract: Out of 15 treatments of weed control methods in turmeric, application of metribuzin 0.7 kg ha^{-1} pre-emergence followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1} at 45 DAP recorded 66.96%, at 90 days after planting (DAP) and 54.67%, at 150 DAP reduced total weed density compared to hand weeding. Application of metribuzin 0.7 kg ha^{-1} pre-emergence followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1} at 45 DAP also recorded reduced density of broad leaved, grassy and sedge weeds. Among all the treatments integrated with metribuzin 0.7kg ha^{-1} followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1} at 45 DAP recorded maximum phyto-toxicity, while treatment integrated with metribuzin 0.7 kg ha^{-1} followed by straw mulch at 10 DAP followed by hand weeding at 75 DAP recorded reduced phyto-toxicity. Application of atrazine 0.75 kg ha^{-1} pre-emergence followed by straw mulch at 10 DAP followed by hand weeding at 75 DAP recorded higher rhizome yield.

Key Words : Fresh yield, Phyto-toxicity, Weed dynamics

Turmeric (*Curcuma longa* L.) is a herbaceous perennial, belonging to the family Zingiberaceae, native to Indo Malayan region. India is the largest producer, consumer and exporter of turmeric in the world market, having an area of 194 (000'ha) with average production of 971 (000' MT) and the productivity is 5 MT ha^{-1} (Anonymous, 2013). Turmeric is largely, takes long time span of about 8–9 months and mainly grown during *kharif* season. The magnitude of yield loss varies from 30 to 75 %, depending upon the growth and persistence of weed density in the standing turmeric crop **(**Krishnamurthy and Ayyaswamy, 2000**)**. Thus, it requires weed free condition for a long period for better production of rhizomes. But, weed control by hand weeding becomes expensive, time consuming and laborious. Hence, the use of herbicides in turmeric production is essential but the efficacy of every herbicide evaluated by type of weed flora, soil type, weather conditions etc. Keeping all the above factors in view, the present investigation was carried out with the objective to find out the best weed management practice for turmeric production.

MATERIAL AND METHODS

A field experiment was carried out on a sandy loam soil, acidic in nature having low organic carbon (4.2g kg^{-1}) and available nitrogen (243 kg ha^{-1}), while medium available phosphorus (19.15 kg ha^{-1}) and potassium (188.16 kg ha^{-1}). The 15 treatments in randomized block design with three replications. The recommended fertilizer dose was 120: 60: 100:: N:P:K kg ha^{-1} and variety sown was *Rajendra Sonia* with seed rate 20 q ha^{-1} and spacing of 45 X 20 cm. All the herbicides alone or in mixture were applied with knapsack sprayer fitted with flat-fan nozzle using 600 litres water ha^{-1}. Population of weeds and dry weight were recorded at 30, 90 and 150 DAP with the help of quadrant (0.5 x 0.5 m).

RESULTS AND DISCUSSION

Among broad leaved weeds *Ageratum conyzoides* (L.) (30.2%), *Celosia argentea* (L.) (4.81%), *Acalypha indica* (L.) (3.05%); *among grassy Digitaria sanguinalis* (L.) (11.2%), *Panicum dichotomiflorum* (4.43%) and among sedges *Cyperus rotundus* (L.) (8.7%) were predominant [broad leaved dominated (60.4%) followed by grassy (28%) and sedge weeds (11.6%)].

Broad leaved weed density (no. m^{-2}): Application of glyphosate, 1.85 l ha^{-1} at 25 DAP followed by two hand weeding at 45 and 75 DAP recorded 33.3 per cent reduced broad leaf weed density compared to hand weeding at 25, 45 and 75 DAP while at 90 and 150 DAP, metribuzin 0.7 kg ha^{-1} pre-emergence followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1} at 45 DAP recorded significantly reduced broad leaf weed density to the tune of 61.35 and 81.91%, respectively compared to hand weeding at 25, 45 and 75 DAP.

Grassy weed density (no. m^{-2}): At 30 DAP grassy weed density reduced up to 9.5 % under glyphosate 1.85 l ha^{-1} at 25 DAP followed by two hand weeding at 45 and 75 DAP compared to hand weeding at 25, 45 and 75 DAP while at 90 and 150 DAP, it reduced by 78.08 and 31.05%, respectively with application of metribuzin 0.7 kg ha^{-1} pre-emergence followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1} at 45 DAP compared to hand weeding at 25, 45 and 75 DAP**.**

Sedge weed density (no. m^{-2}): At 30 DAP application of glyphosate, 1.85 l ha^{-1} at 25 DAP followed by two hand weeding at 45 and 75 DAP recorded 29.41 % reduced sedge

Table1. Weed density (no. m^{-2}) and total dry matter accumulation by weeds (g m^{-2}) in turmeric as influenced by weed control methods

Treatment	Broad leaf weeds (no. m^{-2})			Grassy weeds (no. m^{-2})			Sedge weeds (no. m^{-2})			Total weed density (no. m^{-2})		
	30 DAP	90 DAP	150 DAP	30 DAP	90 DAP	150 DAP	30 DAP	90 DAP	150 DAP	30 DAP	90 DAP	150 DAP
Metribuzin 0.7 kg ha^{-1} *	13.16 (180)	25.80 (667)	19.76 (159)	18.12 (328)	19.03 (363)	15.61 (244)	10.08 (101)	6.48 (43)	5.63 (33)	24.63 (609)	32.72 (1072)	25.83 (667)
Pendimethalin 1.0 kg ha^{-1} *	15.68 (247)	27.98 (789)	23.41 (199)	23.10 (533)	21.43 (459)	20.88 (438)	14.25 (203)	8.03 (64)	9.33 (87)	31.34 (983)	36.16 (1312)	32.71 (1075)
Atrazine 0.75 kg ha^{-1} *	11.91 (142)	25.48 (651)	16.40 (192)	15.47 (243)	18.77 (352)	15.24 (238)	8.19 (67)	6.15 (37)	5.00 (25)	21.22 (451)	32.25 (1040)	22.95 (534)
Oxyfluorfen 0.3 kg ha^{-1} *	7.33 (53)	21.92 (485)	15.15 (375)	15.00 (233)	16.01 (256)	12.94 (167)	7.33 (53)	6.15 (37)	4.18 (17)	18.30 (340)	27.85 (779)	20.46 (422)
Oxadiargyl 0.25 kg ha^{-1} *	7.10 (52)	21.53 (464)	14.08 (248)	14.91 (228)	14.95 (223)	15.24 (238)	6.12 (39)	6.12 (37)	4.12 (17)	17.71 (319)	26.92 (725)	21.29 (454)
Glyphosate 1.25 l ha^{-1} *	5.17 (27)	19.36 (379)	13.83 (550)	13.26 (183)	13.42 (180)	12.63 (159)	3.70 (13)	5.58 (32)	0.71 (0)	14.71 (223)	24.22 (591)	18.72 (350)
Glyphosate 1.85 l ha^{-1} *	4.91 (24)	18.05 (325)	13.79 (487)	13.19 (181)	11.79 (139)	12.52 (158)	3.52 (12)	5.70 (32)	0.71 (0)	14.57 (217)	22.28 (496)	18.62 (348)
Metribuzin 0.7 kg ha^{-1} followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1}	12.08 (148)	12.88 (165)	6.95 (49)	16.20 (264)	6.96 (48)	10.54 (111)	8.51 (72)	3.34 (11)	0.71 (0)	21.95 (484)	14.98 (224)	12.66 (160)
Pendimethalin 1.0 kg ha^{-1} followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1}	13.49 (187)	13.77 (191)	11.55 (238)	18.12 (328)	8.95 (80)	10.66 (113)	13.31 (177)	4.64 (21)	0.71 (0)	26.28 (692)	17.07 (292)	15.72 (248)
Atrazine 0.75 kg ha^{-1} followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1}	7.57 (57)	17.21 (299)	12.64 (390)	15.10 (240)	11.08 (123)	12.25 (151)	7.76 (60)	4.64 (21)	0.71 (0)	18.74 (357)	21.02 (443)	17.61 (311)
Metribuzin 0.7 kg ha^{-1} followed by straw mulch**	13.20 (175)	25.37 (661)	19.28 (135)	16.37 (273)	18.77 (352)	15.48 (240)	9.61 (92)	6.53 (43)	5.07 (25)	23.23 (540)	32.34 (1056)	25.24 (640)
Pendimethalin 1.0 kg ha^{-1} followed by straw mulch **	15.43 (240)	25.80 (667)	22.08 (191)	22.23 (496)	21.16 (448)	17.70 (321)	13.34 (181)	8.03 (64)	7.42 (55)	30.18 (917)	34.34 (1179)	29.33 (862)
Atrazine 0.75 kg ha^{-1} followed by sStraw mulch **	8.82 (77)	24.49 (603)	15.75 (190)	15.32 (240)	18.31 (336)	13.25 (175)	8.16 (67)	6.13 (37)	5.07 (25)	19.48 (384)	31.23 (976)	21.18 (448)
3 Hand weeding	5.87 (36)	20.59 (427)	13.88 (271)	14.14 (200)	14.71 (219)	12.64 (161)	4.20 (17)	5.58 (32)	0.71 (0)	15.89 (253)	25.97 (678)	18.77 (353)
Un- weeded check	17.04 (291)	35.59 (1267)	25.37 (643)	23.85 (569)	24.19 (585)	21.15 (447)	15.03 (226)	15.64 (244)	9.61 (92)	32.94 (1086)	45.79 (2096)	34.39 (1182)
CD (p=0.05)	2.61	3.86	2.22	4.17	1.59	2.98	1.43	1.33	0.82	3.92	3.16	2.60
CV %	14.74	10.30	8.15	14.70	5.95	12.22	9.65	12.11	12.33	10.62	6.66	6.96

Data in parentheses are original values; *Followed by two hand weeding; **Followed by one hand weeding weed density compared to hand weeding at 25, 45 and 75 DAP. At 90 DAP, metribuzin 0.7 kg ha^{-1} pre-emergence followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1} at 45 DAP recorded reduced sedge weed density to the extent of 65.62.

Total weed density (no. m^{-2}): Among chemical weed control methods, application of glyphosate 1.85 l ha^{-1} at 25 DAP followed by two hand weeding at 45 and 75 DAP recorded significantly reduced total weed density at 30 DAP to the extent of 14.22 per cent compared to hand weeding at 25, 45 and 75 DAP while at 90 and 150 DAP metribuzin 0.7 kg ha^{-1} pre-emergence followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1} at 45 DAP recorded 66.96 and 54.67 per cent reduced total weed density compared to hand weeding at 25, 45 and 75 DAP, respectively.

Total dry matter accumulation by weed (g m^{-2}): Reduction in dry matter accumulation by total weeds also followed similar trend as that of weed density. Application of glyphosate 1.85 l ha^{-1} at 25 DAP followed by two hand weeding at 45 and 75 DAP recorded 2.67 % reduced total weed dry matter compared to hand weeding at 25, 45 and 75 DAP while at 90 and 150 DAP, metribuzin 0.7 kg ha^{-1} pre-emergence followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1} at 45 DAP recorded significantly reduced total weed dry matter to the tune of 44.24 and 52.27%, respectively compared to hand weeding at 25, 45 and 75 DAP.

Table 2. Total dry matter accumulation by weeds (g m^{-2}), phyto-toxicity and fresh yield (t ha^{-1}) of turmeric as influenced by weed control methods

Treatment	Total dry matter accumulation by weeds (no. m^{-2})			Phyto-toxicity (0-10 scale)	Fresh yield (t ha^{-1})
	30 DAP	90 DAP	150 DAP	60 DAP	
Metribuzin 0.7 kg ha^{-1} *	8.73 (75.81)	22.65 (512.62)	20.87 (435.06)	3.33	20.95
Pendimethalin 1.0 kg ha^{-1} *	11.75 (137.57)	29.77 (887.76)	22.21 (493.12)	3.00	18.90
Atrazine 0.75 kg ha^{-1} *	7.87 (61.51)	21.29 (452.77)	19.65 (385.77)	2.33	20.58
Oxyfluorfen 0.3 kg ha^{-1} *	6.90 (47.25)	18.56 (344.15)	19.28 (371.41)	3.33	16.07
Oxadiargyl 0.25 kg ha^{-1} *	6.70 (44.35)	18.20 (330.73)	18.35 (336.44)	3.67	15.26
Glyphosate 1.25 l ha^{-1} *	6.84 (46.37)	17.35 (300.54)	17.80 (316.41)	5.00	18.51
Glyphosate 1.85 l ha^{-1} *	6.53 (42.23)	17.02 (289.25)	17.59 (309.25)	5.00	18.16
Metribuzin 0.7 kg ha^{-1} followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1}	7.98 (63.71)	13.48 (181.29)	12.22 (148.88)	7.67	7.44
Pendimethalin 1.0 kg ha^{-1} followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1}	10.77 (115.53)	15.94 (254.04)	15.05 (225.97)	8.00	5.55
Atrazine 0.75 kg ha^{-1} followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1}	7.36 (53.75)	16.59 (274.99)	17.09 (291.71)	8.33	3.25
Metribuzin 0.7 kg ha^{-1} followed by straw mulch**	8.22 (67.59)	21.55 (464.17)	19.27 (370.74)	1.33	28.06
Pendimethalin 1.0 kg ha^{-1} followed by straw mulch **	11.19 (124.88)	26.85 (721.18)	21.01 (441.00)	1.67	26.05
Atrazine 0.75 kg ha^{-1} followed by sStraw mulch **	7.57 (57.69)	20.57 (422.94)	18.43 (339.43)	0.67	29.04
3 Hand weeding	6.62 (43.39)	18.04 (325.15)	17.68 (311.96)	0.00	19.29
Un- weeded check	12.11 (146.11)	33.00 (1089.01)	25.09 (629.97)	0.00	2.81
CD (p=0.05)	0.82	1.12	0.81	1.48	3.19
CV %	5.76	3.25	2.59	22.99	11.44

Data in paranthesis are original values; *Followed by two hand weeding; **Followed by one hand weeding

The reduction in weed density and dry matter owing to application of metribuzin can be due to its mode of action as it inhibits photosynthetic electron flow between the primary and secondary electron acceptor of photosystem II, while fenoxaprop-p-ethyl prevents plant cell division and elongation of susceptible species besides fatty acid synthesis inhibition in grasses, by inhibition of acetyl CoA carboxylase (ACCase). Metsulfuron inhibit the activity of the acetolactate synthase (ALS), which is involved in the synthesis of the branch chain amino acids. Reduction in weed density and weed dry matter owing to metribuzine, fenoxaprop-p-ethyl and metsulfuron has also been reported by Barla *et al.* (2015) and Gohil *et al.* (2014).

Phyto-toxicity (0-10 scale): Plant injury of turmeric as a result of phyto-toxicity recorded at 60 DAP was maximum under integrated with metribuzin 0.7 kg ha^{-1} or pendimethalin 1.0 kg/ha or atrazine 0.75 kg ha^{-1} pre-emergence each followed by fenoxaprop-p-ethyl 67g ha^{-1} + metsulfuron 4 g ha^{-1}at 45 DAP i.e., 7.67, 8.00 and 8.33, respectively at a scale of 0-10. The possible cause can be attributed to treatments with overloaded herbicides combination might have interacted with turmeric plant's delicate tissues resulting epinasty, hyponasty, tip chlorosis, leaf margin scorching and finally whole or partial plant drying. The phyto-toxic effect of herbicide on turmeric plants have also been observed by Barla *et al*. (2015) and Jadhav and Pawar (2014). Among all the treatments, integration of metribuzin 0.7 kg ha^{-1} or pendimethalin 1.0 kg ha^{-1} or atrazine 0.75 kg ha^{-1} pre-emergence each followed by straw mulch at 10 DAP followed by hand weeding at 75 DAP recorded reduced phyto-toxicity on turmeric plant. It appears that application of straw mulch as well as hand weeding at 45 DAP might have given selective stimulation advantage to crop over weeds. Thus, plants were strong enough to tolerate herbicidal effect.

Fresh yield (t ha^{-1}): Application of atrazine 0.75 kg/ha pre-emergence followed by straw mulch at 10 DAP followed by hand weeding at 75 DAP recorded 50.54 per cent higher fresh yield than hand weeding. However, it was similar to metribuzin 0.7 kg ha^{-1} pre-emergence followed by straw mulch at 10 DAP. The higher yield owing to integration with metribuzin 0.7 kg ha^{-1} or pendimethalin 1.0 kg ha^{-1} or atrazine 0.75 kg ha^{-1} pre-emergence each followed by straw mulch at 10 DAP followed by hand weeding at 75 DAP can be justified as combined effect of better weed control and reduced phyto-toxicity. These results were in agreement with results of Barla *et al*. (2015), Manhas *et al*. (2011) and Kaur *et al*. (2008) who have also observed higher yield of turmeric under the treatments having straw mulch along with metribuzin or pendimethalin or atrazine each followed by hand weeding at 75 DAP.

Thus, it can be concluded that application of atrazine 0.75 kg ha^{-1} or metribuzin 0.7 kg ha^{-1} or pendimethalin 1.0 kg ha^{-1} pre-emergence followed by straw mulch and hand weeding at 75 DAP may be practiced for higher productivity of turmeric owing to better weed control.

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Growth Inhibiting Effects of Some Essential Oils against *Callosobruchus chinensis* L. (Coleoptera:Bruchidae) on Stored Chickpea

S. A. Ganie and V. Kaul

Division of Entomology, Faculty of Agriculture,
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India.
E-mail: saganie.ganie@gmail.com

Abstract: Investigations were conducted to evaluate growth inhibiting effects of five essential oils, namely neem (*Azadirachta indica*), eucalyptus (*Eucalyptus globulus*), clove (*Syzygium aromaticum*), camphor (*Cinnamomum camphora*), and tulsi (*Ocimum sanctum*) against *Callosobruchus chinensis* L. at 0.2 %, 0.4 %, 0.6 % and 0.8 %v/w respectively on chickpea. The results revealed that significantly highest ovipositional and ovicidal activity were observed in neem oil followed by tulsi, eucalyptus, clove and camphor oil. Neem oil at 0.6% and 0.8%v/w and tulsi oil at 0.8 %v/w exhibited 100% feeding deterrence. Average repellency percentage indicated that neem oil caused significantly highest repellency and repellent effect was proportional to the concentration and higher concentration has stronger effect. Observed repellency percentage increased with increase in time intervals after treatment.

***Key Words*:** Botanicals, Feeding deterrence, Ovicidal activity, Repellency

India being one of the major pulse growing country in the world, accounts for one third of the total world area under pulses and one fourth of total world production (Sivakumar *et al.,* 2010). The pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) is the most widespread and destructive major insect pest of green gram, chickpea, black gram, peas, cowpea, lentil and pigeon pea (Aslam *et al.,* 2002, Park *et al.,* 2003). Synthetic chemical insecticides have proved very effective in the control of the beetle. However, pesticides involve a high economic cost and a potential health risk for poor farmers with few resources. Furthermore, the indiscriminate use of pesticides by farmers and traders to keep the pest under control has given rise to an urgent need to develop ecologically safer and sounder pest control techniques that must also be economic, simple and practical (Rajapakse, 1990). The aim of this study was to assess ovipositional, ovicidal, antifeedant and repellency activities of five essential oils on *C. chinensis* with a view to develop an environmentally safer, effective and economical control method.

MATERIAL AND METHODS

The culture of ***Callosobruchus*** *chinensis* L. was established from infested chickpea seeds of *C. chinensis by rearing* in plastic container. Healthy adults emerged from the container were shifted to another plastic container and provided with clean chickpea seeds for oviposition and maintained at 30 ± 1°C temperature and 70 ± 5°C % relative humidity. The container was kept undisturbed until the emergence of adults. Freshly emerged subsequent generations were used for further experiments. Five essential oils, *viz*., Neem oil (*Azadirachta indica*), Eucalyptus oil (*Eucalyptus globulus*), Clove oil (*Syzygium aromaticum*), Camphor oil (*Cinnamomum camphora*), and Tulsi oil (*Ocimum sanctum*) were used for the experimental study at 0.2%, 0.4%, 0.6%, 0.8%v/w concentration. The experiment were in a complete randomized design with three replication.

Ovipositional activity

Five pairs of *C. chinensis* beetles, aged 0-24hr were released in petri dish containing chickpea seeds treated with essential oils which were then covered for the next 7 days allowing them to lay eggs. After 7 days, numbers of eggs laid were recorded and the percentage of oviposition deterrence (POD) was (Elhag, 2000)

$$POD \quad \frac{Cs - Ts}{Cs} \quad 100$$

Cs = number of eggs laid on control seeds; Ts = number of eggs laid on treated seeds

Ovicidal activity: To determine the F_1 progeny detergence efficacy of botanicals, 20 g chickpea seeds (each seed with 4-5 eggs) were placed in separate plastic boxes (200 ml) and treated with different doses of essential oils. After 25 days, the numbers of emerged F1 adults were recorded and percent deterrence was calculated (Aldryhim, 1995).

$$PD \quad \frac{Pc - Pt}{Pc} \quad 100$$

Pc = number of progeny in control; Pt = number of progeny in treatment

Antifeedant activity: To determine the *antifeedent property* of botanicals, 500g chickpea seeds were placed in separate plastic boxes and treated with the desired doses of essential oils. The weight losses of chickpea (due to feed by insects) were assessed and the feeding deterrence index was calculated (Isman *et al*. 1990).

$$\mathrm{FDI} \quad \frac{\mathrm{C-T}}{\mathrm{C}} \quad 100$$

C = Consumption of control disks (weight loss in control); T = Consumption of treated disks (weight loss in treated)

Repellent activity: Repellency property of the test insect was tested by treating the chickpea seeds with different concentrations of essential oils by placing them in petri plates. The insects which move to the walls of petri plate were considered as repelled. These observations were recorded after 24 and 48hr interval.

$$\text{Per cent repellency} \quad \frac{\mathrm{A-B}}{\mathrm{A}} \quad 100$$

A= Average number of insects present on control: B= Average Number of insects present on treatment.

RESULTS AND DISCUSSION

The seeds treated with neem oil at the rate of 0.6%v/w and 0.8%v/w and tulsi oil at 0.8%v/w showed 100% oviposition deterrence followed by eucalyptus oil, clove oil and camphor oil. Similar, trend was in F_1 adult deterrence being significantly higher in neem oil followed by tulsi oil. The F_1 adult deterrence increased significantly with the increase in dosage of each treatment (Table 1). The neem oil at the rate of 0.6% and 0.8%v/w and tulsi oil at 0.8%v/w caused 100 per cent feeding deterrence. . The next treatment at 0.8%v/w was eucalyptus oil causing feeding deterrence of 92.63%. From the Table 2, it was also observed that at 24hr after application of treatment, the repellency was significantly

Table 1. Effect of essential oils on oviposition and ovicidal activity of pulse beetle, *Callosobruchus chinensis* on chickpea during 2011 and 2012

Treatments	Conc. (v/w)	No. of eggs laid**	Oviposition deterrence (%)*	F_1 Emerged **	F_1 adult deterrence (%)*
Azadirachta indica	0.2	44.33 (6.72)^{jih}	71.91 (58.27) ^{jihgf}	19.67 (4.54)jih	78.90 (63.32) ^{ihgfed}
	0.4	12.67 (3.67)^{po}	92.20 (76.23) ^{dcb}	0.00 (1.00)r	100.00 (90.00) ^{a}
	0.6	0.00 (1.00)^{s}	100.00 (90.00) ^{a}	0.00 (1.00)r	100.00 (90.00) ^{a}
	0.8	0.00 (1.00)^{s}	100.00 (90.00) ^{a}	0.00 (1.00)^{r}	100.00 (90.00) ^{a}
Ocimum sanctum	0.2	59.50 (7.77)^{f}	62.43 (52.28) ^{nmlkjihg}	31.83 (5.70) ^{fe}	66.05 (54.49) ^{mlkjihg}
	0.4	30.17 (5.55)^{mlk}	81.24 (65.28) ^{gfedcb}	16.17 (4.13) ^{kj}	82.64 (66.57) ^{hgfedc}
	0.6	12.33 (3.65)^{qpo}	92.22 (76.40) ^{cba}	5.67 (2.58) ^{po}	93.91 (77.79) ^{cba}
	0.8	0.00 (1.00)^{s}	100.00 (90.00) ^{a}	0.00 (1.00) ^{r}	100.00 (90.00) ^{a}
Eucalyptus globulus	0.2	67.17 (8.25)^{e}	57.06 (49.08) ^{onmlkji}	40.67 (6.45) ^{d}	56.47 (48.74) ^{onmlkj}
	0.4	45.84 (6.83)^{ih}	70.73 (57.49) ^{kjihgf}	23.00 (4.89) ^{ihg}	75.36 (60.66) ^{jihgfe}
	0.6	22.34 (4.82)^{n}	85.72 (70.37) ^{fedcb}	11.50 (3.53) ^{nml}	87.69 (72.12) ^{edcb}
	0.8	10.01 (3.32)^{rqp}	93.64 (76.92) ^{ba}	4.51 (2.33) ^{qpo}	95.18 (78.34) ^{ba}
Syzygium aromaticum	0.2	83.67 (9.20)^{dc}	46.84 (43.16) ^{qponml}	47.50 (6.95) ^{cb}	49.07 (44.45) ^{ponml}
	0.4	47.50 (6.96)^{h}	70.00 (57.01) ^{lkjihgf}	27.01 (5.28) ^{g}	71.08 (57.72) ^{lkjihgf}
	0.6	30.50 (5.61)^{lk}	80.58 (64.70) ^{hgfedcb}	12.51 (3.67) ^{l}	86.59 (70.98) ^{gfedcb}
	0.8	14.51 (3.93)^{o}	90.94 (74.35) ^{edcb}	7.01 (2.82) ^{o}	92.50 (75,53) ^{dcb}
Cinnamomum camphora	0.2	114.00 (10.72)^{b}	27.31 (31.46) ^{rqp}	53.34 (7.33) ^{b}	43.02 (40.95) ^{qponm}
	0.4	84.67 (9.23)^{c}	47.22 (43.38) ^{ponml}	37.33 (6.19) ^{ed}	59.94 (50.78) ^{nmlkji}
	0.6	55.34 (7.50)^{gf}	65.11 (53.91) ^{mlkjihg}	23.51 (4.94) ^{hg}	74.82 (60.27) ^{kjihgfe}
	0.8	32.67 (5.80)^{k}	79.41 (63.74) ^{ihgfedcb}	11.50 (3.53) ^{ml}	87.65 (72.02) ^{fedcb}
Control		159.84 (12.65)a	-	93.50 (9.72) ^{a}	-
CD(p=0.05)		0.51	13.56	0.42	0.42

* Figures in parentheses are arcsine transformed values.
** Figures in parentheses are square root transformed values.
Values followed by different letters within a column, are significantly different at the 5% level of probability.

Table 2. Effect of essential oils on the feeding activity and repellency of pulse beetle, *Callosobruchus chinensis* on chickpea during 2011 and 2012

Treatments	Conc. (v/w)	Weight loss (%)	Feeding deterrent index (FDI) (%)	Per cent repellency after	
				24 hr.	48 hr.
Azadirachta indica	0.2	22.17 (28.04)^{jihg}	74.88 (60.32)^{jihgfe}	37.80 (37.90)^{mlkji}	36.32 (37.01)^{mlkjih}
	0.4	1.67 (7.41)^{q}	98.09 (83.28)^{ba}	44.31 (41.70)^{jih}	40.25 (39.34)^{kjih}
	0.6	0.00 (0.00)^{r}	100.00 (90.00)^{a}	76.55 (61.52)^{cb}	75.29 (60.61)^{cb}
	0.8	0.00 (0.00)^{r}	100.00 (90.00)^{a}	89.82 (73.16)^{a}	88.71 (73.24)^{a}
Ocimum sanctum	0.2	36.01 (36.83)^{fed}	59.17 (50.33)^{nmlkj}	31.12 (33.85)^{onmlk}j	28.82 (32.42)^{ponmlkj}
	0.4	17.01 (24.31)^{kji}	80.70 (64.81)^{ihgfedc}	38.17 (38.11)^{lkjih}	37.79 (37.89)^{lkjih}
	0.6	7.67 (16.05)^{pon}	91.34 (75.50)^{dcb}	62.37 (52.23)^{gfed}	59.86 (58.74)^{edcb}
	0.8	0.00 (0.00)^{r}	100.00 (90.00)^{a}	81.30 (65.33)^{ba}	80.60 (64.72)^{ba}
Eucalyptus globulus	0.2	43.17 (41.03)^{dc}	51.06 (45.60)^{ponmlk}	29.09 (32.59)^{ponmlk}	29.15 (32.63)^{onmlkj}
	0.4	24.34 (29.51)^{ihg}	72.48 (58.66)^{kjihgf}	32.88 (34.94)^{nmlkj}	32.04 (34.42)^{nmlkj}
	0.6	14.00 (21.93)^{mlk}	84.09 (68.09)^{gfed}c	51.95 (46.11)^{hgf}	48.91 (44.36)^{ih}g
	0.8	6.50 (14.74)^{qpo}	92.63 (75.78)^{cb}	75.32 (60.63)^{dcb}	73.27 (59.20)^{dcb}
Syzygium aromaticum	0.2	50.17 (45.08)^{cb}	43.08 (40.99)^{qponm}	25.61 (30.35)^{rqponm}l	22.35 (28.16)^{srqponm}
	0.4	27.33 (31.47)^{g}	69.05 (56.39)^{mlkjihgf}	29.08 (32.58)^{qponmlk}	28.82 (32.42)^{qponmlkj}
	0.6	15.84 (23.41)^{lkj}	82.06 (66.02)^{hgfedc}	50.08 (45.03)^{ihgf}	49.05 (44.44)^{hg}
	0.8	9.00 (17.42)^{onm}	89.80 (73.13)^{edcb}	68.20 (55.85)^{edc}	66.17 (54.51)^{fedc}
Cinnamomum camphora	0.2	58.34 (49.84)^{b}	33.94 (35.58)^{rqp}	22.65 (26.90)^{srqpon}	20.54 (26.90)^{tsrqpon}
	0.4	38.33 (38.20)^{ed}	56.58 (48.80)^{onmlkj}	30.05 (29.27)^{rqpon}	23.98 (29.27)^{rqponml}
	0.6	25.17 (30.06)^{hg}	71.52 (58.01)^{lkjihgf}	43.76 (40.96)^{kjih}	43.03 (40.96)^{jih}
	0.8	13.34 (21.38)^{nmlk}	84.89 (69.07)^{fedc}	62.87 (52.54)f^{ed}	62.87 (52.54)^{gfedc}
Control		88.34 (71.55)^{a}	-	-	-
CD(p=0.05)		5.33	13.44	8.79	9.02

Figures in parentheses are arcsine transformed values.
Values followed by different letters within a column, are significantly different at the 5% level of probability.

higher in neem oil (89.82%) followed by tulsi oil , eucalyptus oil , clove oil and camphor oil at 0.8%v/w after application. Repellency was minimum at 0.2%v/w in different essential oils. At 48hr after application, the same trend was observed.

All essential oils caused significant inhibitory effect on growth of pulse beetle Callosobruchus *chinensis.* Among essential oils neem oil was most effective followed by tulsi oil, eucalyptus oil, clove oil and camphor oil respectively. Khaire *et al*. (1993) also reported that treating pigeon pea seeds with neem oil showed significant repellent action against egg laying by adult *C. chinensis*. Similarly, chickpea seeds treated with neem oil showed significantly repellent action for egg laying by adult bruchids (Biswas and Biswas, 2005; Pokharkar and Chauhan, 2010). The highest adult deterrence in the present study may be due to active toxic substances present in the oil that could block the microphyle region of the egg chorion and embryo died due to the depletion of oxygen for respiration or the botanicals interfere with the normal embryonic development by suppressing hormonal and biochemical processes (Jayakumar *et al*. 2003). The neem oil completely inhibited adult emergence and appeared to be most promising as a seed protectant against *C. chinensis* (Pokharkar and Chauhan, 2010). The effectiveness of many plant essential oils as repellent, antifeedant and insecticidal against *Callosobruchus* spp. is documented by various workers (Ketoh *et al*., 2005; Kumar *et al.,* 2008; Aboua *et al.,* 2010 and Pandey *et al*., 2011).

Among the five botanicals tested, neem oil proved most effective for the management of C*. chinensis*. Further research is required to explore some new indigenous organic sources of the insecticidal allelo-chemicals, which can more efficiently be utilized for the food-safety purposes and to overcome the dilemma of health hazards and environmental pollution.

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Influence of Weather on the Incidence of Wax Moth (*Galleria mellonela L.*) and Hive Beetle (*Aethina tumida* Murray) in *Apis mellifera L*. Apiaries in Gird Zone of Morena District

Swati Singh and Rajesh Verma

RajmataVijyaraje Scindia Krishi VishwaVidyalaya, Krishi Vigyan Kendra, Morena-476 001, India
E-mail: swati13singh@yahoo.co.in

Abstract: Studies on the honey bee (*Apis mellifera L.*) pests in residential and migratory apiaries and its relation with weather parameters were conducted in five blocks of Morena district in Gird Zone of Madhya Pradesh. Occurrence of greater wax moth (*Galleria mellonela L.*) was significantly higher in migratory aperies in all the blocks except in Morena and Joura. Incidence of wax moth at all the five blocks except in Morena and Joura was significantly higher (13.6) in migratory apiaries as compared to residential apiaries. Incidence of wax moth larvae was not correlated with the weather parameter except for minimum temperature (r = 0.758). The population of hive beetle (*Athena tumida Murray*) was almost similar in residential and migratory apiaries. The population of hive beetles decreased with the increase in minimum temperature (r = 0.615) and maximum(r = 0.686) in temperature, respectively.

Key Words: *Apis mellifera,* apiaries, gird zone, incidence residential, migratory

Gird zone is in northern part of Madhya Pradesh lies between latitude 24° to 26° north and longitude 76° to 79° east. The height from mean sea level varies from 52 to 529 meters. About 40% rainfall is experienced during monsoon season from June to September. Normally the onset of south west monsoon comes in first half of July and withdraws by first fortnight of September. The climate of the zone is characterized as semi arid being extremely hot during May –June (maximum temp. 47ºC) and extremely cold in January (minimum temperature 1ºC). Gird zone is highly suitable for beekeeping. Good quality of bee flora coupled with large acreage under (*Brassica compestris*) and mustard cultivation, sown during October to December provides bee flora from November to February and coriander (*Coriandrum sativum)* and berseem (*Trifolium alexandrinum* L.) in March and April. Knowledge about availability of the bee flora, Knowledge of status of bee flora is essential to evaluated the potential locality for beekeeping as the floristic and climatic situation varies different region (Singh *et al.,* 2014). Beekeepers of this zone are adopted to the stationary beekeeping, they place their apiaries in orchards and in vegetable growing areas during off season and in toria, mustard, and barseem in honey flow season. Beekeepers from adjoining states also migrate their apiaries in the month of October, November and return back in the month of March–April. Occurrence of pests and predators in residential apiaries as well as in migratory apiaries may be different. If so than this may be hazardous and leads exposure of residential and migratory apiaries vice versa. The high infestation of *Galleria mellonella* occurs during August to October, which generally feeds on empty combs and under heavy infestations the colony strength declines drastically.

Studies on pests and predators of (*Apis mellifera* L.) was carried out block of Morena district coming under Gird zone of Madhya Pradesh during the year 2008-2009 and 2009-2010. The beekeepers from the adjoining states regularly have migrated their apiaries in the month of October-November and remains till the end of April. Situation prompted us to work on status of pests and predators, their spread and adoption of beekeeping by the local farmers. To study the scenario of pests and predators complex in residential and migratory apiaries of (*Apis mellifera* L.) in Morena district. Five blocks were selected Viz. Ambah, Morena, Jaura, Kailaras and Sabalgarh. Observations at weekly intervals were recorded on pests and predators complex in the apiaries of *Apis mellifera* placed in above blocks throughout the year. Bee colonies of *Apis mellifera* in residential as well as in migratory apiaries were selected for uniform temperament and performance. Seasonal activity of wax moth was recorded fortnightly interval from selected bee colonies in the apiaries. The sample of frass containing wax moth larvae were collected separately from *Apis mellifera* colonies and counted in a laboratory to know the number of larvae in a frass. Observation on bee pests, and predator complex were recorded at fortnightly interval. The wax moth larvae and pupae hive^{-1} were recorded by observing the silicon galleries and silk covered comb cell at fortnightly interval. After recording observation the larvae were killed and pupal cocoons were removed. The adult and larval population of hive beetle (*Aethina tumida* Murray) and larval population was recorded per square centimeter hive^{-1}. After each observation, thirty larvae were kept a glass chimney along with place of comb to know the per cent of parasitization. The incidence of *Achoria grissela* L. was not seen in any bee colonies throughout the year.

Wax moth (*Galleria mellonela* L.): Incidence of wax moth in migratory apiaries at all the location was significantly higher in migratory apiaries as compared to residential apiaries. In Morena and Joura, the incidence were relatively low in migratory apiaries although the differences were significant. Data further indicated that incidence of wax moth larvae in residential apiaries in different blocks were nearly uniform. But the low or high incidence in migratory apiaries determined the level of significance (Table 1 and 3) in different blocks of Morena district. Amborse *et al.* (1997) reported that there are a number of pests and predators that kill bees or damage beekeeping equipments and honey. Wax moths destroy combs and cause damage to wooden ware. They can also damage section of honey and honey comb. Verma *et al.* (1990) concluded that larvae eat away the wax of stored comb. At times of severe infection by wax moth leads to absconding of the bees from their hives. The greater wax moth (*Gallaria mellonella*) causes serious damage to honey combs. Facility of weather data recording center is only available in Morena, therefore the seasonal activity of wax moth in bee boxes were correlated with weather factor in only Morena location. Data suggested that incidence of wax moth in the bee boxes were not influenced by maximum temperature, minimum relative humidity and rainfall (Table 3). Activity of wax moth was positively correlated with the minimum temperature (r = 0.578) and incidence of wax moth at all the five locations except in Morena and Joura were significantly higher in migratory apiaries. It was not correlated with the weather parameters except with minimum temperature (r = 0.758).

Hive beetle (*Aethina tumida* Murray): Data indicated that in residential apiaries the population of hive beetle differ significantly in Joura and Sabalgarh (Table 2), while in Kailarash, Morena and Ambah, the differences in population of hive beetle in residential and migratory apiary were non-significant. The hive beetle is a minor pest of honey bee colonies, its appearance were meager in migratory as well as in residential apiaries due to adoption of management practices by the beekeepers or due to variation in incidence of the beetle population in residential and migratory apiary. De Guzman *et al.* (2010) concluded that the small hive beetles are more abundant in warmer than cooler regions of the United States. Russian honey bee colonies had fewer beetles than in the Italian honey bee colonies. Adult beetles were found throughout the year with peak infestations observed in the autumn (September and November). The proportion of hot days was found to be the only climatic factor that seemed to contribute in the significant increase of adult. Arbogast *et al.* (2007) recorded seasonal variation in flight activity of small hive beetle, which was monitored at two sites in north–central Florida. The seasonal activities of hive beetle in bee boxes were correlated with weather factor in only Morena location. Activity of hive beetle were highly influenced by the maximum and minimum temperature. The

Table 1. Occurrence of wax moth *(Gallaria mellonella L.)* in residential and migratory in different blocks of Morena district

Observation period fortnightly	Mean population per frame									
	Kailarash		Morena		Joura		Sabalgarh		Ambah	
	R	M	R	M	R	M	R	M	R	M
First fortnight (Nov.)	0.76	16	1.12	0	0	2.49	0	17.1	0.73	24.9
Second fortnight (Nov.)	0.94	8	0.65	0	0	1.26	1.43	58.06	0.65	59.29
First fortnight (Dec.)	0.94	12.25	0.65	0	1.08	1.21	1.51	12.25	0	12.25
Second fortnight (Dec.)	1.28	0.69	0.73	0	1.48	1.22	1.3	0.12	0.86	0.14
First fortnight (Jan.)	0	1.69	0.65	0.94	1.46	2.49	1.25	1.69	0.65	1.69
Second fortnight (Jan.)	1.04	1.51	0.81	0.86	1.48	1.29	1.13	1.51	0.65	1.25
First fortnight (Feb.)	0.69	8.07	0.86	0	1.48	1.33	0	8.07	0.65	8.07
Second fortnight (Feb.)	1.69	2.5	0.94	1.28	1.12	1.26	0.86	2.5	0.94	2.5
First fortnight (March)	0	1.44	1.12	1.72	1.12	2.49	0	1.44	0	0.49
Second fortnight (March)	1.59	1.93	0.86	1.21	1.53	1.26	0	1.37	0	0.76
First fortnight (April)	2.5	1.77	1.04	1.21	1.25	2.49	0	2.28	1.36	0.76
Second fortnight (April)	1.59	1.8	0.86	1.21	0	0.8	0	1.8	0.65	0.49
"t" value	2.50*		4.13**		2.51*		2.30*		2.79*	

R=Residential, M=Migratory

Table 2. Occurrence of **h**ive beetle *(Aethina tumida Murray)* in residential and migratory apiaries in different blocks of Morena district

Observation period fortnightly	Mean population per frame									
	Kailarash		Morena		Joura		Sabalgarh		Ambah	
		M	R	M	R	M	R	M	R	M
First fortnight (Nov.)	0.73	0	0.73	0.94	0	0	1.69	1.36	0	0.65
Second fortnight (Nov.)	0.82	1.12	0.82	1.12	0	0.75	1.21	1.69	0.81	0.86
First fortnight (Dec.)	0.73	0.86	0.73	0.86	0	0.75	0.86	1.12	0	0.86
Second fortnight (Dec.)	0.92	8.46	0.92	8.46	0	0.57	0.81	0.86	0.65	0.86
First fortnight (Jan.)	0.81	0.94	0.81	0.94	0	0.75	0.81	1.21	0.65	0.81
Second fortnight (Jan.)	0.94	0.94	0.94	0.94	0	0.75	0	1.58	0.65	0.94
First fortnight (Feb.)	1.48	0.86	1.48	0.86	0	0	0.65	1.27	0.86	1.21
Second fortnight (Feb.)	0.73	1.18	0.73	1.18	0	1.12	0	1.27	1.12	0.94
First fortnight (March)		1.12	0	1.12	0	0	0.82	0.73	0.81	0.81
Second fortnight (March)	0.81	0.94	0.81	0.94	0	0	0	1.58	0.81	0.73
First fortnight (April)	0.57	0.81	0.57	0.81	0	1.48	0	1.58	1.26	0.65
Second fortnight (April)		0.73	0	0.73	0	0	0.65	0	1.12	0.94
"t" value	.092* NS		1.39 NS		3.50**.		2.49*		1.62NS	

R=Residential, M=Migratory

Table 3. Significance of variables value of paired "t" test between population in Residential and migratory apiaries

Bee pests	Relation between (Residential Vs Migratory apiaries)				
	Kailarash	Morena	Joura	Sabalgarh	Ambah
Wax moth *(Galleria mellonella)*	2.50*	2.13**	2.51*	2.30*	2.79*
Hive beetle *(Aethina tumida)*	0.092 NS	1.39 NS	3.50*	2.49*	1.62 NS

* Significant at 0.05% ** Significant at 0.01% NS - Non-Significant

correlation were negative and significant with maximum temperature (r = -0.615) and minimum temperature (r = -0.686). Other factor like humidity and rain fall did not affect the incidence of hive beetle (Table 3).

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Evaluation of IPM Modules For Management of Lepidopteron Insect-Pests and Diseases in Cabbage

S. D. Sharma, R. Devlash, Jitender Kumar, Brij Bala and R. S. Jamwal

Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya,
Hill Agricultural Research and Extension Centre, Bajaura-175 125, India
E-mail: sukhdevsharma40@gmail.com

Abstract: The IPM module consisting of a 2 spray schedule after 45 and 60 days of transplanting with lambda-cyhalothrin @ 0.004% (Bravo 5%) followed by mixture of malathion (0.05%) and zineb (Dithane Z 78) @ 0.25 was most effective in minimizing the infestation of lepidopteron larvae i.e. larvae of cabbage butterfly (*Pieris brassicae)*, diamondback moth (*Plutella xylostella*) and cabbage semi-looper (*Plusia orichalcea*), alternaria blight and black rot. This module was most economic resulting in maximum marketable yield (370.48 q ha^{-1}) and maximum net returns of Rs.16.26 per rupee spent.

Key Words: Cabbage, Diseases, IPM, Insect-Pest

Cabbage (*Brassica oleracea* var. *capitata* Linn.) is an important vegetable crop of Himachal Pradesh, India. In lower Kullu valley, different varieties of this crop are grown almost throughout the year but summer crop (March-September) is an important off season crop. This crop is jeopardized by the ravages of many species of insects at one or the other stage of its growth and among them lepidopterous insect pests are the most serious (Amoabeng *et al*., 2013). Besides, the crop is also attacked by several diseases, mostly caused by fungi and bacteria leading to severe crop losses (Faruk, 2015).

Several researchers have reported the control of lepidopterous insect pests and diseases by the spray of insecticides and fungicides. But for the efficient use of time, labour and resources, the present investigations were carried out with an objective to evaluate the efficacy of some IPM modules by the combination of insecticides and fungicides taking in to account their compatibility for the eco-friendly and economical management of lepidopterous insect pests and diseases in cabbage.

Field trials were conducted during summer 2011 at three locations. The experiments were conducted in randomized block design with 5 modules (Table 1), each replicated four times. About one month old seedlings of cabbage (cv. Varun) were transplanted during the third week of March 2011 at a spacing of 45 cm x 30 cm in plots of 3.15 x 2.70 m. Each module received two sprays of pesticide and the sprays of insecticides and/or fungicides under each module were initiated after about 45 days of transplanting and second subsequent spray was given as per the modules. Data on the incidence of lepidopterous larvae i.e. the larvae of cabbage butterfly (*Pieris brassicae)*, diamondback moth (*Plutella xylostella*) and cabbage semi-looper (*Plusia orichalcea*) were recorded on 10 plants per plot and on the disease incidence viz. alternaria blight caused by *Alternaria alternata* and black rot caused by *Xanthomonas campestris* were recorded from the entire plot at one- day before and 15 days of each spray. Data were also recorded on the plants formed heads and did not form the heads, marketable and unmarketable heads due to

Table 1. Pest management modules evaluated on cabbage

M_1	2- spray schedule consisting of spraying with lambda- cyhalothrin @ 0.004% (Bravo 5%) after 45 days of transplanting followed by the second spray of mixture of lambda-cyhalothrin @ 0.004% (Bravo 5%) and difenconazol @ 0.02% (Score 25 EC) after 15 days of 1^{st} spray
M_2	2 spray schedule consisting of spraying with azadirachtin @ 5ml L^{-1} (Neembaan 0.15%) after 45 days of transplanting followed by the second spray of mixture of azedarachtin @5ml/L (Neembaan 0.15%) and difenconazol @ 0.02% (Score 25 EC) after 15 days of 1^{st} spray. Mechanical destruction of infested leaves for egg clusters/ young larvae of cabbage butterfly at frequent intervals.
M_3	2 spray schedule consisting of spraying with lambda-cyhalothrin @ 0.004% (Bravo 5%) after 45 days of transplanting followed by the second spray of mixture of malathion (0.05%) and zineb @ 0.25% (Dithane Z78) after 15 days of 1^{st} spray.
M_4	2 spray schedule consisting of spraying with azadirachtin @ 5ml/L (Neembaan 0.15%) after 45 days of transplanting followed by the second spray of mixture of Btk (15g/10 L) and zineb @ 0.25% (Dithane Z 78) after 15 days of 1^{st} spray. Mechanical destruction of infested leaves for egg clusters/ young larvae of cabbage butterfly at frequent intervals.
M_5	Control (No treatment)

insect/ disease attack. Yield was recorded on whole plot basis. Economics of different pest management modules was calculated on the basis of market price of cabbage and pesticides and net return (Rs ha^{-1}) of each module was calculated. Data of all the three sites were pooled. The crop was raised by adopting recommended practices (CSKHPKV,2010). Four modules were evaluated against a control for insect-pest and diseases of cabbage (Table 1).

All the modules were significantly superior to untreated control in protecting cabbage crop from lepidopterous insect pests and diseases (Table 2). Among the lepidopterous insects, larvae of *Pieris brassicae* were the main pest along with larvae of diamond back moth, cabbage semi- looper and fruit borer. The pre-treatment population of lepidopteron insect pests varied between 39.97 to 43.17 per 10 plants in all the modules and per cent plant infestation with these larvae varied between 41.25-48.83. The module M_3 was the most effective IPM strategy against lepidopteron insect pests and diseases resulting in hundred per reduction in larval population and plant infestation. This module also resulted in minimum alternaria blight severity with 5.32% (76.88% reduction over untreated control) and black rot incidence with 7.93% (68.55% reduction over untreated control). The present finding of better efficacy of the module M_3 in case of the control of lepidopteron insect pests is attributed to the spray of cypermethrin @ 0.0075% followed by the spray of malathion and these observations are more or less in conformity to those of Sharma *et al.* (2015) who reported two sprays of cypermetnrin @ 0.0075% for the control of leaf miner in pea to be highly effective. Vukovic *et al*. (2014) also reported synthetic pyrethroids like tau-fluvalinate and lambda cyhalothrin highly effective against lepidopterous caterpillars including *Pieris rapae* and *Plutella xylostella* infesting cabbage.

The present observations regarding of the superiority of Malathion (used as a 2^{nd} insecticide in M_3) find support from Rao and Lal (2001), who reported malathion as the most effective insecticide for controlling lepidopterous caterpillars, particularly *P. xylostella*. The present study revealed that better efficacy of the module M_3 in the management of alternaria blight attributed to spray with zineb and these findings are in agreement to those of Verma and Verma (2010) who *inter alia* reported this chemical to be effective against alternaria blight. Module M_3 was followed by M_1 for the control of lepidopteron insect pests and diseases like alternaria blight and black rot with 97.63 per cent reduction over untreated control, plant infestation (%) with these larvae as 3 per cent (91.11 % reduction over untreated control). This module M_1 also was also second best in the control of alternaria blight severity with 63.05% reduction over untreated control and black rot incidence by 53.95%.

Highest percentage of marketable heads (86.89%) were formed in case of M_3 followed by M_1 (84.13), whereas, in untreated control, significantly lowest marketable heads (69.01%) were formed. The proportion of plants that failed to form heads due to insect infestation and disease incidence was minimum in M_3 (6.06 and 4.47%) followed by M_4. Marketable yield, in all the IPM modules was significantly higher than in control. Among the modules, highest marketable yield (370.48 q ha^{-1}) was obtained from M_3.

Table 2. Incidence of lepidopterous larvae and diseases on cabbage

Modules	Pre-treatment larval incidence		Post – treatment larval incidence		Plant infestation (%) with lepidopterous insects		Disease incidence			
	No. of larvae** per 10 plant)	Plant infestation** (%)	No. of larvae per 10 plant*	Reduction over control	Plant infestation* (%)	Reduction over control	Alternaria blight* severity (%)	Reduction over control	Black rot* incidence (%)	Reduction over control
M_1	41.25 (39.94)	44.58 (41.86)	0.50 (1.18)	97.63	3.00 (1.90)	91.11	8.50 (3.07)	63.05	10.82 (3.43)	53.95
M_2	39.97 (38.68)	41.25 (39.94)	2.53 (1.81)	88.04	5.00 (2.29)	85.18	9.39 (3.18)	59.19	11.33 (3.50)	51.78
M_3	43.17 (40.57)	42.58 (40.70)	0.00 (1.00)	100.00	0.00 (1.00)	100.00	5.32 (2.50)	76.88	7.93 (2.98)	68.55
M_4	41.80 (39.77)	47.91 (43.78)	1.25 (1.43)	94.04	5.41 (2.38)	83.97	11.22 (3.49)	51.23	12.29 (3.64)	47.70
M_5	39.97 (38.68)	48.83 (44.31)	21.16 (4.37)		33.75 (5.88)		23.01 (4.89)		23.50 (4.94)	
CD (p=0.05)	NS	NS	(1.40)		(0.96)		(0.44)		(0.37)	

Figures within the parentheses are: * $\sqrt{n+1}$ transformation and ** arc sine transformation

Table 3. Effect of different pest management modules on the yield attributes, yield and economics of cabbage

Modules	Plants with head formation (%)	Plant (%) that did not form the heads	Marketable heads (%)	Unmarketable heads (%) due to		Average marketable yield (q ha^{-1})	Increase in yield over control (%)	Net additional return (Rs. ha^{-1})	Net return per Rs. invested
				Insect attack	Disease incidence				
M_1	96.11 (9.85)	3.89 (2.21)	84.13 (9.22)	8.78 (3.09)	6.23 (2.66)	362.48	34.92	60,562.33	13.17
M_2	96.62 (9.88)	3.38 (2.09)	79.50 (8.97)	10.31(3.31)	7.24 (2.85)	326.43	21.50	40,864.67	6.52
M_3	97.96 (9.94)	2.04 (1.74)	86.89 (9.37)	6.06 (2.64)	4.47 (2.31)	370.48	37.89	65,707.67	16.26
M_4	96.41 (9.86)	3.59 (2.14)	83.77 (9.20)	7.66 (2.90)	5.96 (2.61)	328.36	22.22	42,606.22	7.80
M_5	95.47 (9.82)	4.53 (2.35)	69.01 (8.36)	15.47 (4.00)	9.80 (3.24)	268.66	-	0.00	0.00
CD (p=0.05)	NS	NS	(0.22)	(0.52)	(0.29)	37.51			

Figures within the parentheses are: $\sqrt{n}+1$ transformation

However, it did not differ significantly from M_1 which recorded yields of 362.48 q ha^{-1}.

The highest net additional returns of Rs. 65,707.67 and net returns per rupee invested (16.26) were recorded in case of module M_3 followed by M_1, which recorded net additional returns of Rs. 60,562.33 and net returns per rupee invested as 13.17 (Table 3).

Module M_3 consisting of spraying with lambda-cyhalothrin @ 0.004% (Bravo 5%) followed by mixture of malathion (0.05%) and zineb (Dithane Z 78) @ 0.25 after 45 and 60 days of transplanting respectively, was the most effective in protecting the cabbage crop from insects and diseases.

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Evaluation of Newer Insecticides for Predator Management of *Kerria lacca* (Kerr)

Sandeep Kumar Janghel, Moni Thomas, A. S. Thakur and Sushma Nema
Directorate of Research Services, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004, India
E-mail: sandeepthkr43@gmail.com

Abstract: Field evaluation trial of new insecticides for predator management of *Kerria lacca* (Kerr) was carried out on the natural stand of *Butea monosperma* trees. A combination of Cartap hydrochloride + Mancozeb (75 WP), Emamectin benzoate + Mancozeb (75 WP) and control was evaluated against common predator of *K. lacca*. There was significant difference in the mean weight of sticklac among Cartap hydrochloride + Mancozeb and Emamectin benzoate + Mancozeb. It was highest in Emamectin benzoate + Mancozeb (47.81g), control (39.74 g) co and Cartap hydrochloride + Mancozeb (36.74 g). Higher weight of stick lac yield from insecticide treated plants than control indicated that insecticides- Cartap hydrochloride and Emamectin benzoate are safe for *K lacca*. The mean fresh weight of 100 mature healthy lac cells obtained from the sticklac at harvest did not differ significantly among three treatments. The mean weight of 100 mature lac cells was highest (4.08 g) in Emamectin benzoate + Mancozeb followed by 4.04 g in Cartap hydrochloride + Mancozeb and control (3.66g). The brood lac yield per *B. monosperma* tree was highest (6.72 kg tree^{-1}) in Emamectin benzoate + Mancozeb, followed by (5.68 kg tree^{-1}) Cartap hydrochloride + Mancozeb and control (4.96 kg tree^{-1}). Cartap hydrochloride and Emamectin benzoate were safe for lac insects.

***Key Words*:** Broodlac, New insecticides, *Rangeeni,* Sticklac

Lac is a commodity of commmerce and export and produced by lac insect *Kerria lacca.* Lac production is also an important additional income generation activity of over 18000 lac growers in Seoni districts (Janghel *et al.,* 2014a). The mean net returns of lac from 50 *B. monosperma* trees and 50 *Zizyphus mauritiana* trees were Rs 32,285 and Rs 58,480 (Shah and Thomas, 2015). *K. lacca* is susceptible to parasites and predators (Sharma *et al.,* 2006) and can cause Lac yield loss varying from 5-10 percent and 35-40 percent respectively (Jaiswal, 2008; Khobragade *et al.,* 2012; Kumari *et al.*, 2012). Application of pesticides-Emamectin benzoate and Cartap hydrochloride reduces the incidence of predators- *Eublemma amabilis* and *Psuedopypatatopa pulverea* by 90 and 86.18%, respectively over the control (Janghel *et al.,* 2014b). Insecticides application for predator management in lac crop is not a general practice. However, predator management in *Rangeeni* lac increases the cost: benefit ratio upto 1:6.05 (Janghel *et al.,* 2014b). Patel *et al.* (2014) reported an increase the yield of *kusmi* lac upto 29.82 per cent while that in *Rangeeni* lac it was 29.67 per cent due to predator management by pesticides. The present work was to study the evaluation of new insecticides for predator management of *Kerria lacca* (Kerr).

Experimental details: The study planned under randomized block design with 10 replications (10 women lac growers) and 3 treatments [spray of insecticides-cartap hydrochloride 50 SP; emamectin benzoate in combination with fungicide Mancozeb M-45 at 30 and 60 days after broodlac inoculation (BLI) and untreated control] . *B. monosperma,* which are over five years old, healthy, pruned and possessed sufficient succulent branches were selected for the study. The major operations during the experiment were as mentioned in Table 1.

Table 1. Major operations and its period

Operation	Period
Pruning of *B. monosperma*	March , 2012
Brood preparation, grading and bundling	15th July,2012
Brood lac inoculation	19th July to 20th July, 2012
Date of *phunki* removal	14th August to 16th August, 2012
Date of first spray of pesticides	24th August to 26th August, 2012
Date of second spray of pesticides	20th September to 21th September, 2012
Harvesting of Broodlac	9th November to 11 th November, 2012

Depending on the size of the tree, healthy and quality broodlac weighing 500g to 1000g were used per *B. monosperma* tree for inoculation. The brood lac were divided into six to seven bundles for its inoculation in the July 2012. After 7 to 8 days of the inoculation process, the broodlac bundles were carefully shifted to different branches on the same tree. This was to ensure uniform distribution of the brood on branches where there was no or insufficient larval settlement. Larvae of lac insect from broodlac settle on the branches of the host tree in a period of three weeks of its inoculation. The broodlac without brood called *phunki*, is infact sticklac. *Phunki* usually consists of predators, removed after 21 days of broodlac inoculation and scrapped to recover raw lac. This process removes or reduces the predator load.

The solution of pesticides was prepared by adding its desired quantity (@1g of cartap hydrochloride litre^{-1} of water + 2.5g Mancozeb litre^{-1} of water and in case of Emamectin benzoate@ 0.4g litre^{-1} of water + 2.5g Mancozeb litre^{-1} of water) in a small container followed by brisk stirring with a piece of stick. Two sprays were applied, one between 30-35 days of BLI and second spray at 60-65 days after BLI.

Observations: At the maturity of the lac crop, three-stick lac (twigs of host plants with mature lac encrustations) was randomly harvested from each of the *B. monosperma*, each measuring 30 cm in length for post harvest observations. The weight of 30cm sticklac was measured on digital balance to record difference in weight in different treatments. One hundred mature lac cells (each lac insect secretes resin body cover to protect itself) from different treatments were recorded in both fresh and shade dry stages. Finally the yield of broodlac per tree was recorded.

The mean weight of sticklac was highest (47.81g) in Emamectin Benozoate + Manzozeb followed by that (39.74g) in control and Cartap hydrochloride +Manzozeb (36.74g). There was no significant difference in the mean weight of the 30cm sticklac among the treatments. The mean fresh weight of 100 mature healthy lac cells obtained from the sticklac at harvest did not differed significantly among three treatments. The mean weight of 100 mature lac cells was highest (4.08 g) in Emamectin benzoate + Dithane M-45, followed (4.04 g) Cartap hydrochloride + Dithane M-45 and Control (3.66).

Patel *et al.* (2014), reported that the mean fresh weight of Kusmi 100 cell of lac insect was the highest (4.88 g) with two sprays of Cartap hydrochloride + Dithane M-45 (at 30 and 70 day after BLI), while it was 3.61g with lac growers practices i.e., no use of pesticides, in case of Rangeeni lac it was 3.38 g with two sprays of Cartap hydrochloride + Mancozeb and 2.97g in control.

Mean dry weight of 100 lac cells: The mean dry weight of 100 healthy cells of lac insect obtained seven days after shady drying varied from 2.24 g (control) to 2.43 g (Cartap hydrochloride + Mancozeb) and 2.54g (Emamectin benzoate + Mancozeb). Though there was difference among three treatments but was not significant. The mean dry weight (g) of 100 lac cells of lac insect in nutrient managed *Z. mauritiana* reported by Namdev *et al.* (2015) varied from 5.18 to 7.08g. The finding revealed that pesticide application minimized the avoidable losses due to predators and parasites. Emamectin benzoate + Dithane M-45 and Cartap hydrochloride + Dithane M-45 was found safe for lac insect. Thus, both these insecticides can be recommended for predator management on lac production. However, Emamectin benzoate is better. Even Bhattacharya *et al.* (2005) reported that all the three doses (0.05, 0.075 and 0.1%) of CHC safe to the lac insect and effectively controlled of *E. amabilis* and consequently increase in lac crop yield.

Yield of broodlac: The mean broodlac per *B. monosperma* tree was highest (6.72 kg tree^{-1}) in Emamectin benzoate + Mancozeb, followed by 5.68 kg tree^{-1} with Cartap hydrochloride + Mancozeb and control (4.96 kg tree^{-1}). There was a significant difference in the mean broodlac per *B. monosperma* tree among the treatments. Earlier workers reported yield loss due to predator and parasites by 35.36 % (Khobragade *et al.,* 2012) and 40% (Bhattacharya *et al.,* 2007). Parasitisation during rainy season crop adversely affected, fecundity and resin production capability of two strains i.e. Kusmi and Rangeeni of *K. lacca* (Sharma and Ramani, 2001). The present findings are not in agreement with the findings of Sharma *et al.* (2005), where low brood to yield ratio was recorded. In this study, the ratio of broodlac to brood yield was 1:7.57 (Cartap hydrochloride + Mancozeb), 1:8.96 (Emamectin benzoate + Mancozeb) in comparison to 1:6.61 in control. Pal *et al.* (2010) reported yield gap of 38 per cent on *B. monosperma*. In the present case, the yield gap

Table 2 . Consolidated data of Lac under insecticide evaluation

Treatments	Mean			
	Weight (g) of 30 cm of sticklac	Fresh weight (g) of 100 lac cells	Dry weight (g) of 100 lac cells	broodlac yield (kg) per tree at harvest
Cartap hydrochloride (50SP)+ Dithane M-45 (75 WP)	36.74	4.04	2.43	5.68
Emamectin benzoate (5SG) + Dithane M-45 (75 WP)	47.81	4.08	2.54	6.72
Control (Lac growers practices i.e. no use of insecticides)	39.74	3.66	2.24	4.96
CD (p=0.05)	7.06	0.47	0.29	0.76
SEm±	2.38	0.16	0.10	0.26

between control and Cartap hydrochloride + Mancozeb was just 12.67 per cent, while between control and Emamectin benzoate + Mancozeb was 26.19 per cent.

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Influence of Climatic Factor on Population Dynamics of Mustard Aphid *(Liphaphis Erysimi* Kalt.) On Brasica Cultivars in Madhya Pradesh

Dharvendra Singh, Swati Singh Tomar, Reena Sharma and S. V. S. Chauhan

RVSKVV, Krishi Vishwavidyalaya , Krishi Vigyan Kendra, Morena-476 001, India
E-mail: dharvendrasingh56@gmail.com

Abstract: The field experiment was conducted on seven different popular cultivars of rapeseed–Mustard. The peak level of aphid population was recorded during of 4th week of December to 2nd week of March. Aphid density was positively associated with maximum as well as minimum temperature while it showed a negative correlation with relative humidity. The aphid *Liphaphis erysimi* (Kalt.) population during showed positively correlated with the rainfall and negatively correlated with aphid population. It was observed that during the establishment phase the rainfall and relative humidity were negatively correlated whereas temperature was positively correlated while during the declining phase. Temperature is not positively correlated with aphid population.

***Key Words*:** Aphid, *Brassica* sp., Climate, *Liphaphis erysimi*, Mustard, Rapeseed, Temperature, Weather

Rapeseed-Mustard is the most important oilseed crop of Morena District in Madhya Pradesh India. It is grown rain fed as well as irrigated condition. The yield of mustard crop in Morena district is very low pest. The mustard aphid (*Liphaphis erysimi* Kalt.) is one major limiting factor for low yield Aphid present throughout the year in the field and its population reached to peak during December to February. It infests mustard at vegetative, flowering and pod stage. Environmental factor such as temperature, relative humidity, rainfall and total sunshine usually influence the insect population. Therefore, the present study was undertaken to observe the population dynamics of mustard aphid in relation to weather.

The climate of the experimental area Morena is characterized as semi arid with extreme hot and cold period during May-June (49-50°C Maximum and 1-2°C minimum temperature). The weather is generally dry except during monsoon. The mean annual rainfall is 750 mm mostly concentrated during the month of July, August and winter rains are scanty and occasional. The field experiment was conducted in Rabi crops 2010-11 and 2011-12 on seven different cultivars of Rapeseed–Mustard at RVSKVV, Krishi Vigyan Kendra, The variety viz. JM-4, Rohini, NRCDR-2 belong to *Brassica juncea* L. and Bhavani, JT-1, PT 303 belong to *Brassica compestris L.* and local cultivars represented *Brassica compestris* variety and sowing was done last Week of October and Ist week of November during 2010 and 2011 in 4x3 m^2 plot at a spacing of 30x10 cm in randomized block design with three replication.The recommended agronomic practices were followed in raising the crops. No of plant protection measure was taken throughout the crop season. Observations on mustard aphid population were recorded at weekly interval from the initial appearance to final disappearance of the pest by removing aphid from 10 cm top portion of the terminal shoot on a white paper sheet with the help of removing brush. The aphid populations were influenced by weather factor meteorological parameters viz. temperature, relative humidity and rainfall, etc. Simple correlation coefficient were worked out between the weather parameters and mean aphid population on *Brassica* varieties.

The aphid infestation of (*Brassica compestris* L. and *Brassica juncea* L.) variety year 2010-11, 2011-12 was recorded on Standard meteorological week (SMW) 52nd. The peak of aphid infestation on all varieties of *Brassica juncea* was on 7th SMW. In case of Indian mustard such as NRCDR-2 and JM-4, population of aphid reached the peak level on SMW 8th and 9th. The first aphid infestation was noticed during first week of January. The highest aphid population 161.87 $plant^{-1}$ was observed in the third week of January and declined gradually. The ambient minimum and maximum temperature 12.71°C and 25.14°C and relative humidity 91.28% might be favorable for increasing aphid population (Rasid *et al.,* 2007). Whereas, in Rohini, the peak level of aphid was observed too early on SMW 1st. On the local varieties, aphid population reached its peak on SMW 4th. Initiation of aphid infestation was recorded on SMW 3rd (Table 1). Experiment data from six north Indian locations were used to study the role of weather on the incidence and development of mustard aphid, temperature was found to regulate the aphid appearance and population build–up. In warm humid climate, time to attain peak population was

Table 1. Population of *Liphaphis erysimi (Kalt*). on *Brassica* cultivars during experiment period 2010-11 and 2011-12

SMW*	NRCDR-2	JM-4	Rohini	JT-I	PT-303	Local	Temperature		RH %		RF (mm)
							Max.	Min.	Morning	Evening	
52	0.30	0.58	0.2	1.25	3.20	6.60	26.5	5.8	86.2	72.6	0
1	15.32	18.71	39.0	12.20	16.6	5.78	17.3	5.4	83.6	73.0	0
2	14.25	8.95	25.62	8.45	12.0	6.20	20.1	5.4	90.8	75.3	1.0
3	7.01	0.34	18.92	6.40	3.45	14.0	21.2	5.4	90.2	73.0	0
4	2.50	0.37	6.95	48.2	10.20	50.2	21.5	5.7	83.1	63.7	0
5	0.56	7.25	11.95	63.02	26.9	31.2	22.6	6.5	83.4	65.8	0
6	5.92	5.23	7.93	65.2	52.20	20.8	21.8	7.7	77.5	65.0	3.0
7	6.93	13.02	10.98	72.0	63.0	9.79	23.3	8.8	78.2	60.0	0
8	13.92	44.2	9.52	18.6	64.0	7.23	25.8	10.9	73.9	60.1	0
9	38.20	42.1	26.0	27.1	32.90	0.6	29.8	11.3	75.3	58.8	0
10	18.94	19.0	10.30	0	15.0	0	30.2	12.6	75.4	60.1	0
11	12.96	8.50		0	0		32.9	13.4	79.2	65.0	0

*SMW = Standard meteorological week

Table 2. Correlation coefficient between aphid population and weather parameters during 2010-11 and 2011-12

Brassica cultivars	Weather parameters				RF (mm)
	Temperature		RH %		
	Maximum	Minimum	Maximum	Minimum	
NRCDR-2	0.568	0.580	0.241	-0.503	0.035
JM-1	0.758*	0.745	0.345	-0.523	0.582
Rohini	0.145	0.280	0. 035	-0.112	0.054
Bhawani	0.843*	0.421	0.305	-0.491	-
JT-1	0.902*	0.504	0.25	-0.630	--
PT-303	0.860*	0.575	0.341	-0.694	-
Local	0.220	0.575	0.091	-208	-

* ,** Significant at 5, 1% level, respectively

relatively shorter than in cool climates. Functional relation proposed in the present investigation between aphid incidence and population, using previous week's weather and pest data for majority of the location (Rao *et al.,* 2014). High cloudiness, relative humidity and dew point favoured the aphid population and slight rainfall quickly declined the aphid population. Data indicated that the population dynamics of mustard aphid on seven popular rapeseed - mustard cultivars. The incidence of aphid commenced from 52 and 2nd SMW a very low population level on all the cultivars. Chaudhary *et at.* (2009) also recorded the peak level from SMW 9th in the mustard aphid (*Liphaphis erysimi* Kalt). Aphid population activity peak period remained confined to January and first fort night of February. The correlation coefficient between aphid population and climatic factor could not establish a clear trend (Table 2). The peak level of aphid population was recorded during the beginning of 4th week of February to 2nd week of March. Aphid density was positively associated with maximum as well as minimum temperature while it showed a negative correlation with relative humidity but positive correlation with the rainfall. It was observed that during the establishment phase, the rainfall and relative humidity were negatively correlated, whereas, temperature was positively correlated. It is assumed that for a major part of rabi season climatic parameters remained conductive for the rapid multiplication of the aphid moreover, the degree of infestation and the rates of population change of the aphid on different variety seemed to be governed by varietal characteristics on every variety. Aphid population reached peak level at flowering stage. The variety JT-1 harboured highest population during both season followed by PT-303. It was further observed that *Brassica compestris* varieties have relatively higher population of aphid than *Brassica juncea*.

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Weed Density and Dynamics of Weeds of Soybean [*Glycine max (L.)* Merrill] as Influenced by Crop Configuration and Weed Management

Sita Naik and R. Lakpale

College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur-492 012, India
E-mail: sita.naik108@gmail.com

Abstract: Field experiment was conducted to find out the appropriate crop configuration and weed management of soybean (*Glycine max* L. Merrill). Lowest population and dry matter production of weeds were observed under cross sowing of soybean 30 cm apart and two hand weedings at 20 and 40 DAS. *Digeria arvensis, Comellina benghalensis, Convolvulus arvensis, Echinocloa colonum, Cynodon dactylon and Cyperus rotundus* were the dominant weeds throughout the crop growth period. The lowest weed density, lower weed growth rate and highest weed control efficiency over the chemical control were recorded under imazethapyr @ 50-60 g ha^{-1}.

Key Words: Crop configuration, Soybean, Weed density, Weed dynamics

Intensive weed competition is one of the important constraints for low productivity in soybean. Weed in soybean at early stage of crop growth is critical, as it causes yield losses up to 35 to 50%. Hand-weeding is difficult due to continuous rainfall and lesser availability of laborers at the critical stage of crop–weed competition. Use of herbicides not only improves crop yield but also makes available significant laborers for other productive activities. However, herbicides alone may fail to give satisfactory control of weeds because of their short period of persistence, late emerging and the resistant weeds cause severe reduction in crop yield. Therefore, alternation in crop geometry of varieties by way of manipulation of inter- and intra-row spacing, without changing plant density, particularly in high plant density crops like soybean may also play important role in smothering weeds and increasing the crop productivity. Narrow crop row spacing in soybean can be an effective part of an integrated weed management strategy (Shwan *et al.,* 2005).The present investigation was therefore undertaken to study the weed density and dynamics of weeds of soybean as influenced by crop configuration and weed management.

The experiment was conducted during rainy (*kharif*) 2014 at Raipur (Chhattisgarh). The soil of the experimental field was clayey in texture (*Vertisols*) with low in available N (219.7 kg ha^{-1}), medium in P (13.8 kg ha^{-1}) and high in K (365.31 kg ha^{-1}). The experiment was laid out in split plot design with four crop configuration as main-plot and four weed management practices as sub-plot with three replications and plot size 4.20 m^2. The crop configurations were broadcasting method of sowing, cross sowing of soybean 30 cm. apart, closed space sowing 20 cm row apart and recommended spacing of sowing (30 cm) row apart and the weed management practices selected for study were pendimethalin @ 1 kg ha^{-1} as pre-emergence, imazethapyr @ 50-60 g ha^{-1} post emergence, two hand weeding at 20 and 40 DAS and control (weedy check). Soybean 'JS 93-05' was sown @ 65 kg ha^{-1} on 4 July along with fertilizer dose of 25 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1}. Pendimethalin was applied on the next day of sowing, while imazethapyr was applied 20 days after sowing. The data on species-wise weed density and weed dry matter were recorded at 30, 60 days after sowing and at harvest. Weed control efficiency and weed index were calculated.

Crop configuration in soybean show significant effect on total dry matter and density of weeds, seed and straw yield. The maximum weed population and dry matter were in broadcasting method of sowing, whereas, it was the lowest in cross sowing of soybean 30 cm apart. Cross sowing of soybean 30 cm apart showed highest weed-control efficiency (WCE) of 72.54%. The closed space sowing 20 cm apart treatment showed the highest weed index (30.54%) as weeds caused greater reduction in plant dry weight and seed yield/plant. However, weed index was the lowest (6.15%) and seed yield was maximum in cross sowing of soybean 30 cm apart which was significantly superior to other crop configuration treatments.

Important weed flora infesting soybean crop during the study period included *Commelina benghalensis* L., *Convolvulus arvensis* and *Digeria arvensis* L. among broad leaf weeds; and *Echinochloa colonum* (L.) Link, *Cynodon dactylon* (L.) Pers. and *Cyperus rotundus* (L.), Pers. among grassy weeds. All the weed management treatments

Table 1. Effect of crop configuration and weed control measures on weed density and weed dry matter

Treatments	Density of total weeds (No. m^{-2})			Dry matter of total weeds (g m^{-2})		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Crop configuration						
Broadcasting method of sowing	5.30 (38.90)	5.70 (42.30)	4.80 (30.20)	3.60 (18.50)	3.90 (20.80)	4.70 (29.90)
Cross sowing of soybean 30 cm apart	4.40 (27.80)	4.40 (26.90)	4.20 (23.10)	3.00 (12.90)	3.20 (14.50)	3.80 (20.90)
Closed space sowing 20 cm apart	5.10 (35.80)	5.30 (37.60)	4.60 (27.70)	3.50 (16.80)	3.60 (18.60)	4.40 (27.40)
Recommended spacing of sowing (30 cm)	4.80 (32.90)	5.00 (34.40)	4.30 (24.40)	3.40 (16.20)	3.40 (16.40)	4.20 (24.70)
CD (p=0.05)	0.23	0.01	0.01	0.01	0.01	0.02
Weed management practices						
Pendimethalin @ 1 kg ha^{-1} as pre emergence	6.20 (39.00)	6.10 (37.00)	3.80 (14.60)	4.30 (18.00)	4.00 (16.30)	3.80 (14.40)
Imazethapyr @ 50-60 g ha^{-1} as post emergence	3.30 (10.70)	2.90 (8.00)	3.10 (9.60)	2.00 (3.70)	1.70 (2.50)	2.70 (7.10)
Two hand weeding at 20 and 40 DAS	0.90 (0.46)	1.80 (3.00)	2.10 (4.10)	0.78 (0.10)	1.20 (1.10)	1.90 (5.20)
Control (weedy check)	9.20 (85.30)	9.60 (93.20)	8.80 (77.10)	6.50 (42.60)	7.10 (50.50)	8.70 (76.20)
CD (p=0.05)	0.18	0.008	0.01	0.01	0.01	0.01

Figures in the parentheses are original values; data were transformed through $\sqrt{x}$+0.5 which are given in bold

Table 2. Effect of crop configuration and weed control measures on weed control efficiency and weed index and yield of soybean

Treatments	Weed control efficiency (%)	Weed index (%)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Crop configuration				
Broadcasting method of sowing	60.72	24.52	1668	1692
Cross sowing of soybean 30 cm apart	72.54	6.15	2074	2094
Closed space sowing 20 cm apart	64.04	30.54	1535	1577
Recommended spacing of sowing (30 cm)	67.56	15.79	1861	2078
CD (p=0.05)			51.22	132.70
Weed management practices				
Pendimethalin @ 1 kg ha^{-1} as pre emergence	81.01	20.49	1757	1796
Imazethapyr @ 50-60 g ha^{-1} as post emergence	90.67	7.82	2037	2080
Two hand weeding at 20 and 40 DAS	93.17	-	2210	2252
Control (weedy check)	-	49.90	1107	1314
CD (p=0.05)			33.40	117.70

Figures in the parentheses are original values; data were transformed through $\sqrt{x}$+0.5 which are given in bold

significantly reduced total weed dry matter compared with the weedy check. The lowest number of weeds and dry matter was under the treatment 2 hand weedings, because this treatment resulted in broad-spectrum weed control. The maximum weed control efficiency (93.17%) was obtained with 2 hand weedings followed by imazetapyr @ 50-69 g ha^{-1} as post emergence followed by pendimethalin @ 1.0 kg ha^{-1} as pre emergence revealed that the former treatment was more effective in controlling weed than the latter ones. The weedy check (control) showed the highest weed index (49.90%), due to the fact; there was minimum seed yield under this treatment due to high infestation of weeds at critical crop weed competition period, which reduces the availability of yield components. However, minimum weed index (7.82%) was registered under in treatment imazethapyr @ 50-60 g ha^{-1} as post emergence. All the weed-control treatments produced significantly higher seed and stover yield than the weedy check. Two hand weeding produced the maximum seed yield, among herbicides, Imazethapyr @ 50-60 g ha^{-1} as PoE gave highest value. These highest levels of yield were due to weed managed from early crop growth stage. The present findings corroborate the findings of (Kushwah and Vyas, 2005 and Pandya *et al*., 2006).

Thus, the soybean crop should be sown in cross sowing at 30 cm apart to obtain higher productivity. Weed management by 2 hand weedings or imazethpyr gave higher yield. However, total reliance on hand weeding does not appear practical due to non-availability of labour at peak time of demand on large scale. Therefore, post emergence application of imazethapyr is recommended.

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Letting Information Flow: Distributing Farmer Training Videos Through Existing Networks

Paul Van Mele[1,2], Jeffery Bentley[2], Md. Harun-ar-Rashid[3], Florent Okry[1] and Tom van Mourik[4]

Access Agriculture[1], Agro-Insight[2], Agricultural Advisory Society[3], Helen Keller International[4]
Grote Baan 24, 3670 Meeuwen-Gruitrode, Belgium
E-mail: paul@accessagriculture.org

Abstract: Most projects can distribute videos and other farmer learning material easily by paying to have it done. But organisations that do not have projects need to identify actors who can distribute learning videos for free. The authors and colleagues engaged with actors in various countries, from radio stations in Benin to tea stalls in Bangladesh. We gave them free DVDs, with farmer learning videos, and encouraged the actors to find their own ways of sharing the information. Later we went back for follow-up visits. Experiences from five countries show the power of distributing farmer training videos through existing social networks. In Benin, radio stations broadcast sound tracks and distribute DVDs. In Uganda and Bangladesh many private and public agencies show videos. In Mali, farmers and NGOs often screen videos under difficult circumstances. Malawi has a burgeoning rural business with young "DJs" copying videos from a computer onto ordinary cell phones. In all five countries, volunteer service providers helped farmers to access training videos, because the content was relevant, of good quality and the videos were in the enlightened self-interest of the farmer and the agency.

Key Words: Farmer learning videos, ICT, DVDs, Rural advisory services, Farmer experiments

Rural telecentres (public places where people can access computers, and the internet to send and receive information) were once seen as the best way to enable communities to access information, but due to lack of funding, weak demand, and irrelevant content many have stopped functioning after development projects ended. The need to be self-supporting has often forced the telecentres to drop their initial objective of supporting socio-economic development and social inclusion, in favour of selling goods and services (sometimes unsuccessfully). The failure of many telecentre initiatives is also partly due to Western assumptions that hardware alone would suffice. However, the focus of ICT-based interventions is gradually shifting from hardware (e.g. setting up telecentres) to software (e.g. processes and content management).

Access to ICT must be adaptable and flexible enough to ensure that useful knowledge is made available at the right place and time (Glendenning and Ficarelli, 2012). Unless the ICT content is useful, even the best ICT tools may make little impact. For example, the "Open Knowledge Network," with nearly 200 telecentres in Africa and South Asia, failed because the content was supply-driven and did not meet demand for local content.

Many continue to believe that it is sufficient to use outside knowledge while ignoring local knowledge and social dynamics. Indeed, knowledge from the industrialized world may do little to trigger appropriate change in the South. As Charlotte Scarf says digital content initiatives are founded on the understanding that connectivity will be meaningless for the world's poorest people who will find very little information of relevance to their lives and almost nothing in their own language in the absence of a complementary investment in digital content creation.

Agricultural extensionists broker information between mainly Western-based and local knowledge systems, but the quality of their interactions is highly variable. The more extension is driven by demand, the more extensionists need to widen their own expertise and search for new information. One in six extension agents in developing countries uses YouTube or Google to find agricultural videos, but cannot find what they are looking for or are distracted by the overload of irrelevant videos (this 2013 scoping study is available at www.agroinsight.com). Most of the videos that extensionist are exposed to are based on Western knowledge and in the languages of Western Europe.

Farmers more readily accept ideas from other farmers, yet more complex knowledge is less easily communicated between farmers and often does not spread beyond the village where the training was held. Farmer-to-farmer videos can be made according to the zooming-in, zooming-out method, which identifies problems that have a broad geographical relevance, then zooms in on solutions which are scientifically sound and which have been used by real farmers (who show their innovations and explain them on the video). The innovations are then "zoomed out" to a large audience via videos competently translated into various languages. Zooming-in, zooming out can help to communicate complex ideas in easy-to-understand ways and overcome the challenge of scale, because they stimulate the learning and adapting of ideas to local contexts .

Organisations have used different models to produce and use videos, often blinded by a false assumption that farmers will only learn from videos that are made locally. This is especially prevalent among people trying out with participatory video models. It is too often assumed that "provision of content for farmers is more useful if it is location and context specific" . That can be true, but it is often taken to absurd extremes, such as suggesting that each speech community or each cluster of villages must have its own videos on its own variations of a theme. In fact, a video (like any extension message) is often relevant to a very wide area, e.g., the problems a poor household faces when storing rice seed are similar in Bangladesh or West Africa (Van Mele *et al*., 2013).

Farmers in developing countries like to learn from farmers in other developing countries. Farmers in south-western and northern Nigeria reacted positively to videos on rice seed health (made in Bangladesh), on parboiling (filmed in Benin) and rice cultivation (from Mali). The farmers criticized the videos freely, but had no preference for watching videos featuring West African or Bangladeshi farmers. The Nigerian smallholders only cared about the technical content of the film. However, a key question remains: how best to reach out to millions of smallholder farmers without having to make videos in every single village, or expecting farmers themselves to access videos directly from the internet? To draw a parallel to the entertainment industry, part of the success of Nollywood (Nigerian) films is that people can easily relate to the content and that the visuals are attractive . Although initially developed in major Nigerian languages only, English and French versions of Nollywood movies can now be found across sub-Saharan Africa.

The entertainment industry can also help to shed light on how best to reach large audiences. Unlike Hollywood movies, Nollywood and Bollywood mainly distribute by packaging many movies onto a single DVD (digital video disc), and selling these with very low margins through informal networks of local outlets and a dispersed body of mobile vendors. Nollywood videos have spread widely because of the flexibility of distribution through VCD and DVD (Bentley and Van Mele, 2011; Bentley *et al*., 2007).

To support agricultural extension in developing countries, a new knowledge broker called "Access Agriculture" was created in 2012, based in Nairobi, with an office in Cotonou, with over 200 professional collaborators. The international NGO Access Agriculture facilitates local language translations and distribution of videos through DVD and other formats via existing social networks. Drawing on examples from five countries, this paper explores the challenges and opportunities of an open system, non-project approach to scaling-up farmer training (for more details, see www.accessagriculture.org).

MATERIAL AND METHODS

Five experiences with video distribution are presented: one from East Africa, one from Southern Africa, two from West Africa and another from South Asia. The case studies share some similarities. The video discs contained multiple farmer-to-farmer training videos on rice cultivation, integrated striga and soil fertility management and conservation agriculture. The videos were high quality, locally appropriate and regionally relevant. All videos were made without subtitles and voiced in the farmers' own languages. The organisations that distributed the videos at the national level used public funds from development projects, whereas those further distributing and using the video discs at the grassroots level did this on their own initiative, without being paid to do so. Each group mobilized its own resources and social networks, resulting in different approaches (Table 1).

RESULTS AND DISCUSSION

Benin: mobilising entrepreneurship of local radio stations: Although the situation has changed over the past five years in West Africa, in 2009 video compact discs (VCDs) were far more widespread than DVDs. The growing popularity of Bollywood and Nollywood movies has triggered villagers to buy DVD players. In 2009, as a way to learn about distribution channels, the Africa Rice Center (AfricaRice) distributed about two thousand VCDs to 25 local radio stations across Benin. Some copies went to farmer organisations and extension services. This experience is one of the reasons Access Agriculture was started in 2012 (Dalohoun *et al*., 2009; Okry *et al*., 2014).

The videos were translated into five important local languages of Benin; Fon, Mina, Yoruba, Dendi and Bariba. Each VCD contained five or six rice videos in a local language. The videos were distributed according to the major local languages spoken in the area. When the language of a particular area was not available (Benin has over 70 languages and multi-lingualism is common), videos of a similar language were given to the radio stations.

Radio stations distributed VCDs in different ways as they felt that the videos were perfectly relevant to their area,

Table 1. Video distribution mechanisms tested in East Africa, West Africa and South Asia

Country	Number of video discs distributed	Organisation distributing videos at national level	Organisations distributing and using videos at local level	Key lessons learned
Benin	2500 VCDs	AfricaRice, an international research organisation	25 local radio stations	Radio stations use video to strengthen the agricultural knowledge of their staff and use the videos creatively to strengthen links with their communities Commercial radio stations sell videos to farmers and extension agents, whereas community radio stations distribute them for free, but could also sell video as a future source of income generation
Uganda	7500 DVDs	Farmers Media, a communication company	18 public and private sector service providers	Depositing boxes with hundreds of DVDs to an organisation may be ineffective without proper planning and monitoring Private sector value chain actors who see a direct benefit in strengthening farmers' skills play an important role in distribution and use of video
Bangladesh	1250 DVDs	The Agricultural Advisory Society, a national NGO in collaboration with CIMMYT	Over 300 tea stalls, NGOs, extensionists, community-based organisations, local government, local village shops and many others	Giving a few copies to many service providers creates a lot of local initiative to view and further share videos
Mali	10,000 DVDs	ICRISAT, an international research organisation	Over 300 NGOs, ministry of agriculture, local government and extension, radio stations, cooperatives, farmer field schools and many others	Carefully planning and following up helps to ensure that organisations use the DVDs. Farmer clubs and cooperatives find ways to watch quality training videos that are relevant, even if there is no electricity

even though they were filmed in Bangladesh, Burkina Faso and Mali, as well as Benin). The commercial radio station of Glazoué used persuasive advertisements to sell most of the 240 VCDs to farmers and extension agents, whereas the community radio stations distributed most VCDs free of charge. About 20% of all the VCDs were sold, suggesting that some farmers are willing to pay for informatio .

None of the nine radio stations surveyed organised village video shows, because they lacked equipment and travel money. But one third of the stations invited farmers to their stations to watch the videos. The video shows organised at three of the nine radio stations grouped on average 200 farmers.

Seventy eight per cent of the radio stations organized video sessions for their staff. During these sessions, which often coincided with the weekly planning meetings, radio staff selected several topics from the videos that reflected the interests and priorities of the rice producers of their area. They extracted parts from the videos as audio files, and aired them as such or used them to organise interactive thematic discussions, roundtables or quizzes.

The radio stations of Tanguiéta and Ouaké decided to play the audio tracks of the videos in slots dedicated to agricultural programmes and even in open slots. At the end of each session they announced that copies of the videos could be collected from their radio station. Staff of the radio stations of Tanguiéta even made the extra effort of visiting farmer organisations to hand over VCDs, distributing 100 copies free of cost. The training videos contributed to a better positioning of radio stations as partners in agricultural knowledge dissemination .

Local radio stations are under-studied, especially in Africa, where their audience, financing, sponsorship, and mandates are not yet fully understood and differ from one place to the next. All of the stations need money to cover their operational costs and when approached by an outside agency many think that there is money to be made. As this was the first time that local radio stations were approached with video content for farmers, many may not yet have realised that they could sell DVDs to earn income. Yet all of the radio stations were able to do something worthwhile with the videos.

In Benin, as in many countries, the producers of the DVDs were just getting to know some of the potential distributors. The challenge is to make the DVDs seem important enough that an organization will distribute them. In Benin, the video producers did not at first realize how crucial it was for the stations to make money, and the radio stations did not all understand that they could sell the DVDs (besides using the videos to generate content to broadcast). Simply telling the broadcasters during initial negotiations that it is OK to sell videos can be helpful.

Uganda: Value chain actors are more effective distributors than large development agencies: In Benin, Access Agriculture learned that radio stations alone would not reach all farmers. So in Uganda, they explored how effective different kinds of public and private-sector agricultural service providers were in showing and distributing videos to farmers. Eleven farmer-to-farmer learning videos made in Bangladesh and West Africa about growing rice, from seed to post-harvest, were dubbed into five major languages of Uganda (plus English, Swahili and French). These “Rice Advice” videos were copied onto a single DVD and in 2011 some 7,500 copies were distributed to 18 public and private-sector organisations in Uganda. Most of them received between 100 and 1000 DVDs.

As organisations are often rewarded for conducting projects, not for distributing information, some failed to properly distribute the videos. Some of the larger organisations did not give DVDs to their grassroots extension workers, or to farmers' associations. Instead, they handed out the DVDs as freebies at conferences and trade fairs. At least one organisation sold some DVDs, like the radio station in Benin, which suggests that encouraging a distributor to sell DVDs may be an opportunity to get the videos to people who want them enough to pay for them.

Some value chain actors are excellent distributors of training videos. For example, the rice millers quickly realized that the videos helped raise farmers' rice production and improve rice quality, so they made efforts to get videos into farmers' hands. As part of building farmers' trust, Upland Rice Millers has a dormitory room where farmers can sleep while they wait for their rice to be milled, and gives them free meals while they wait. Upland Rice Millers is a big operation, the second largest rice mill in Uganda (Katungi *et al*., 2008). When farmers get good prices and friendly treatment, they respond by telling their friends on their cell phones and by growing more rice. Farmers who used to bring two sacks of rice to Upland now bring in six. The manager of Upland Rice Mills explained that “The Rice Advice videos helped make this possible because the videos help the farmers produce more rice and better rice. When the farmers come to mill their rice, Upland Rice Millers shows them all 11 videos. It really helps that it's multilingual. There are 55 languages in Uganda, but everyone can understand at least one of the five major Ugandan languages on the DVD close parenthesis here.

The agro-input dealers and the Uganda Development Trust (UDET), a national NGO, also played significant roles in dissemination of technology and distributed 100 and 250 DVDs to paddy growers, respectively. This resulted in higher production of better quality.

In Uganda, as elsewhere, organisations are rewarded for completing projects, not for distributing DVDs, even when the videos fit the agencies' stated mandate. The challenge is to convince the organisation that the farmers need the DVD. There is an opportunity to distribute DVDs through private entrepreneurs, such as rice millers, who benefit as farmers' harvests improve, and through input dealers, who can give DVDs to customers to help build relationships. In the future, with large organisations (public or NGOs) there may be an opportunity for them to sell DVDs, or to help them craft a sound distribution plan.

Bangladesh: tapping into grassroots organisations and local entrepreneurs: The distribution of DVDs in Bangladesh was a big improvement, and was based mostly on small-scale, private-sector actors. In 2012, the International Maize and Wheat Improvement Center (CIMMYT) hired the NGO AAS (Agricultural Advisory Society) to show a video on strip tillage and bed planting for wheat and maize to farmers in southern Bangladesh. AAS showed the video on conservation tillage machinery in 332 villages through open air video screenings to over 85,000 farmers. AAS also distributed a DVD with the tillage video, but also with four other videos on rice seed health, which had been made in 2003 in Bangladesh with IRRI (International Rice Research Institute). AAS provided 1250 DVDs covering over 300 tea stalls, NGOs, community-based organisations (CBOs), custom tillage operators, input dealers etc.

A telephone interview by CIMMYT to those who had received a DVD revealed that 70% had shown the videos to farmers and 6% handed them over to others who had a DVD player. An in-depth non-random sample in two out of the four districts revealed a very similar figure: 80% of the community service providers voluntarily showed the videos to on average 100 farmers, so through the DVDs at least 100,000 farmers benefited.

Few of these community members were extensionists and each group showed the videos in its own way. The tea stalls showed the videos many times, but reached far more men than women. Some of the NGOs and CBOs did a better job of sharing the videos with women. Those who did not have DVD players (e.g. some of the shopkeepers, custom tillage providers and farmers' clubs) usually gave their copy of the DVD to someone else who did have a DVD player, who was likely to screen the video to neighbours.

Of the 29 tea stalls interviewed, 27 showed the videos to their clients. Many of the tea stall owners said that they were too busy making tea to watch the videos themselves, but just turned them on for their customers. The tea stalls show the videos, until all the regular customers have seen them or until their clients stop asking to watch them.

In the past few years, Bangladesh has developed small cable TV companies called “dish-lines” that download commercial TV stations with satellite dishes and feed the cables to a few hundred homes and businesses in several villages. They all played the agricultural videos that were given to them either by AAS or by one of the community-based organisations. Bangladesh is not like Africa where radio and TV stations are starved for content in the local language. Bengali is the world's sixth most widely spoken language and in Bangladesh media outlets are overloaded with content. Yet, despite the wealth of entertainment content, all six of the cable owners showed the videos. If there was a large enough supply of attractive learning videos, a dish-line might be able to create an audience, e.g., broadcasting the educational programs as a regular feature, at specific times.Perhaps the best strategy to motivate cable TV in the future is to have CBOs or local authorities give agricultural videos to the local cable operators, so they feel that their clients want them to show the videos, not an outside agency that may have money.

The Union Information Centres (privatised facilitators of paperwork based in local government offices) always showed the videos, sometimes to large audiences. About half of the government extension agents showed the videos to about 250 farmers each; NGOs and CBOs to about 150 farmers (and often reached more women than other actors); and the power tiller operators, local village shops and agro-dealers were less likely to show the videos and reached slightly less than 100 people each.

All service providers received one to a few DVDs for free, but none were paid to show the videos to farmers. Some showed the videos out of social motivation, others because it helped raise the profile of their business. One reason for the success in Bangladesh was that AAS had two convincing field agents who told volunteers that if they would show the videos, they would be doing a service for the community and helping the farmers.

Mali: mobilising farmer field schools and cooperatives: By 2012, Access Agriculture had learned a lot about effectively distributing farmer training videos, e.g. that villagers will watch the videos again if they have their own copy of the DVD, and that NGOs could effectively show videos, with the right motivation. Ten new videos on managing striga, a persistent and damaging parasitic weed, had solid technical content from experienced researchers at ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) and their partners and from farmer-experimenters who had studied striga in FFS (farmer field schools). Drawing on past experiences, Access Agriculture advised ICRISAT and other organisations across Africa to distribute some 50,000 DVDs of the “Fighting Striga” series.

In Mali, ICRISAT and partners carefully planned the distribution of about 10,000 DVDs. Most of these went to extension agents, farmer groups, and cooperatives and almost all of these groups watched the videos, which had 8 language soundtracks, so everyone in Mali could understand them. Some radio stations also aired the soundtracks. Many groups gathered in open air public viewings in the village centres, and usually managed to overcome limitations such as lack of electricity or scarce DVD players. Farmers found ways to use solar panels, batteries and various kinds of equipment to watch the videos and several groups took the initiative to copy them further on computers, I-pads, USB sticks or more DVDs. The NGOs did an especially good job of screening the videos in villages, because they realized how much the videos helped farmers control striga and improve their cereal yields.

Farmers in FFS groups were especially good at organising public screenings, so everyone could watch the videos. Before watching the videos, farmers in Mali were not aware of the danger of striga seeds, which are the size of dust particles. So farmers unconsciously let the striga plants flower, and disperse their thousands of seeds. After watching the videos, many viewers realised that they needed to uproot the striga plants before they set seed, but this is a tedious job. Some of the women's work groups were soon busy making money pulling up striga.

Some social changes revolved not around the agricultural technologies, but around the video itself. In the village of Kouna, an NGO (Aga Khan Foundation) showed the 10 striga videos to 40 village residents, who immediately realised the importance of the information. The village leaders organised a “video committee” to screen the videos in the village square every night for two weeks, and to take copies to outlying hamlets, until they were satisfied that everyone in the large village had seen the videos, including women and youth (www.agroinsight.com).

In Mali, DVDs were provided to village elders. Like most other countries, the older people are not the most inclined to new digital technology. DVD players and cell phones may be increasingly common over most of Africa, but the young farmers are the most eager adopters. In Mali, elders who received a DVD often gave it to their son or another young adult who knew how to show it. Elders are the authority in a village, but they need young people to access digital technology.

Malawi: a job for youth: Based on insights learned in Mali, in Malawi the new, burgeoning business of making videos available in villages and small towns was explored. Nearly every settlement that is large enough has a cluster of shops. But now they also have a “video show” where village youth can watch an American, Nigerian or Indian movie on someone's TV with DVD player (Esan, 2008).

Villagers off the electrical grid come to town to do their business, and while there they have their cell phone charged up for a small fee, and then go get some new videos. Later the whole family can watch the videos on the phone screen.

The mobilisation of actors in agricultural development beyond project mode resonates with what Dalohoun calls “a self-organising system of innovation”, where entrepreneurs responded to new technologies by promoting them on their own (often in the hopes of creating additional business). Access Agriculture (www.accessagriculture.org) gets training videos into the hands of farmers by combining an innovation systems approach with the goals of entrepreneurs. For example, among private, rural radio stations in Benin the standard is that any services the radio stations offer should be paid, otherwise the stations cannot operate as a business. Out of principle, Access Agriculture does not pay any service provider to distribute or show videos, as it believes that quality and relevance will motivate service providers to reach farmers. Radio staff in Benin realised that their rural audience would appreciate the ideas on the videos, and found creative ways to broadcast the contents, and distribute the videos to farmers. The stations share farmers' goals of improving rural livelihoods .

Professional networks in Uganda distributed the rice videos to millers, who shared them (pro bono) with farmers to strengthen customer relations, and to encourage farmers to harvest more and better quality rice, which would also benefit the mills. In Bangladesh many members of the rural services community relate to farmers well enough to make an effort to show them videos if the topic is of interest and the video is attractive and well made. These actors had many different motives, depending on their business. For example the tea stall owners knew that the videos retained an audience of paying customers. The operators of the UISCs (Union Information Service Centres) wanted to improve client relations and demonstrate some of their ICT equipment (Gurumurthy, 2006).

Some organisations in Uganda and a commercial radio station in Benin sold copies of the training videos to farmers thereby engaging in monetary entrepreneurship; they received the DVDs for free, from partners of Access Agriculture, but selling the disks defrays the vendors' transaction cost and encourages them to deal in DVDs in the future. Farmers are eager to obtain training videos and are willing to pay for them once they know the content is relevant to them, as in Nigeria where 95% of farmers are willing to pay for improved extension services. Future sales of agricultural DVDs by local entrepreneurs would most likely rely on informal networks and network-generated trust, as in many developing countries markets.

In country where broadcast TV in rural areas is limited (for lack of money, lack of content, or language barriers) farmers are best reached with DVDs through existing local service providers. Entrepreneurs that show soccer and action movies, such as the *kibandas* in Uganda or video shows in Malawi, might sell or show agricultural training videos. In Fiji, where DVD selling has a history of about 30 years, most integrate DVD sales into other activities: car washes, churches, shoe repair stores, bookstores, internet cafes and electronics stores .

Well-planned distribution of DVDs to local service providers (including the DJs) and grassroots organisations will be needed, and then local entrepreneurship and social networks will spontaneously help to distribute and screen the videos in rural communities. Members of farmer associations readily share information between themselves. By targeting farmer associations for the distribution of agricultural DVDs they will become better equipped to also provide advice in response to their members' needs.

Public and commercial TV stations across Africa have approached Access Agriculture to obtain free access to high quality farmer training videos, as they see a growing potential to broadcast videos of relevance to their audience .
The growing availability of quality, attractive training videos in multiple languages (www.accessagriculture.org) opens the door to entrepreneurs to play a role in distributing and showing farmer training videos. Contrary to taking part in projects or workshops, which is often motivated by farmers' desire to boost their reputation or to obtain material benefits, paying for copies of training videos or to attend video shows would attract only farmers that are motivated by learning to improve their farming. Providing farmers with attractive and useful services is the most reliable way to promote and foster effective and sustainable farmer financial participation (Moumouni and Streiffeler, 2010),

CONCLUSION

Many farmers will watch a really good training video, but only if someone in the community gets a copy of it.

Now that so many remote villages have at least one person with a DVD player, many videos can be put on a DVD (in several languages) and distributed as a low-cost, high-quality extension method, as is now being promoted by the NGO Access Agriculture. New digital technology (e.g. DVDs, mobile phones, smart projectors, digital TV) will make it easier for farmers to access agricultural videos, but will require some time to grow and to explore the best ways to distribute and show videos in each context.

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How Policy Intervention Impacted Adoption of Mango (*Mangifera indica*) Cultivation in Subtropics of Jammu, India?

Fatima Bano, Rajinder Peshin, V.K. Wali[1] and L. K. Sharma

Division of Agricultural Extension Education, [1]Division of Fruit Science
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India
E-mail: fatimahussain26@yahoo.in

Abstract: A study was conducted in sub-tropical Jammu and Samba districts of Jammu and Kashmir (J&K) state, to analyse the adoption of technologies recommended by the Department of Horticulture, Jammu under the Horticulture Mission for North East and Himalayan States (HMNEH) programme. Before the HMNEH intervention, lack of farming experience in fruit crop cultivation, distance of a village from a fruit plant nursery and market, and un-irrigated landholdings caused a variation of 66% in non-adoption. The introduction of diversification programme under HMNEH, in the rain-fed areas of Jammu, resulted in change in land use pattern with the reduction in area under maize and wheat from 3.48 ha (in both the cases) to 0.99 ha and 0.93ha, respectively. The survival percentage of the mango trees planted under the HMNEH programme ranged from 6 to 100 per cent. The study revealed that the department of horticulture succeeded in providing benefits of the programme to its deserving end users.

***Key Words*:** Diversification programme, Land use, Non-adoption, Outcomes, Survival percentage

The Technology Mission for Integrated Development of Horticulture in North Eastern States of India including Sikkim was launched by the Government of India in 2001-2002, with the objective of improving the production and productivity of horticultural crops by harnessing the potential of the region (MOA, 2010). The scheme was subsequently extended to the states of Jammu & Kashmir (J&K), Himachal Pradesh and Uttrakhand in 2003-2004. The scheme has since been renamed as Horticulture Mission for North East and Himalayan States (HMNEH). The programme has completed a decade since its inception in 2001-2002. According to an impact evaluation report by Agricultural Finance Corporation Limited (AFCL) in 2012, due to interventions under HMNEH, a momentum has been generated in the overall growth in horticulture sector with increase in area and production of fruits from 66,588 ha and 0.449 million tonnes in 2003-2004 to 0.2 million ha and 0.8 million tonnes, respectively in 2011-2012, resulting in increase of 33.29% in area and 56.13% in production during the last nine years (AFCL, 2012).

Under the Mini Mission-II of HMNEH, constitutes the diversification and area expansion programme, which aims at increasing the total area under horticultural crops by providing incentives to farmers for the establishment of horticultural crops specific to their area (MOA, 2010). In this respect, mango (*Mangifera indica*) being an important fruit crop in the sub-tropical region of J&K, the Department of Horticulture Jammu under the area expansion programme provided incentives to farmers for the establishment of mango orchards. Three hundred one beneficiaries were covered in Jammu district in 2011-2012 under the area diversification programme of HMNEH, which consisted of 217 beneficiaries (out of which 186 beneficiaries were considered for the study) under mango, 84 beneficiaries under other fruit crops [aonla (*Emblica officinalis*), kinnow (*Citrus* spp.), mossambi (*Citrus limetta*) and litchi (*Litchi chinensis*)] covering a total area of 274 hectares. To assess the impact/outcomes of development programmes, empirical evaluation studies must be conducted to report the successes or failures of such programmes.

Impact evaluation is a mode of scientific inquiry and a form of applied social science is the systematic acquisition and assessment of information to provide useful feedback about some object. Evaluation helps in identifying the key evaluation questions, on the basis of which form of evaluation, appropriate model of evaluation and design of research can be selected (Peshin *et al*., 2009). The common types of evaluation based upon purpose of evaluation are formative and summative evaluation. Formative evaluation identifies the shortcomings of a programme and reports back for its improvement, whereas, summative evaluation reports about the outcomes/impacts of the programme to be evaluated (Scriven, 1991). Therefore, a study was conducted to find out the factors responsible for non-adoption of fruit farming in the rain-fed areas, area expansion and survival rate of planted orc

MATERIAL AND METHODS

The state of J&K is situated in North West Himalayan region extending over 32º 17' and 36º 58'North latitude and 73º 26' and 80º 30' East longitudes. Jammu region has 10 districts falling in temperate and sub-tropics. The sub-tropical region of the Jammu region constitutes entire Jammu and Samba districts, parts of Kathua, Udhampur, and Rajouri districts. The Jammu and Samba districts in the sub-tropical region of Jammu region comprises of eight blocks and four blocks, respectively were selected for the study. Five blocks from Jammu district (Akhnoor, Khour, Marh, Dhansal and Bhalwal) and all the blocks of Samba district (Samba, Vijaypur, Ghagwal and Purmandal) were selected for the study. Farmers having at-least fifty and above number of mango fruit bearing trees were considered for the sampling. Accordingly among the 217 beneficiaries of HMNEH, 186 beneficiaries fulfilled this criterion. From the selected blocks two sets of samples were selected for the study. One set of sample was the farmers who were mango orchardists before the start of HMNEH intervention in the study area. Most of these orchards were irrigated. As per the list provided by Department of Horticulture, Jammu their number was 90, out of which 25 orchardists were selected by proportionate random sampling method. Second set of sample of 50 was selected from a list of 186 beneficiaries covered under HMNEH till 2011-12 by the Department of Horticulture, Jammu. The HMNEH beneficiaries were mostly having un-irrigated farms. The data were collected from the respondents by using pre-tested interview schedules. Pre- testing was carried out to evaluate the interview schedule by interviewing farmers not included in the study.

Empirical model: Binary logistic regression model was applied for analyzing the factors responsible for non-adoption of fruit farming by the farmers in rain-fed areas before the HMNEH intervention. The result of this type of regression can be expressed as follows:

$$\text{Ln}\,[p/1\text{-}p] = b_0+b_1x_1+b_2x_2+b_3x_3\text{...........}b_kx_k$$

-where p represents the probability of an event

-b_0 is the y- intercept, and

- x_1 to x_k represents the independent variables included in the model.

For the validation of the model, chi-square and Hosmer and Lameshow goodness of fit tests were taken into account. The Nagelkerke's R^2 was used as measure of determination of variation caused by predictors. The sample for binary logistic regression model comprised of 75 respondents (25 old mango and 50 HMNEH orchardists). In case the variance for a parameter between non-HMNEH and HMNEH orchardists was significant, unequal variance values for a statistic and degree of freedom have been used otherwise equal variance values have been used.

RESULTS AND DISCUSSION

The HMNEH and Non-HMNEH orchardists significantly differed in case of bio-physical variables of average irrigated landholding (t=3.068, p=0.005) and average age of orchard (t=5.372, p=0.000). In addition, the socio-personal variables of education level (t=3.975, p=0.000), average farming experience (t=3.827, p=0.001) were also statistically significant (Table 2).

Factors responsible for non-adoption of fruit cultivation: Binary logistic model was applied on the 75 respondents in order to analyse the reasons for the non-adoption of mango cultivation by the rain-fed farmers prior to the introduction of HMNEH programme. The factors impeding the adoption of fruit cultivation were predominantly biophysical variables namely distance from a market, distance from fruit plant nursery and irrigated area that caused a variation of 66 % in non-adoption (R^2= 0.656 and with a chi square value of 14.122). Besides, only socio-personal variable contributing to non-adoption was experience in fruit cultivation (Table 3). This means that these were the factors which proved to be constraints for the farmers residing in the rain-fed areas of

Variable	Code	Measurement
Dependent variable		
Adoption	Y	1 for adoption 0 for non adoption
Independent variables		
Age	X_1	Chronological age of the orchardist.
Education	X_2	Number of years of formal schooling
Experience as orchardist	X_3	Number of years of experience in farming and cultivation of fruit crops
Land holding	X_4	Number of hectares of land under cultivation
Irrigated area	X_5	Number of hectares of land irrigated
Distance from market	X_6	Kilometres
Distance from nursery	X_7	Kilometres

Table 2. Descriptive statistics of the sampled group of mango orchardists

Parameter	Non-HMNEH orchardists (n=25)	HMNEH[1] orchardists (n=50)	Diff.	d.f	Statistic
Socio-personal variables					
Mean age(years)	53.9±11.72	55.6±13.20	1.00	73	t=0.532(0.596)
Mean education(Formal number of schooling years completed)	8.4±4.28	4.12±4.61	4.28	51.465	t=3.975(0.000*)
Education level (%farmers)					
Illiterate	12	54	42.00	-	z=4.3807(0.000*)
Below primary	8	0	8.00	-	-
Primary	4	4	0.00	-	-
Middle	20	22	2.00	-	z=0.2017(0.840)
Matriculate	44	20	24.00	-	z=2.1004(0.035*)
10+2	4	0	4.00	-	-
Graduate and above	8	0	8.00	-	-
Average farming experience (years)	10.4±7.32	4.34±4.26	6.06	32.400	t=3.827(0.001*)
Average family size (No.)	7.08±4.40	6.94±2.83	0.14	73	t=0.166(0.869)
Average number of adults	5.32±3.09	4.7±2.12	0.62	-	-
Average number of children	1.76±1.80	2.24±1.64	0.48	-	-
Total family size (No.)	177	347	170	-	-
Workforce (No.)	75(42)	134(39)	-	-	-
Households solely dependent on farming (% farmers)	12	14(28)	-	-	-
Households having non-farming income (% farmers.)	88	36(72)	-	-	-
Agriculture+ Govt. Job	11(50)	18(50)			
Agriculture+ Private job	9 (41)	19(53)	-	-	-
Agriculture+ Business	7(32)	8(22)	-	-	-
Others	0	1(3)	-	-	-
			-	-	-
Bio-physical variables					
Average operational land holding(ha)	2.64±1.22	3.48±9.67	0.84	73	t=0.434(0.665)
Average irrigated area (ha)	1.09±1.53	0.13±0.53	0.96	26.892	t=3.068(0.005*)
Average unirrigated area (ha)	1.54±1.42	3.36±9.69	1.81	73	t=0.933(0.354)
Categorization of farm size (% farmers)[2]					
Marginal (<1ha)	0	14	14.00	-	-
Small (1-2ha)	36	40	4.00	-	z=0.3379(0.735)
Semi medium (2-4ha)	36	30	6.00	-	z=0.518(0.604)
Medium (4-10ha)	28	14	14.00	-	z=1.3681(0.171)
Large (>10ha)	0	2	2.00	-	-
Average area under mango orchard (ha)	1.05±0.52	1.07±0.53	0.02	73	t=0.138(0.890)
Average age of orchard (years)	11.6±8.00	3	8.6	24.000	t=5.372(0.000*)

Figures in the parentheses are p values
[1]HMNEH orchardists: Horticulture Mission for North East and Himalayan States, under which the Department of Horticulture, Jammu provided incentives to the farmers for laying out of new mango orchards.
[2]Categorization of farm size as per MOA (2011). *Significant at $p \leq 0.05$

Jammu for cultivation of fruits. Prior to the introduction of the HMNEH in the rain-fed areas, the farmers were having no experience in fruit cultivation and their villages were far away from the input sources.

Outcome of HMNEH programme: HMNEH programme intervention resulted in change in land use pattern of the beneficiaries residing in the rain-fed areas of Jammu. Before the implementation of HMNEH in the study area, farmers used to cultivate maize *(Zea mays*) in summer and wheat (*Triticum aestivum*) in winter season with an average area of 3.48 ha in both the cases. With the policy intervention under the HMNEH, the farmers shifted from cereal cultivation to fruit crop cultivation and the average area under maize and wheat reduced to 0.996 ha and 0.935 ha, respectively. As a result of the HMNEH programme average area under mango increased to 1.06 ha whereas, 0.6 ha in case of other fruit crops. The diversification programme under the HMNEH has greatly impacted the area expansion of mango in the remote and rain-fed areas of Jammu and Samba districts as is evident from the decrease in area of other crops and increase in area of mango crop accordingly (Fig. 1). As a result of HMNEH programme the area under fruit crops increased from zero to 179 ha, an increase of 100 %. The number of adopters of fruit cultivation under HMNEH was 217.

Under the HMNEH programme, the beneficiaries were provided 75% of the cost of establishment of the orchard i.e. Rs. 60,000 ha^{-1} in 3 installments of 60:20:20 subject to survival rate of 75% in 2nd year and 90% in 3rd year. Fig. 2 represents the survival percentage of the individual mango orchards established under the HMNEH. It was observed that the survival percentage ranged between 6 and 100 %, and the overall survival percentage was 83.06 %.

Studies have been done on the socio-economic variables in diffusion and adoption research to find out the association of socio-economic variables with adoption (*ex-post-facto*) and to predict the socio-economic factors impacting adoption/non-adoption of technologies (Rogers, 2003). Pattanayak *et al*. (2003) identified a set of variables impacting adoption namely farmer preferences, resource endowments, market incentives, bio-physical factors, risk and uncertainty. The present study revealed that the factors in the non-adoption of fruit cultivation were predominantly bio-physical variables. Counterfactual is, without the HMNEH intervention the factors impacting non-adoption of fruit cultivation were experience in fruit cultivation, distance of village from market and nursery and irrigated area which caused a variation of 66 %. But the HMNEH intervention by the government was able to overcome these barriers resulting socio-personal variables impacting the non-adoption of fruit cultivation into insignificance. Accordingly the land use pattern underwent a change. Farmers merely relying on rain-fed cultivation of cereals (maize and wheat) have shifted to cultivation of fruits for better income. In addition, contrary to earlier research findings that the extension services are always oriented towards progressive farmers as Roling (1990) states that extension agents and progressive farmers attract each other like a magnet, the Department of Horticulture has successfully provided the benefits of the HMNEH programme to farmers of Jammu and Samba districts who had no experience in fruit cultivation

Table 3. Factors in the non-adoption of mango cultivation

Step	Factors affecting input use	Coefficient (B)	S.E.	Wald	Probability	Model specifications
1	Distance from nursery	-.065	.016	16.05	.000	R^2 = 0.391
	Constant	1.62	.608	7.06	.008	^{2} =34.51
						-2 log likelihood= 70.72
2	Distance from nursery	-.056	.017	11.58	.001	R^2 = 0.656
	Irrigated land	-2.89	.979	8.72	.003	^{2} =14.122
	Constant	3.72	1.19	9.64	.002	-2 log likelihood= 47.527
3	Experience	.178	.084	4.56	.033	R^2 = 0.656
	Distance from nursery	-.063	.019	10.81	.001	^{2} =14.122
	Irrigated land	-1.84	1.01	3.32	.068	-2 log likelihood= 47.527
	Constant	2.00	1.30	2.37	.124	
4	Experience	.209	.087	5.72	.017	
	Distance from market	.124	.058	4.64	.031	R^2 = 0.656
	Distance from nursery	-.115	.035	10.89	.001	^{2} =14.122
	Irrigated land	-3.04	1.41	4.68	.030	-2 log likelihood= 47.527

Table 4. Change in land use pattern

Crop	Area under different crops before HMNEH (ha)	Area under different crops after HMNEH (ha)	Average land use before HMNEH	Average land use after HMNEH	Change in area (%)
Kharief maize	174	49.80	3.48	0.996	-71.4
Rabi wheat	174	46.75	3.48	0.935	-73.1
Mango	0	53.0	0	1.06	100.0
Others	0	30.5	0	0.61	100.0

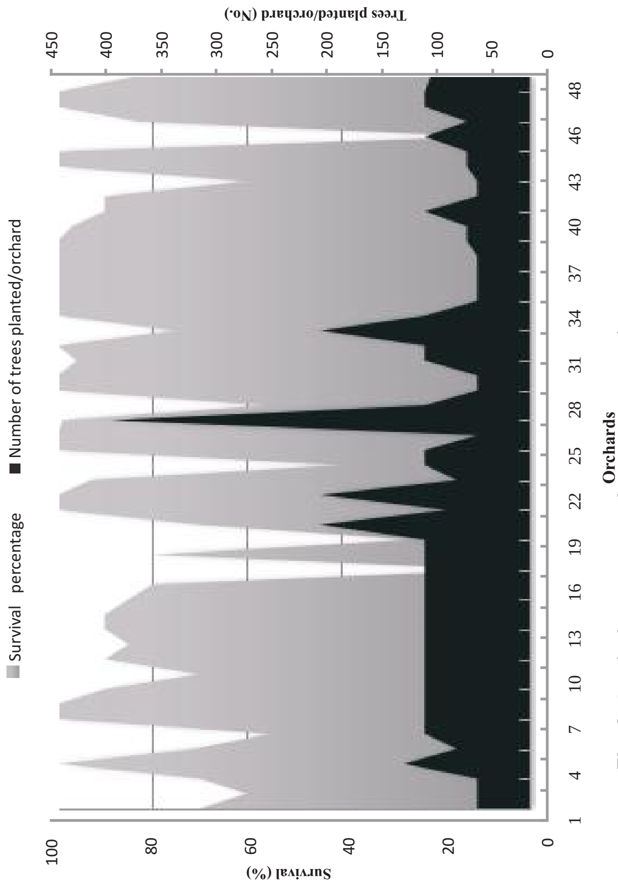

Fig. 2. Survival percentage of mango trees under HMNEH programme

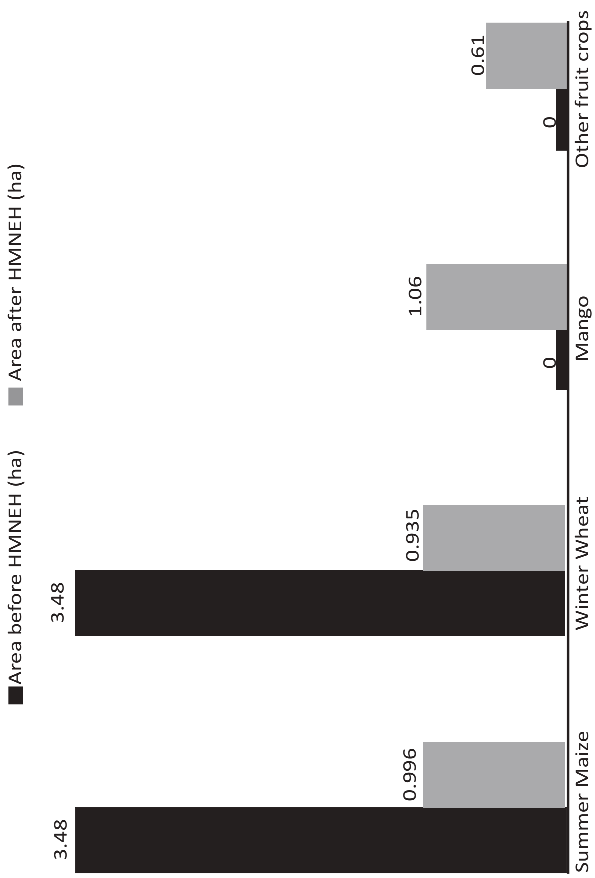

Fig. 1. Change in land use pattern due to HMNEH programme

and had poor natural resources like unavailability of irrigation water, and residing far away from the input sources.

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Stastical Analysis for Optimization of Bacterial Polyhydroxybutyrate Production Using Agriculture by Products

Mukesh R. Jangra, Akanksha Jain, Ritu Batra, Rekha Ahlawat and Virendra K. Sikka
Department of Molecular Biology, Biotechnology & Bioinformatics, Centre of Food Science and Technology
Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004, India
E-mail: jangra.mukesh02@gmail.com

Abstract: Stastical media optimization using surface response methodology was employed to optimize the growth towards Polyhydroxybutyrate (PHB, a bioplastic) production. Media were developed using nutrients from agribyproducts to expedite PHB production and high growth potential. Strain B3 on fructose as carbon sources and mustard cake and yeast extract as nitrogen source, exhibited a maximum biomass of 0.031g l^{-1} with PHB recovery of 0.45g l^{-1}. A significant increase in the PHB production using renewable carbon and nitrogen sources in a time period of just 3 days was an important outcome of the experiments.

Key Words: Agribyproducts, Bioplastic, Optimization studies, Polyhydroxybutyrate, Response surface methodology

Living "green" has become a popular trend in the last twenty years, and reducing environmental pollution remains an important goal for the sustainably-minded society today. The economic and ecological drawbacks of polymer/petroleum-based plastics have pushed researchers to develop and investigate biodegradable plastics as an environment-friendly alternative. French researcher, discovered the first biodegradable plastic from bacterium Bacillus megateriumand named it poly-3-hydroxybuturate (PHB) (Lemoigne, 1926). Bioplastics or Green plastics are plastic like biopolymers which have their origin from biological sources such as microorganisms. Polyhydroxyalkanoates are the polyster of hydroxyacids which is naturally synthesized by bacteria as carbon reserve under stress conditions. It is beneficial for bacteria to store surplus nutrients within their cells, especially as their general physiological health is not affected. Its accumulation in cytoplasmic inclusion has occurred due to unbalanced growth conditions usually characterized by an excess supply or the stress conditions. Polyhydroxybutyrate (PHB), a biodegradable plastic is the first and most studied PHA to be discovered. In their metabolism, three enzymes play important role. Bacteria produce acetyl-coenzyme-A (acetyl-CoA), which is converted into PHB by three biosynthetic enzymes (Pouton and Akhtar, 1996). In the first step, 3-ketothiolase (*PhaA*) form acetoacetyl-CoA by combining two molecules of acetyl-CoA which is reduced to 3-hydroxybutyryl-CoA by CoA reductase (*PhaB*) Finally, PHB synthase (*PhaC)* polymerizes 3-hydroxybutyryl-CoA to PHB, coenzyme-A being liberated. Only (R)-isomers are accepted as substrates for the polymerizing enzyme (Steinbuchel and Schlegel, 1990). These are gaining importance as biopolymers to the petroleum based plastic due to increasing environmental pollution and its ecofriendly nature (Sujatha *et al*., 2005). This polymer is easily degraded in the soil and sewage, and is at present used in making polyethylene or polypropylene films. The PHB content and its composition are affected mainly by the strain of the microorganism, the type of substrate used and its concentration and other growth conditions (Jangra and Sikka, 2015). The high cost of PHB can be curtailed by strain development, improving fermentation, separation process and using low cost carbon sources like agribyproducts. An optimal medium might enhance and maintain PHB recovery and help to maximize the cell growth in terms of optical density and PHB production. The parameters like carbon source and nitrogen source of medium affects metabolism of these bacteria and accumulation of PHB. Response surface methodology is a statistical tool, helps to study the interactive effect of all the parameters on the cell growth and PHB recovery with improved product yield. In the present study, bacterial isolate B3 was grown under conditions favoring maximum PHB production. Attempts were made to use economical strategies to reduce the production costs of PHB as well as its expeditious production from agribyproducts and its applications in various fields. The aim of this study was to optimize PHB production and to study the interaction of various factors which help to enhance the PHB production through statistical media optimization for its possible applications in various scales up studies.

MATERIAL AND METHODS

Bacterial strains, media, growth conditions and screening: The polyhydroxybutyrate producing bacteria B3 was used in this study were isolated from garden soil at Hisar, India. One mg of different soil samples were dissolved in 1 ml of sterile distilled water and serial dilutions were made 5-6 times. 100 microliter of samples from these dilutions were taken and spread on plates containing tryptone yeast extract media. Bacterial colonies appeared after 24 hrs. A single colony was taken from the plate and streaked on a fresh TY plate for isolation of pure colony. The process of streaking is repeated several times for obtaining the single colony. The isolated pure cultures were stored at 4ºC in plates containing undefined nitrogen source containing media. For screening the PHB producing bacterial isolates Nile Blue A stain was added to the autoclaved medium at the final concentration of 25 µg ml^{-1}. These bacterial isolates were screened under UV light after 3 or 4 days of incubation. The PHB producing strain gave an orange/yellowish color florescence. Extent of florescence indicated the intracellular quantity of PHB.

Characterization of selected bacterial strain: Morphological and biochemical tests were performed for characterization of selected PHB producing bacterial strain B3 for its tentative generic identification. Various biochemical tests namely triple sugar iron, nitrate reduction test, urea hydrolysis , carbohydrate fermentation, citrate utilization , methyl red, gelatin hydrolysis , catalase, Indole, hydrogen Sulfide production, and morphological test like spore staining, gram staining, color, shape and morphology.

Analytical procedures: The amount of PHB was estimated by chemical method. Cell mass is collected by centrifuging bacterial culture broth at 8000 rpm. The cell mass collected from two liter broth was treated with 10 ml sodium hypochlorite (4%) by vortexing it and samples were boiled for five to ten minutes in boiling water bath. After cooling 20 ml of chloroform was added to the boiled samples and kept it at 65ºC. Chloroform evaporated and dissolved PHB was recovered. 50 µl of dissolved PHB was added to 2 ml of sulphuric acid and incubated the mixture for one day at 65ºC. After that the spectrophotometer reading was taken at 235 nm.

Comparison of PHB production in different media by selected strains: The test isolate B3 was producing maximum PHB by weight so these were used for further media optimization studies towards scaled up production of PHB. Twenty four different media were investigated to determine the suitable composition for the maximum PHB accumulation by B3 strain. One liter of media inoculated with equal starter culture for media optimization studies and incubated for 72 hrs. Based on the results of these experiments, for B3 strain carbon source fructose when used in combination with nitrogen source mustard cake and yeast extract gave the maximum PHB production.

Experimental design and optimization using response surface methodology: The optimization of process parameters in growth associated PHB production by B3 strain was studied using central composite design (CCD) of RSM (Stat Ease, Inc Design Expert software, trial version 9.0.3, Minneapolis, USA). The CCD for three independent variables fructose (A), Mustard cake (B) and yeast extract (C) each at five levels including 6 replicates at the center point, 6 axial points and 8 factor points leading to a total number of 20 experiments was in work for optimization of media for maximum PHB production. Each variable was calculated at two different levels (-1, +1) and center point (0) which is midpoint of each factor range (Table 1). The initial concentration varied to 2 to 4 g l^{-1}, the concentration of mustard cake and the yeast extract varied from 0.5 to 1 to observe the effect of culture conditions on PHB production. Concentration range for the variables was determined on the basis of literature reports for PHB production. Responses were measured in terms of O.D. and PHB recovery. This data was used to fit in the design of the experiments for response surface optimization.The experiments were done in Erlenmeyer flasks containing 250 ml media incubated for 72 hrs for B3.

Table 1. Experimental design matrix for B3 in terms of actual, coded factors for the responses- O.D. and PHB recovery

Factor	Name	Units	Min.	Max.	Coded	Values
A	Fructose (C- source)	g l^{-1}	1.318	4.681	-1.00=2	1.00=4
B	Mustard cake (N-source)	g l^{-1}	0.159	1.840	-1.00=0.5	1.00=1.5
C	Yeast Extract (N- source)	g l^{-1}	0.159	1.840	-1.00=0.5	1.00=1.5

The experimental results were fitted with a second-order polynomial function:

$$Y = b_0 + b_1x_1 + b_2x_2 + b^{11}x^2{}_1 b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3$$

where, Y is the predicted response, b_0 the intercept, b_1, b_2, b_3 the linear coefficient, b_{11}, b_{22}, b_{33} the squared coefficient and b_{12}, b_{13}, b_{23} the interaction coefficient.

FTIR spectrum analysis: Fourier-transform infrared spectroscopy (FTIR) was used to detect functional groups in an organic compound. FTIR spectra of PHBs that were produced using different carbon and nitrogen sources and the spectra were recorded in KBr (GJUS&T, Hisar).

RESULTS AND DISCUSSION

Screening of bacteria accumulating PHB: Microbial strains were isolated from different sample that effectively accumulated PHB. By Nile Blue A staining method, about 300 hundreds of colonies were screened for their ability to produce PHB in minimal media. Based on the cultural, morphological features, growth rate, the intensity of fluorescence under UV-light, kinetic studies, expeditious and maximum PHB producers were screened. Then twenty four different media with a combination of organic and inorganic nitrogen and carbon source with agribyproducts were used for maximum PHB production. Based on the dry weight and Crotonic acid estimation of the extracted PHB, an effective producer of PHB was chosen. From a comparison of their cell growth in terms of optical density and PHB recovery (data not shown), B3 with a highest PHB content for given cell dry weight was selected for further study.

Identification and characterization of strain B3 for PHB production: An isolate B3 was identified using a series of morphological characteristics and biochemical tests. Microbiological properties were studied and investigated according to the methods described in Bergey's manual of systematic bacteriology (Kreig and Holt, 1984) and the bacterial isolate selected in this study was identified as a member of the genus *Pseudomonas*.

Production and characterization of PHB: By inoculating a 2% seed culture of B3 into the minimal media, the growth curve was determined and the result showed that the organism reached the log and the stationary phases at 56th and 69th hour, respectively. Subsequently, the organism was inoculated into a production medium containing agribyproducts like mustard cake, cotton cake as nitrogen sources and fructose as carbon source. Interestingly, PHB production gets increased as compared to the reference media. The accumulated PHB was extracted and subjected to FT-IR analysis. The spectroscopic analysis revealed 4 major peaks at 2920, 1722, 1461, 1250 cm^{-1}, whereas the remaining peaks are closely lying between 3430 cm^{-1} and 649 cm^{-1}. The predominant peak at 2921 and 1461 which represents the methane groups, followed by a peak at 1722 corresponds to C=O stretch of an ester group present in highly ordered crystalline structure whereas the peak at 1276 correspond to CH group. The presence of these marked peaks demonstrated the presence of PHB in strain B3 (Hong *et al*., 1999; Kansiz *et al*., 2000). PHB is the most common member of the PHAs family and it belongs to the medium-chain-length PHAs (mcl- PHAs) (Steinbuchel and Schlegel, 1991).

Response Surface Methodology

Effects of process variables on bacterial growth and PHB recovery of B3 strain: The quadratic model obtained from regression analysis for bacterial growth in terms of **o**ptical density (O.D) was developed as follows:

Optical density of B3 strain (nm) (Y_1) = +0.65+0.012*A +0.052*B -0.073*C -0.033*AB +0.015*AC –0.012*BC +0.014*A^2 - 0.010*B^2 -0.031*C^2

PHB recovery of B3 strain (g l^{-1}) (Y_2)= +0.024 +8.504E-003*A +3.728E-003*B +3.545E-003*C+2.750E- 003*AB +2.250-003*AC +7.500E-004*BC +7.501E-004*A^2 - 8.409E-004*B^2 -3.105E-004*C^2

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors were coded as +1 and the low levels of the factors were coded as -1. The coded equation was useful for identifying the relative impact of the factors by comparing the factor coefficients. The significance of coefficient of fitted quadratic model was evaluated by using F-value and P-value. The Model F-value 18.94 implied the model was significant. There was only a 0.01 % chance that an F-value this large could occur due to noise for B3 strain (Table 3).

Significant model terms were indicated by the values of "Prob> F" which is less than 0.0500. A, B, C, C^2 were significant model terms. Non significant terms were indicated by the values greater than 0.1000. Model reduction may improve the model, if there were many insignificant model terms (not counting those required to support hierarchy), The "Lack of Fit F-value" was 3.27. It implied the Lack of Fit was not significant relative to the pure error. Non-significant lack of fit was good - we wanted the model to fit. The fit of model was expressed by the coefficient of determination R^2, which was found to be 0.94. The analysis of variance for B3 (Tables 3) indicated that A, B, CB as significant terms ($p<0.05$) for cell optical density and PHB recovery. In fig. 2 (7-12) were shown the surface plots for the interactive factors fructose, mustard cake and yeast extract.

The maximum predicted optical density (0.897) increased with increase of fructose and mustard cake up to 4.6gl^{-1}and 1gl^{-1} (Fig. 2, 7-9). PHB recovery (Fig. 2, 9-12) also increased with increase of fructose, mustard cake and yeast extract up to 4 g l^{-1}, 1.5 g l^{-1}and 1.5 g l^{-1}, respectively. The graphs showing the interaction between carbon source fructose, nitrogen sources mustard cake and yeast extract. So, the effect of interaction of various nutrients on the PHB production (z axis) was studied by plotting three dimensional response surface curves. These curves were plotted against any two independent variables while keeping the other independent variable at their "0" levels. Therefore two response surfaces were obtained by considering all three possible combinations. From the response surface 3D plots (Fig. 2), it is understandable that all nutrients has considerable effect on PHB production with the optimized medium the production of PHB obtained was 0.45 g l^{-1}.

Fourier transform infra-Red (FTIR) analysis confirmed presence of PHB: The FTIR spectroscopic analysis of B3 strain was done Fourier Transform Infra-Red (FTIR) spectrum of the PHB sample revealed 4 major peaks at 2920, 1722, 1461, 1250 cm^{-1}, whereas the remaining peaks are closely lying between 3430 cm^{-1} and 649 cm^{-1}. The predominant peak at 2921 and 1461 which represents the

Table 2. Response surface methodology yield of PHB by strain B3

Run	A:fructose (C-source)	B:mustard cake (N-source)	C:yeast extract (N- source)	O.D.	PHB Recovery
	g l^{-1}	g l^{-1}	g l^{-1}	nm	mg l^{-1}
1	4	1.5	1.5	0.925	45
2	4	0.5	0.5	0.599	19
3	3	1	1	0.625	21
4	3	1	1	0.648	23
5	3	1	1	0.656	23
6	4.6	1	1	0.897	41
7	1.3	1	1	0.427	16
8	3	1	1	0.696	29
9	3	1	1	0.689	28
10	3	0.1	1	0.487	13
11	3	1	0.1	0.407	20
12	3	1	1	0.623	21
13	3	1	1.84	0.659	25
14	2	0.5	0.5	0.495	15
15	4	0.5	1.5	0.774	34
16	2	0.5	1.5	0.559	17
17	2	1.5	0.5	0.468	12
18	4	1.5	0.5	0.752	31
19	2	1.5	1.5	0.629	21
20	3	1.84	1	0.699	29

Table 3. Analysis of variance (ANOVA) for B3 strain

	Optical density		PHB recovery	
	F	p-value	F-value	p-value
Model	18.94	< 0.0001*	12.57	0.0002*
A-fructose (C- source)	102.03	< 0.0001*	75.71	< 0.0001*
B-mustard cake (N-source)	17.69	0.001*	14.55	0.0034*
C-yeast extract (N- source)	35.52	0.0001	13.15	0.0046*
AB	4.16	0.068**	4.64	0.0567**
AC	0.92	0.359**	3.10	0.1085**
BC	0.55	0.475**	0.34	0.5700**
A^2	1.43	0.259**	0.62	0.4487**
B^2	0.72	0.414**	0.78	0.3975**
C^2	6.92	0.025*	0.11	0.7508**
Lack of Fit	3.27	0.110**	1.14	0.4430**

Note- *=significant at 5% **=non-significant

methane groups, followed by a peak at 1722 corresponds to C=O stretch of an ester group present in highly ordered crystalline structure whereas the peak at 1276 correspond to CH group. The presence of these marked peaks demonstrated the presence of PHB in strain B3 (Fig. 1). The FTIR results of pseudomonas B3 strain was in agreement with the earlier works (Muthazhagan and Thangaraj, 2014). A new efficient Polyhydroxybutyrate (PHB) producer, that utilized Mustard cake as nitrogen sources for production was isolated from garden soil, and medium conditions were optimized for high PHB production. Response surface methodology is a promising method to optimize medium concentration and the interactions of other variables involved in the production. The validity of the model was proved by fitting the values of the variables into a model equation (Deepak *et al*., 2008). Additionally, the benefit of RSM is the study of interactions between the coded variables which is very difficult to be studied in conventional one-factor-at-a-

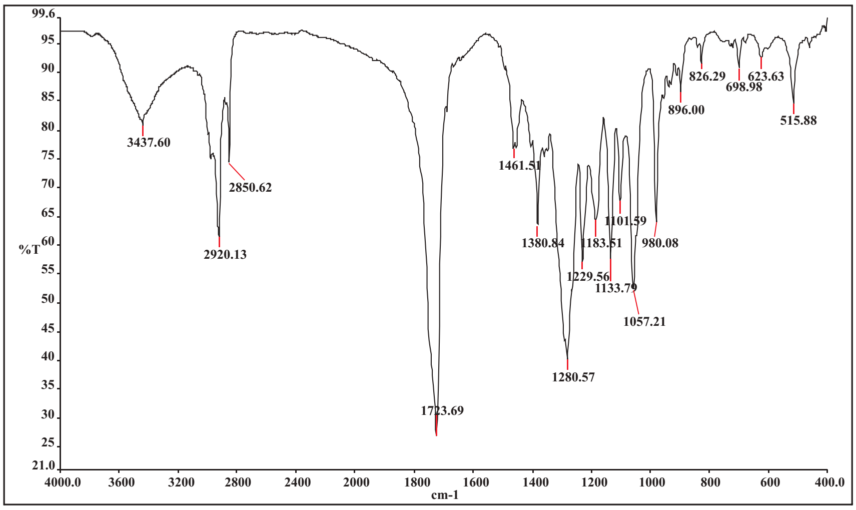

Fig. 1. FTIR spectrum of PHB produced by strain B3

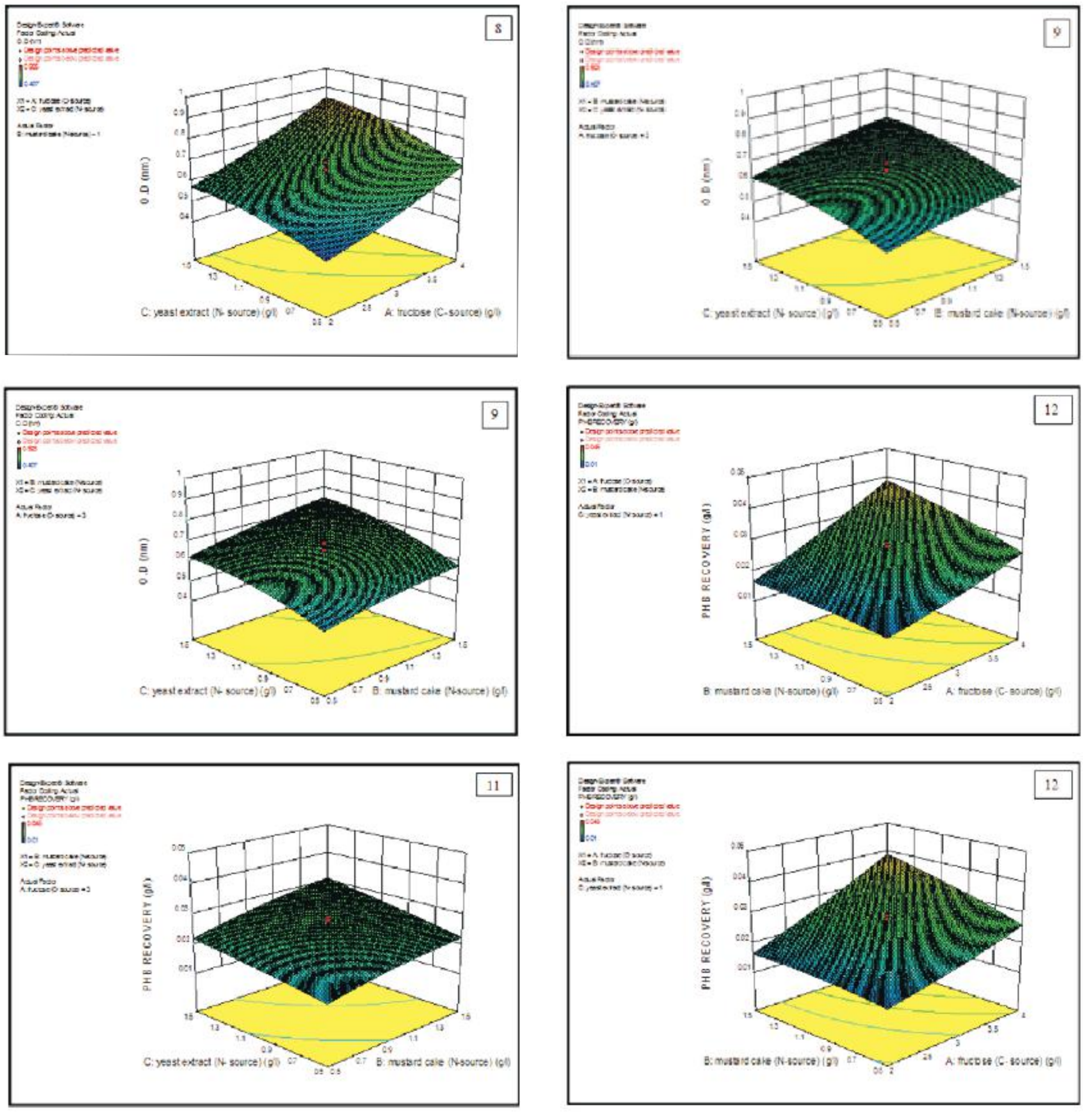

Fig. 2. 3-D plots showing the interactive effect of mustard cake, yeast extract and fructose for the responses Optical Density and PHB Recovery in strain B3 (7-12)

time method. Although PHB production was enormous in earlier studies, the raw materials used in those studies are expensive. For the production of PHB (PHAs), the cost of the carbon and nitrogen source is supposed to be low and yield should be the maximum. According to Lee *et al.* (1997), many carbon sources derived from wastes like whey, cane molasses and sugar beet molasses were used for production of PHB and for mineral source mixture of different salts had been used. However, mustard cake, one of the least expensive, renewable and easily available resources was supplied as a nitrogen source. In this study we demonstrated the production of PHB on industrial and large scale towards low cost bioplastics as a solution to environmental problems due to petrochemical plastics has created a renewed interest in biologically derived polymers. To apply PHB as product plastics, the utilized raw materials should be inexpensive (Khanna and Srivastava, 2005) and it has to be easily available. The media and PHB production process developed on the novel pseudomonad has enabled to achieve these goals to help the environment of the globe at large.

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Financial Profitability, Marketing Analysis and Technical Efficiency of CabbageCultivation in Jammu Region of J&K State, India

Anil Bhat, Jyoti Kachroo[1] and Rakesh Sharma

Krishi Vigyan kendra, R.S. Pura, Jammu-181 102, India
[1]Division of Agricultural Economics and Agribusiness Management
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India
E-mail: drbhatanil@gmail.com

Abstract: Three districts Jammu, Udhampur and Samba were selected to analysed the financial profitability, marketing analysis and technical efficiency of cabbage cultivation in Jammu region of Jammu and Kashmir state. Data Envelopment Analysis (DEA) have been used for estimating the technical efficiency. The overall cost of cultivation varies from Rs. 9863.90 acre^{-1} in Samba district to Rs. 9950.94 acre^{-1} in Jammu district. The overall gross returns for Jammu, Samba and Udhampur districts were found to be Rs. 42578.36 acre^{-1}, Rs. 39051.10 acre^{-1} and Rs. 40694.21 acre^{-1}, respectively.

Key Words: Cabbage, Jammu, Marketing, Profitability

India is the second largest producer of vegetables in the world (ranks next to China) and accounts for about 15% of the world's production of vegetables. During 2012-13, production level of vegetables was over 162186.6'000 MT with the total area around 9205.2 000 hectares and the productivity of 17.6 MT ha^{-1} (Anoymous, 2013).

Cabbage (*Brassica oleracea*) is grown as an annual vegetable crop for its dense-leaved heads. Fresh cabbage is an excellent source of natural antioxidant, vitamin C. It is also rich in essential vitamins such as panthothenic acid (vitamin B-5), pyridoxine (vitamin B-6) and thiamin (vitamin B-1). The vegetable is a storehouse of compounds which are powerful antioxidants and known to help protect against breast, colon and prostate cancers and held reduce LDL or bad cholesterol levels in the blood. It is very low in saturated fat and cholesterol and is a good source of fiber. It is very popular in Jammu &Kashmir in India. Vegetables play a vital role to supply adequate quantity of nutrition in human diet. The per capita availability is less than the prescribed requirement of 200gms person^{-1} day^{-1}. Therefore, to address the excess demand the vegetables are imported from outside J&K. 1.99 lakh metric tonnes of vegetables have been imported ending in the year 2014. Cabbage has a definite market advantage and provide assured better returns to the farmers. The Jammu, Samba and Udhampur district of the state has become famous for the production of quality cabbage and being short-duration crop, 3-4 crops of cabbage can be taken by the farmers to augment their income. In this backdrop, the present study was conducted to investigate the economics of cultivating cabbage in Jammu division.

MATERIAL AND METHODS

The primary data were collected by survey method using well designed and pre-tested schedules. Collection of data was done by the personal interview method and Bhalwal and Marh blocks from Jammu district, Vijaypur and Samba blocks from Samba district, Udhampur and Chenani blocks from Udhampur district were selected on the basis of highest area under vegetable production and the growers were selected randomly from each block so as to constitute sample units of 40 growers from each district with the total of 120 growers. To achieve the stipulated objectives, the required information was collected on farm implements, machinery, farm inputs and crop yields to work out cost and returns, technical efficiency, resource use efficiency, marketing behaviour. To work out the cost of cabbage production, various cost concepts of CACP were used.

Technical efficiency: Data Envelopment Analysis (DEA), originally proposed by Charnes, Cooper and Rhodes (CCR) was used to analyse the performance of the decision making units (DMUs).

$$\textbf{Minimise}\, z_0 = \theta - \varepsilon \sum_{r=1}^{r=s} s_r^+ - \varepsilon \sum_{i=1}^{i=m} s_i^-$$

$$\sum_{j=1}^{j=n} \lambda_j y_{rj} - s_r^+ = y_{r0} \text{ for } r = 1, \ldots\ldots, s$$

$$\theta x_{i0} - \sum_{j=1}^{j=n} \lambda_j x_{ij} - s_i^- = 0 \quad \text{for } i = 1, \ldots\ldots, m$$

$$\sum_{j=1}^{j=n} \lambda_j \geq 1 \text{ for } j = 1, \ldots\ldots, n$$

$$s_r^+ \text{ for } r = 1, \ldots\ldots, s$$

$$s_i^- \text{ for } i = 1, \ldots\ldots, m$$

where x_{ij} is amount of i^{th} input required by j^{th} DMU; y_{rj} is amount of r^{th} output produced by the j^{th} DMU; å is small positive integer; $ë_j$ is a weight of i^{th} DMU; S_r^+ is a slack variable of r^{th}output; S_i^- is a slack variable for i^{th} input; è obtained will be the efficiency score of i^{th} farmer. The CRS TE scores can be decomposed into pure TE and SE. The SE score can be measure by conducting both CRS and VRS-DEA. The SE can be roughly measured as the ratio of TE_{CRS} to TE_{VRS}. The DEA model in this study is calculated under CRS and VRS conditions. In the present study to calculate the level of TE and other indicators of the vegetable growers in Jammu region of J&K state VRS-DEA model has been applied.

Output variable (O) includes gross returns (Rs acre^{-1}) from cabbage production in the present case and expenses incurred in Rs acre^{-1} on land preparation, nursery/seedlings, irrigation, fertilizers, farm yard manure, plant protection, hired human labour and family labouras inputs (I). The models were solved using the DEAP version 2.1 taking an input orientation to obtain the efficiency levels.

Analysis of marketing: Marketing part is analysed with the help of ethos as proposed by Kachroo and Bhat (2012)

Marketing margins, costs and loss

1. Net Farmer's Price

$NP_F = GP_F - \{C_F + (L_F \times GP_F)\}$or

$NP_F = \{GP_F\} - \{C_F\} - \{L_F \times GP_F\}$

Where

$NP_F$is net price received by the farmers (Rs. kg^{-1})

GP_F is gross price received by the farmers or whole sale price to farmers (Rs.kg^{-1})

$C_F$is the cost incurred by the farmers during marketing (Rs. kg^{-1})

L_F is physical loss in produce from harvest till it reaches assembly market (kg^{-1})

b) Marketing margins:

Intermediaries = Gross price – Price paid – Cost of marketing during wholesaling– Loss in value

Margin (sale price) (cost price)

Net marketing margin of the wholesaler is given

Table 1. Cost and return structure of cabbage in various district of Jammu division (Rs ha^{-1})

Particulars	Jammu			Samba			Udhampur		
	Bhalwal	Marh	Overall Avg.	Vijaypur	Samba	Overall Avg.	Udhampur	Chenani	Overall Avg.
Land preparation	1565	1626	1596	1626	1517	1571	1745	1513	1629
Nursery/seedlings	8500	8094	8297	7635	7963	7799	7375	7875	7625
Irrigation	525	495	510	463	544	503	567	510	538
Fertilizers	3176	2961	3069	2689	2869	2779	3200	3075	3138
FYM	2938	3063	3000	2468	2533	2500	2475	2325	2400
Plant protection	4214	3909	4061	3688	3868	3778	3900	3675	3788
Hired human labour	3500	3250	3375	4500	5250	4875	5125	4625	4875
Land revenue + Depreciation on buildings equipments etc	537	684	611	481	515	498	476	474	475
Total	24956	24082	24519	23549	25057	24303	24863	24071	24467
Interest on working capital @6% p.a	366	351	359	346	368	357	366	354	360
Total Cost A1	25322	24433	24877	23895	25425	24660	25229	24425	24827
Cost A2	25322	24433	24877	23895	25425	24660	25229	24425	24827
Interest on amount of owned capital invested	1136	946	1041	1041	1085	1063	1264	1153	1208
Cost B1	26458	25379	25919	24936	26510	25723	26492	25578	26035
Rental value of owned land	6375	7625	7000	5750	7125	6438	7375	6500	6938
Cost B2	32833	33004	32919	30686	33635	32161	33867	32078	32973
Family labour	7500	6000	6750	5625	4875	5250	4750	5750	5250
Cost C1	33958	31379	32669	30561	31385	30973	31242	31328	31285
Cost C2	40333	39004	39669	36311	38510	37411	38617	37828	38223
	4033	3900	3967	3631	3851	3741	3862	3783	3822
Cost D	44367	42904	43635	39942	42361	41152	42479	41611	42045

mathematically by

$MM_w = GP_w - GP_F - C_w - (L_w \times GP_w)$ or

$MM_w = \{GP_w - GP_F\} - \{C_w\} - \{L_w \times GP_w\}$

Where,

MM_w is net margin of the wholesaler (Rs kg^{-1}),

GP_w is wholesaler's gross price to retailers or purchase price of retailer (Rs. kg^{-1})

C_w is cost incurred by the wholesalers during marketing (Rs.kg^{-1}),

L_w is physical loss in the produce at the wholesale level (kg^{-1})

Total margin of the wholesaler

$MM_w = MM_{w1} + \ldots\ldots + MM_{wi} + \ldots\ldots + MM_{wn}$

Where MM_{wi} is the marketing margin of the i-th wholesaler.

Net marketing margin of retailer

$MM_R = GP_R - GP_W - C_R - (L_R \times GP_R)$ or

$MM_R = \{GP_R - GP_W\} - \{C_R\} - \{L_R \times GP_R\}$

Where MM_R is net margin of the retailer (Rs./Kg),

GP_R is price at the retail market or purchase price of the consumers(Rs./Kg)

L_R is physical loss in the produce at the retail level (per kg),

C_R is the cost incurred by the retailers during marketing (Rs./Kg).

Total marketing margin of the market intermediaries (MM)

$MM = MM_W + MM_R$

Total marketing cost (MC)

$MC = C_F + C_W + C_R$

Total Marketing Loss (ML)

$ML = \{L_F \times GP_F\} + \{L_W \times GP_W\} + \{L_R \times GP_R\}$

Marketing efficiency (ME)

$$ME = \frac{NP_F}{MM + MC + ML}$$

Where NP_F is net price received by the farmers (Rs kg^{-1}),

MM is the marketing margin,

MC is marketing cost,

ML is marketing loss.

RESULTS AND DISCUSSION

Cost structure of cabbage: The cost involved in the land preparation for cabbage on an average worked out to be Rs.628.58 in Samba district which was slightly lower as compared to Udhampur district and Jammu district. The block level per hectare land preparation cost worked out to be varied from Rs.1513 in Chenani block to Rs. 1745 in Udhampur block. Similarly cost for nursery/seedlings varied from Rs. 7375 ha^{-1} in Udhampur block to Rs. 8500 ha^{-1} in Bhalwal block. The perusal of data makes it clear further that as far as irrigation was concerned it varied from lowest overall average of Rs.503 ha^{-1} in Samba district to highest of Rs. 538 ha^{-1} in Udhampur district. Total per hectare working cost was between Rs. 24303 in Samba district to Rs. 24519 in Jammu district. As in the sample area there was no leased in land the Cost A_1 and Cost A_2 was same. The overall ultimate Cost D varied from Rs.414152 ha^{-1} in Samba district to Rs. 43635 ha^{-1} in Jammu district.

Table 2. Input-use and yield from vegetable cultivation across various districts in Jammu and Kashmir (ha^{-1})

Items of Inputs	Cabbage		
	Jammu	Samba	Udhampur
Seed/seedlings (kg)	1.75	1.5	2.5
FYM (q)	75	62.5	60
Urea (kg)	300	262.5	312.5
SSP (Kg)	162.5	150	162.5
MOP (kg)	12.5	10	12.5
Total chemical fertilizers (kg)	475	422.5	487.5
Family labour(human days)	45	35	35
Hired labour (human days)	22.5	32.5	32.5
Total human labour (human days)	67.5	67.5	67.5
Yield (q)	237.5	225	225

Input use and yield from cabbage cultivation across various districts of Jammu division: In Jammu and Udhampur districts, 1.75 and 2.5kg ha^{-1} of seed was used, while as in Samba district it was 1.5kg ha^{-1}. The usage of FYM was highest for Jammu district (75q ha^{-1}) whereas the urea used in Udhampur district was highest (31.25kg ha^{-1}) as compared to other districts. The human labour utilization was almost equal in all the districts. The yield was maximum for Jammu district (237.5q ha^{-1}). The total chemical fertilizers (urea, SSP and MOP) used was 475, 422.5 and 487.5kg ha^{-1} for Jammu, Samba and Udhampur districts, respectively.

Economics of cabbage cultivation in different districts of Jammu division: The overall per hectare cost of cultivation varied from Rs. 24660 in Samba district to Rs. 24877 in Jammu district. The per quintal production cost was highest for Udhampur (Rs.110) followed by Samba and then by Jammu district. The block wise per quintal price received varied from Rs. 506 in Vijaypur to Rs. 592 in Marh with highest overall average of Rs. 563 in Udhampur district. The overall per hectare gross returns ranged between Rs. 122288 in Samba district to Rs. 131323 in Jammu district. Net returns per quintal varied from Rs 434 in Samba district to Rs. 452 in Udhampur district. The results are in close conformity with Bala *et al.* (2011).

Technical Efficiency

Jammu district: It was observed that about 75 per cent cabbage farmers under assumption of constant returns to scale performed with efficiency level equal to 0.80 or greater in Jammu district. The average efficiency score was 0.99.

Table 3. Economics of cabbage cultivation across different districts of Jammu division (ha^{-1})

Particulars	Jammu			Samba			Udhampur		
	Bhalwal	Marh	Overall Avg.	Vijaypur	Samba	Overall Avg.	Udhampur	Chenani	Overall Avg.
Cost of cultivation (Rs ha^{-1})	25322	24433	24877	23895	25425	24660	25229	24425	24827
Average Yield (q ha^{-1})	220	255	238	213	238	225	200	250	225
Average cost of production (Rs q^{-1})	115	96	105	112	107	110	126	98	110
Average price received (Rs q^{-1})	514	592	552	506	579	544	550	575	563
Gross returns (Rs ha^{-1})	113137	150863	131323	107738	137750	122288	110000	143750	126563
Net returns over cost A1 (Rs ha^{-1})	87815	126431	106446	83843	112325	97628	84771	119325	101736
Net returns (Rs q^{-1})	399	496	447	393	472	434	424	477	452

Table 4. Efficiency measures and descriptive statistics for Cabbage producing farms according to scale of operations in various districts of Jammu division

Districts	Technical efficiency	Efficient farms ($\geq$90)		Efficiency measures	
		No.	%	Mean	Std. Dev.
Jammu	Constant returns to scale	30	75.0	0.99	0.01
	Variable returns to scale	32	80.0	0.94	0.02
	Scale efficiency	33	82.5	0.95	0.01
Udhampur	Constant returns to scale	30	75.0	0.89	0.11
	Variable returns to scale	34	85.0	0.99	0.12
	Scale efficiency	35	87.5	0.90	0.10
Samba	Constant returns to scale	31	77.5	0.88	0.12
	Variable returns to scale	36	90.0	0.90	0.02
	Scale efficiency	35	87.5	0.89	0.13

Based on this, it could be inferred that remaining 10 farmers, which did not operate at the maximum efficiency level, could reduce the input level and maintain the same level of cabbage production as achieved by 75 per cent of the farmers. When the assumption of constant returns to scale was relaxed and the model with variable returns to scale was calculated, the impact of production scale on technical efficiency level was visible. In cabbage farms, the number of efficient farms increased to 80 per cent. These better results from the model with variable returns were mainly due to the inclusion of scale efficiency, which the previous model did not take into consideration. As regards to the scale efficiency, 82.5 per cent of cabbage farms (33 out of 40 farms) either performed at the optimum scale or were close to the optimum scale (farms having scale efficiency values equal to or more than 0.90).

Udhampur district: It was observed that about 75 per cent cabbage farms under assumption of constant returns to scale performed with efficiency level equal to or greater than 0.90. The average efficiency score was 0.89. Based on this, it could be inferred that remaining 10farmers, who did not operate at the maximum efficiency level, could reduce the input level by 11.45 per cent and maintain the same level of cabbage production. The number of efficient farms when variable returns to scale was used increased to 85 per cent and the average technical efficiency score increased to 0.99. As regards to the scale efficiency, 87.5 per cent of cabbage farms either performed at the optimum scale or were close to the optimum scale (farms having scale efficiency values equal to or more than 0.90).

Samba district: It was observed that about 77.5 per cent under assumption of constant returns to scale performed with efficiency level equal to 0.90 or greater. The average efficiency score was 0.88. Based on this, it could be inferred that remaining farmers, which did not operate at the maximum efficiency level, could reduce the input level by 12.88 per cent and maintain the same level of production. The number of efficient farms when variable scale to returns

Table 5. Prices Spread of cabbage through different marketing channels(Rs q^{-1})

Particulars	Jammu			Samba			Udhampur		
	Channel I	Channel II	Channel III	Channel I	Channel II	Channel III	Channel I	Channel II	Channel III
Producer's level									
Sale price	583	583	583	562	562	562	571	571	571
Producer's expenses									
Packing	21	21	-	17	17	-	15	15	-
Weighing charges	7	7	-	10	10	-	10	10	-
Loading/unloading	10	10	-	15	15	-	13	13	-
Transport	35	35	14	32	32	15	27	27	12
Tax/market fee	10	10	-	10	10	-	10	10	-
Commission @7%	41	-	-	39	-	-	40	-	-
Others	-		4	-	-	2	-	-	3
Total costs	124	83	18	123	84	17	115	75	15
Spoilage due to physical injury and rotting, etc. (PHL)	12	12	15	5	5	9	4	4	9
Net sale price	447	488	550	434	473	536	452	492	547
Retailer's level									
Purchase price	583	583	-	562	562	-	571	571	-
Expenses incurred									
Transport	56	56	-	47	47	-	45	45	-
Packing	19	19	-	21	21	-	21	21	-
Loading/unloading	12	12	-	10	10	-	10	10	-
Rehri/ shop rent	11	11	-	10	10	-	9	9	-
Total costs	98	98	-	88	88	-	85	85	-
Spoilage due to physical injury and rotting, etc. (PHL)	16	16	-	13	13	-	15	15	-
Marketing Margin	215	215	-	200	200	-	184	184	-
Consumer price	912	912	583	863	863	562	855	855	571
Producers' share in consumers' rupee (%)	49.15	53.51	94.34	50.21	54.81	95.37	52.87	57.54	95.80

was used increased to 90 per cent and the average technical efficiency score increased to 0.90.

Marketing Analysis

The major items of producer's expenses included packing, weighing charges, loading/unloading charges, transportation cost and market fee. In channel – I, commission of the forwarding/ commission agent was also added to the marketing cost in addition to other costs. These costs varied to the extent of lowest of Rs. 15 q^{-1} in Udhampur district incurred in channel – III to Rs. 124 q^{-1} incurred in channel in Jammu district. Per quintal marketing cost incurred on commission in all the districts was found in channel I only with its value ranged between Rs. 39 in Samba to Rs. 41 in Jammu district. The cost incurred on other components in channel I and II in all the districts was found to be same.

Marketing cost borne by the retailer in channel I and II was found to be same with its value ranged between Rs.85 q^{-1} in Udhampur to Rs. 98 q^{-1} in Jammu district. The table further revealed that the q^{-1} maximum cost was incurred on transportation in all the districts and highest (Rs. 56) was found in Jammu followed by Rs. 47 in Samba and Rs. 45 in Udhampur. The perusal of the data further indicated that in channel III whole of the marketing cost was borne by the producer as there was the direct marketing of produce. The q^{-1} marketing margin of the retailer was Rs. 215 in Jammu district followed by Rs. 200 in Samba district and Rs. 184 in Udhampur district.

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Impact of Government Policy Intervention in Procurement of Wheat in Jammu Region of Jammu and Kashmir State

Rajinder Peshin, Rakesh Sharma*, Rakesh Nanda, L. K. Sharma, Raj Kumar, Sudhakar Dwivedi, Vinod Gupta and K. S. Risam

Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 001, India
**E-mail: sharmar1975@gmail.com*

Abstract: A study was undertaken to analyze the impact of government intervention in procurement of wheat in the sub-tropics of Jammu Region in Jammu & Kashmir State. In *rabi* marketing season (RMS) 2013-14, the farmers in Group I [where Procurement Centres (PCs) were setup in RMS 2012-13 and 2013-14], Group II (where PCs were setup only in RMS 2013-14) and Group III (where "PCs" were neither set up in RMS 2012-13 nor in 2013-14) got Rs 107, Rs 80 and Rs 38 higher q^{-1} respectively than the minimum support price (MSP). Thus, the indirect benefit of government policy to procure wheat through PCs to Group-I compared to the Group-II was to the tune of Rs. 27 q^{-1}, which was not statistically significant. In case of Group-I and III the difference was Rs. 42 q^{-1}, which was statistically significant. This shows that the establishments of PCs have benefited the farmers by having healthy competition between private players and government intervention. Thus, it is concluded that the setting up of PCs created healthy competition in the market, had broken the monopoly of private players, and reduced the distress sale of produce by famers below MSP.

Key Words*:* Impact assessment, Procurement centres, Rabi marketing season, Wheat

The procurement policy is part of national commitment to make the minimum support price (MSP) policy effective. The procurement operations aim at enabling farmers to get remunerative prices for their produce and prevent distress sale. The Food Corporation of India (FCI) under the Department of Food and Public Distribution and other designated state agencies undertake procurement of cereals (wheat and rice). The coarse grains are being procured by the state governments and its agencies under MSP operations and for oilseeds and pulses, the task is performed by the National Agricultural Cooperative Marketing Federation of India Limited (NAFED) and its designated agencies in the various states. The procurement for cotton and jute, is done by the Cotton Corporation of India (CCI) and Jute Corporation of India (JCI) along with their related agencies. The farmers are at liberty to sell their produce to the procurement agencies at MSP or in the open market, whichever is advantageous to them. The government policy of procurement of food grains has the broad objectives of ensuring MSP to the farmers and ensures effective market intervention, thereby keeping the prices under check. The basic purpose of these policies is to achieve the target of cereal crops and to ensure farmer's higher income (Dorosh and Salam, 2008).

In the state of Jammu and Kashmir (J&K), there was no procurement policy in place for procurement of rice and wheat till 2010. The Government of J&K in collaboration with the Directorate of Consumer Affairs and Public Distribution (CAPD) Jammu, FCI and Department of Agriculture started the procurement of rice and wheat in 2010-11 for the first time, to avoid distress sale of the produce by farmers. In *rabi* marketing season (RMS) 2011-12, the procurement of wheat was to the tune of 92500 quintals (q) was achieved through seven procurement centers (PCs) established by the Government of J&K (Anonymous, 2012). A study was commissioned by the Department of Agriculture Jammu, to find out the impact of government intervention in procurement of wheat. However, in RMS 2013-14, no procurement was made at the PCs and it was therefore challenging to study the impact of government intervention in RMS 2013-14.

MATERIAL AND METHODS

The study was conducted in the districts of Samba, Kathua, Jammu and Udhampur of sub-tropics of Jammu division. These districts were selected purposively for the study as wheat PCs were set up in these districts in RMS 2013-14. Non-equivalent with/without control group research design was employed to study the impact. In this, the sampled farmers were divided into 3 groups, i) Group I: where wheat PCs were set up in RMSs 2012-13 and 2013-14, ii) Group II: where PCs were set up only in RMS 2013-14, and iii) Group III: where wheat PCs were neither setup in RMS 2012-13 nor in 2013-14. With PCs/without PCs, and before (RMS 2012-13)/ after (RMS 2013-14) was employed for finding the impact on market prices in these 3 groups.

Sampling plan: Multistage sampling technique was employed for selecting the final sample.

Stage I: All the PCs namely Khour, Pragwal, Channu Chak, Gajansoo, Swankha Morh, Sanji Morh and R.S. Pura were selected for the study. In addition, all the PCs set up during the 2013-14 RMS namely Jourian, Banachak, Sohanjana, Banachak, Ramgarh, Parole Nagri, and Udhampur were also selected. For selecting the control villages under Group III, in each of the sub-division namely Akhnoor, Marh, R.S.Pura, Samba, Hiranagar and Udhampur, the list of the villages were downloaded from the respective district websites and Census 2011 website for drawing random sample without replacement. However, the villages where 12 PC were set up were excluded for drawing the sample.

Stage II: For drawing the sample of respondents in Group-I, a list of farmers who had marketed their wheat produce at PCs in RMS 2012-13 was procured from FCI Jammu. From the list, for each PCs, a random sample of 15 farmers was drawn and out of which at least 10 farmers from each centre were interviewed. Thus, total sample size selected and interviewed was 74. In Group II, where the PCs for wheat were set up for the first time in RMS 2013-14, no actual procurement had taken place. Therefore, with the help of Department of Agriculture officers, a list of wheat growers of the villages namely Jourian, Sohanjana, Banachak, Parole Nagri, Ramgarh (Keso), Udhampur (Meldi) were prepared, and from the list of each village a sample of 15 wheat growers were drawn by random sampling without replacement. This was done to ensure that at least 10 farmers are administered the interview schedule for data collection (Table 1). In Group III, out of the randomly selected 9 villages, the list of wheat growers was prepared. From the list of each village a random sample of 15 farmers was drawn. Thus the total sample for these 9 villages was 135 out of which 91 wheat growers were interviewed. Thus, the total sample size for present study was 225.

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RESULTS AND DISCUSSION

Socio-economic profile of wheat growers: The mean age of the sampled farmers in Group-I and Group-II was about 50 years where as in Group-III, it was about 53 years (Table 1). The average education was highest in case of Group-I, followed by Group-II and Group-III. This indicates that the farmers who availed the procurement facility in RMS 2012-13 were having higher education level and is in agreement with the results of the study on impact of government intervention in procurement of rice in 2012-13 (Peshin *et al.,* 2013).The average farming experience ranged between 21 and 24 years with the average family size between 6.23 and 7.39 members per family. The average land holding of the respondent farmers in Group-I was 3.40 ha (Table 2). The average owned land holding of this group was far higher than the average land holding of the farmers in the Jammu region, which stands at 0.91 ha (DES 2012). This indicates that the

Table 1. Sampling plan for the study

Group I*			Group II*			Group III*		
Procurement centres	N_1	n_1	Procurement centres	N_2	n_2	Randomly selected villages	N_3	n_3
Akhnoor sub-division (District Jammu)								
Pargwal	260	11	Jourian	79	11	Garkhal	100	09
Khour	46	10				Muthi	151	10
Marh sub-division (District Jammu)								
Gajansoo	192	11	Sohanjana	53	09	Shikhapir	22	09
Channu Chak	202	11				Taro chak	55	11
R.S.Pura sub-division (District Jammu)								
R.S.Pura	182	11	Banachak	53	10	Khana chak	67	10
Samba sub-division (District Samba)								
Swankha Morh	60	10	Keso	162	10	Rarian	77	12
Hiranagar sub-division (District Kathua)								
Sanji Morh	47	10	Parole Nagri	194	10	Chakdrabkhan	65	10
Udhampur sub-division (District Udhampur)								
			Meldi	29	10	Satani/Ghard	71	10
						Phangyali	58	10
07	989	74	06	570	60	09	666	91

*Group-I: Where wheat "Procurement Centers" were setup in RMSs 2012-13 and 2013-14

**Group-II: Where wheat "Procurement Centers" were setup only in RMS 2013-14

***Group-III (control group): Where wheat "Procurement Centers" were neither set up in RMS 2012-13 nor in 2013-14 large holding size farmers have higher marketable surplus. The farmers of Group-I had also leased-in land, on an average 0.88 ha, which is almost equal to the average land holding size of the Jammu region. The farmers of the Group-II had an average owned land holding of 1.53 ha. Similarly, in the Group-III, the average owned land holding was 1.19 ha, and leased-in was 0.18 ha (Table 2). In these two groups, the average owned land holding is comparatively same to the average land holding size of the Jammu region.

The farmers of Group-I where PC were setup in RMS 2013-14 were at an average distance of 4.26 km from the nearest PCs. Though in Group-II the farmers residing around a PC were studied and distance of the nearest PCs was 1.51 km, but the facilities were not availed by the farmers as the produce price of wheat was higher in the open market. From this we can imply that the distance is not a limiting factor if it is economically beneficial for getting the higher price of the produce.

Production, marketed surplus and market price: In case of Group-I, the land holding were large, therefore, the higher production as well as higher marketed surplus, which was to the tune of 83.10% in RMS 2012-13, whereas it was 70.60% in Group-II and 52.46% in Group-III (Table 3). In RMS 2013-14, in Group-I the marketed surplus was 82.64%, whereas, in Group-II it was 67.96%, and Group-III it was only 49.41%.

Impact of procurement policy: The MSP of wheat in RMS 2012-13 was Rs. 1285 q^{-1}, whereas from our selected samples, it was worked out to be Rs. 1283 q^{-1} because the PCs used to deduct some amount for cleaning of wheat. In case of the farmers of Group-II, where there were no PCs in RMS 2012-13, the mean market price was Rs. 1180 q^{-1} (SD=108.78). In Group-III also the market price was significantly lower compared to Group-I and Group-II, and the standard deviation was higher than Group-II. This shows that the PCs fetched higher market price of wheat produce to the farmers in RMS 2012-13, amounting to Rs. 103 q^{-1} compared to Group-II and Rs. 157 q^{-1} compared to Group-III, and both the differences were statistically significant at $p < 0.01$ (Table 4). Therefore, 989 wheat growers (as per the list provided by FCI),who sold their produce PCs in RMS 2012-13 had generated an additional income of Rs. 1,28,367 with Rs.130 q^{-1} compared to the farmers who sold their surplus produce in open market. These results confirm that PCs benefitted the farming community and are in line with finding of Peshin *et al.* (2015) that the setting up of PCs had broken the monopoly of private players, created healthy competition and reduced the sale of produce by famers below MSP.

In case of Group-I where PCs were set up in RMS 2012-13 and RMS 2013-14, the private millers and dealers on an average purchased wheat at Rs. 1457 q^{-1} (with standard error mean 9.28) thus providing on an average Rs. 107 q^{-1} higher than the MSP of Rs. 1350 q^{-1}. Whereas, in

Table 2. Descriptive statistics of the sampled group of farmers

Parameters	Group-I (n=74)	Group-II (n=60)	Group-III (n=91)
Mean age (years)	50.05 ±12.60	49.63 ±14.71	52.91±12.51
Mean education (Formal schooling years completed)	10.18 ±3.28	8.73 ±3.65	7.27 ±4.24
Farming experience (years)	21.04±13.37	23.73±14.64	22.93 ±13.07
Family members (no.)	7.39 ±4.03	6.23 ±3.39	7.12 ±4.47
Mean operational farm size (ha)			
i. Owned	3.40 ±4.10	1.53 ±1.25	1.19 ±1.14
ii. Leased in	0.88 ±2.06	0.17 ±0.50	0.18 ±0.82
iii. Leased out	0.02 ±0.10	0.02 ±0.15	0.01±0.09
Operational land holding(ha) (i+ii-iii)	4. 28 ±5.33	1.68 ±1.33	1.37±1.68
Irrigated (ha)	3.69 ±4.00	1.38±1.42	0.98 ±1.66
Un-irrigated (ha)	0.62 ±1.92	0.30 ±0.69	0.41 ±0.67
Distance from PC (km)	4.26 ±5.35	1.51 ±1.28	4.00 ±2.40

Note: Figures in the parentheses are standard deviations (SD)

Table 3. Production, marketable surplus and sale price

Group	RMS 2012-13				RMS 2013-14			
	Production (q)	Marketable surplus (q)	Marketable surplus (%)	Sale price ($Rs.q^{-1}$)	Production (q)	Marketable surplus (q)	Marketable surplus (%)	Sale price ($Rs.q^{-1}$)
I	7621.80	6336.07	83.10	1283 (12.52)	8578.94	7089.60	82.64	1457 (77.12)
II	2047.50	1445.50	70.60	1180 (108.78)	2360.15	1604.00	67.96	1430 (89.42)
III	1936.85	1016.00	52.46	1126 (128.42)	1896.34	937.00	49.41	1388 (131.36)

Group-II where PC setup for the first time, private dealers purchased the wheat at an average price of Rs.1430 q^{-1}, higher than MSP per quintal. In case of the Group-III, where there was no PC established in both the years, the private buyers purchased wheat on average price of Rs.1388 q^{-1}, which was Rs. 38 q^{-1} higher than the MSP. The indirect benefit to Group-I compared to the Group-II was to the tune of Rs. 27 q^{-1}, which was not statistically significant (Table 4). In case of Group-I and III, the difference was Rs. 42 q^{-1}, which was statistically significant ($p < 0.05$) (Table 4). This shows that the PCs especially in Group-I and in Group-II have benefited the farmers by having healthy competition between private players and government intervention. In the absence of government intervention of procuring wheat, farmers' profit margins have been taken by middlemen as reported Khan et al 2013. Whereas in Group-III, there was no competition; the farmers were taken for a ride by the private buyers, who on an average saved Rs. 150 q^{-1} by purchasing directly from the farmers as the FCI sale price of procured wheat was Rs. 1538 q^{-1}, higher by 10.80%. Thus, the results revealed that the PCs created competition in the market and private millers and buyers aggressively purchased the wheat produce directly from farmers, and increased per quintal wheat prices above MSP of Rs.1350 as high as Rs.1600 q^{-1}. The study further revealed that the farmers who had sold their marketable surplus wheat at PCs in RMS 2012-13, on an average got higher market prices of wheat (Rs.1457 q^{-1}), followed by the villages in which PCs were set up for the first time in wheat in RMS 2013-14 (Rs.1430 q^{-1}) and prices were lowest where there was no PCs either in 2012-13 or 2013-14 marketing seasons (Rs.1388 q^{-1}).

In RMS 2013-14, none of the sampled farmers had sold their produce at the PCs, but all the farmers of Group-I highly appreciated the government policy, thereby stopping distress/ forced sale. About 57% of the farmers of Group-I reported that government intervention has provided better price of their produce, 34% reported that it has created competition in the market and 7% reported that there is less exploitation of the farmers by the dealers (Table 5). While analyzing the impact of the procurement, Gulati and Sharma (1990) found that the procurement prices are the major factor driving the market prices.

Suggestions of the farmers for improving the functioning of PCs: The farmers also offered suggestions for improving the mechanism of procurement. The major suggestions were: setting of PCs for early disposal (16%), creation of better infrastructure facilities (29%), reducing the charges made by the PCs for labour, cleaning, etc (15%), proper electricity arrangements for facilitating weighing even at late hours (13%), bonus over MSP like in some other states

Table 4. Impact of procurement policy on sale price of wheat crop

Year	MSP (Rs. q^{-1})	Sale price (Rs. q^{-1})			Mean difference in sale price (Rs. q^{-1})		
		Group I	Group II	Group III	Group (I-II)	Group (I-III)	Group (II-III)
RMS 2012-13	1285.00	1283 (1.48)	1180 (17.20)	1126	103* (17.30) P = 0.000	157* (17.04) P = 0.006	54* (19.33) P = 0.006
RMS 2013-14	1350.00	1457 (9.28)	1430 (13.63)	1388 (18.57)	27 (19.40)	69* (18.55) P = 0.000	42* (20.77) P = 0.047

Figures in the parentheses are mean std. error

Table 5. Benefits of the procurement centers as reported by sampled farmers (% farmers)

Benefits	Group I (n=58)	Group II (n=36)	Group III (n=21)
Better price	57	08	43
Higher market competition	34	40	33
Less exploitation by private buyers	07	00	10
Proper and timely payments	14	28	19
Proper weighing	10	22	10
Reduced monopoly	03	00	14
Assured market	07	00	00
Less fluctuation in prices	02	00	00
Beneficial even through time consuming	02	00	00
Less risky	03	00	00
No corruption	00	00	05

#Decimals have been rounded up to nearest whole numbers

Table 6. Suggestions of the farmers for improving the functioning of procurement centers (% farmers)

Suggestions	Group I (n=62)	Group II (n=23)	Group III (n=27)
Proper electricity arrangements	13	17	00
Timely establishment of PC	06	17	15
Early disposal	16	30	07
Better infrastructure facility	29	00	30
Less labour charges	15	00	15
Timely payment of cheque	15	00	04
Proper weighing	08	13	11
Transportation support for farmers	08	00	04
Cleaning charges should be abolished	15	13	30
Permanent procurement centre	23	09	00
Bonus facility like Punjab	06	17	00
Cash payment at PCs	13	00	15
Prior information of establishment of PCs	09	00	11
More PCs should be established	06	00	19
Availability of gunny bags in time	03	13	07
Better rates	03	00	00
Procurement agencies should be more	02	00	00
Proper labour arrangements	00	17	00
Rates should be more at PCs	00	13	00
Lifting of produce directly from field without cleaning	00	17	04

#Decimals have been rounded up to nearest whole numbers

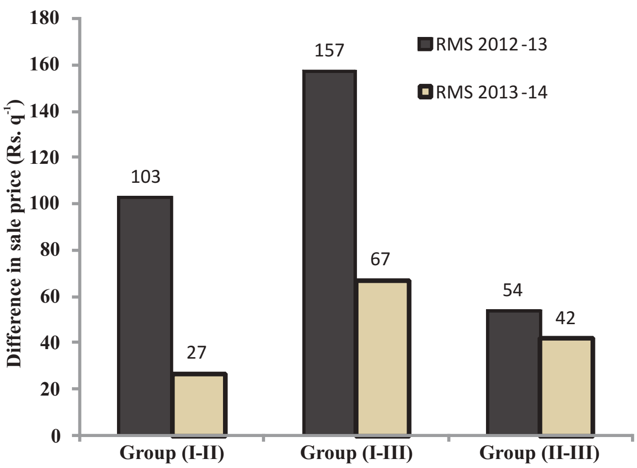

Fig. 1. Difference in sale price of wheat between GI, GII and GIII

(6%), setting up of permanent PCs (23%), abolition of cleaning charges at the PCs and prompt payment (15%). The detailed suggestions are provided in Table 6.

Thus, it is concluded that the setting up of PCs created healthy competition in the market, had broke the monopoly of private players, and reduced the sale of produce by famers below MSP. The government should not abandon the procurement policy and instead they should strengthen in by developing permanent PCs with all physical facilities like concrete floors storage sheds and other facilities. In case the government withdrawn this market facility the farmers will again go in hand of private players for distress sale as was the case earlier. Moreover, there is need to make wider publicity using different mass media for making farmers aware about the procurement centers and MSP.

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Production and Marketed Surplus of Vegetables under Protected Cultivation in Himachal Pradesh

Brij Bala, Priti Pari and K. D. Sharma

Choudhary Sarwan Kumar Himachal Pradesh KrishiVishvavidyalaya
Hill Agricultural Research and Extension Centre, Bajaura, Kullu-175 125, India
E-mail:balab72@gmail.com

Abstract: Protected cultivation technology got a big boost in the state under the NABARD sponsored scheme entitled 'Pandit *Deen Dayal Kisan Bagwan Samridhi Yojna'* that had an outlay of Rs. 154.92 crores. As a result, the production of commercial crops produced under protected cultivation regime has witnessed manifold increase. Fifty polyhouse beneficiaries were selected from Two blocks namely, Sunder Nagar and Balh, having maximum number of polyhouses through proportional allocation method. Capsicum, tomato and cucumber were the major crops grown during main season and frenchbean, spinach and coriander were taken as the filler crops. Among sampled farms, 72% were growing capsicum, 20% tomato and only 8% were growing cucumber. Per farm production was highest for capsicum followed by tomato and cucumber. About 2 to 6% of total produce was retained for utilizations while losses came out to be 1 to 8%. The marketable surplus of polyhouse produce was quite high (94-98%). And marketed surplus varied from 90-96 per cent. Lack of knowledge among farmers, non-availability of recommended inputs, defective construction of polyhouses, poor soil-testing facilities, and poor/no assistance for repair of polyhouses, were the major constraints. Encouraging marketing strategies that increase producers' share in consumers' rupee is required to be realised.

Key Words: Constraints, Marketed surplus, Protected cultivation technology, Production

Protected cultivation of vegetables offers distinct advantages of quality, productivity and favorable market price to the growers (Singh and Sirohi, 2008). In the times to come, protected vegetable production is likely to be common commercial practice not only because of its potential but out of sheer necessity. The protected cultivation technology holds special significance for Himachal Pradesh where arable land is scarce due to uneven terrain and holdings are small and fragmented. Polyhouse cultivation got a big boost under the NABARD sponsored scheme for the production of cash crops by adopting precision farming techniques. As a result, the production of commercial crops produced under protected cultivation regime has witnessed manifold increase. The present study was conducted to study the impact vegetables protected cultivation of vegetables. Efforts have been made to assess the bottlenecks/shortcomings hampering the promotion of protected cultivation, which will enable the research, extension and development agencies as well as the policy makers to address and minimize/remove all these problems and bottlenecks.

MATERIAL AND METHODS

The present study was conducted in Mandi district of Himachal Pradesh with the maximum number of polyhouses in the state. Fifty polyhouse beneficiaries were selected randomly from the list of beneficiaries of the selected two blocks (Sunder Nagar and Balh) through proportional allocation method. The selected beneficiaries were divided into two strata (small and large) using cumulative cube root frequency method. The polyhouse owners having an area of 252 m^2 and less under protected cultivation were categorized as small while those with an area of more than 252 m^2 were kept in the category of large farmers. Thus, in all 23 small and 27 large polyhouse units were selected in both the blocks.

The required data were collected through survey method on specially designed schedules for sampled farmers. The primary data from selected farmers were collected through personal interview method. The secondary information required for the study was obtained from various published/unpublished sources. The data were then tabulated and analysed using different analytical tools like tabular and statistical techniques.

Multiple linear regression model: To meet out the requirements of second objective i.e. factors influencing marketed surplus of different polyhouse commodities, multiple regression model was used. Based on the goodness of fit (R^2), linear regression model of the following form was used:

$$Y_i = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_4x_4 + U_i$$

where,

Y_i = Marketed surplus of i^{th} crop (q)
b_0 = Intercept
b_i = Regression coefficients (i = 1, 2….4)
x_1 = Volume of production (q/farm)
x_2 = Losses (q $farm^{-1}$)

x_3 = Average price received (Rs q^{-1})
x_4 = Family size (No.)
U_i = Random term

Significance of regression coefficient was tested by employing student-'t' test as follows:

$$t = \frac{bi}{SE(bi)}$$

where, SE (bi) = Standard error of regression coefficient.

RESULTS AND DISCUSSION

Socio-economic profile of sampled growers: The average family size in the study area was 5.52 persons comprising of 56.52 per cent males and 43.47 per cent females with 79.34 per cent adults (above 15 years) and 20.65 per cent children (below 15 years). The average size of family was more on large farms (5.59 persons $farm^{-1}$) as compared to small farms (5.43 persons $farm^{1}$). Most of the families had joint family structure (60%), where parents were living with their married children.

Sixty seven per cent working population ranged in the age group of 16-60 years, whereas, it was slightly lower on large polyhouse units (66.89%) as compared to small farms (67.20%). The overall sex ratio was 769 females per thousand male population. It was relatively higher on large polyhouse units (888) as compared to smaller ones (645).

Overall literacy rate was about 87 per cent (male literacy - 87.82% and females - 85%). Bala *et al.* (2011) also reported that the overall male literacy rate was higher (91.39%) as compared to females (84.77%) in Kullu, Mandi and Solan districts of H.P.. The literacy rate was slightly higher on large farms (87.41%) as compared to small farms (85.60%). More than 36 per cent of the population was educated upto matric and higher secondary and a very few were graduates and above (8%).

The size of holding was 1.20 hectare on an average farm, it was 1.32 ha. in case of large farms and 1.05 ha. on small farms. Seventy three per cent of the total land was cultivated and entire cultivated area was reported to be irrigated. The main sources of irrigation were canal, borewell, tubewell, stream etc. The average size of polyhouse units on sampled farms was 365 m^2 with 201 m^2 on small and 505 m^2 on large farms. Capsicum, tomato and cucumber were the major crops being grown during main season which lasted for 8-9 months and frenchbean, spinach and coriander were being taken as the filler crops during the remaining 3-4 months. Among sampled farms, 72 per cent were growing capsicum, 20 per cent tomato and only 8 per cent were growing cucumber. About 60 per cent farmers kept their polyhouses fallow, 34 per cent took frenchbean and 6 per cent opted for spinach and coriander as filler crop.

Production, marketable and marketed surplus of vegetable commodities: Among all the vegetables grown in polyhouse, per farm production was maximum in capsicum (19.81q/polyhouse) and lowest in case of coriander (0.012 q/polyhouse) on the overall farm situation (Table 1). Sharma *et al.* (2015) also reported that capsicum gave the highest yield among all the crops being grown under protected cultivation. The total production of all the vegetables grown in polyhouses was higher on large as compared to small farms. The total utilization varied from just 2 to 6 per cent. The per cent share of utilization to total production was lowest (2.85 per cent) in spinach and highest (4.69 per cent) in case of tomato. This was because the spinach crop lasted for two months only while the tomato crop took about 7-8 months and also the tomatoes are consumed daily. The total production kept for home consumption decreased with the increase in the quantum of production thereby indicating that the large farmers disposed off greater proportion of their total production as compared to small farmers.

The marketable surplus came out to be 94-98 per cent of total production for different vegetables grown in polyhouse under different farm categories. Bala (2013) reported that the marketable surplus varied from 90 to 95 per cent of the total produce of vegetables. Moreover, the marketed surplus was 90 and more than 90 per cent of the total production for all polyhouse vegetables under consideration. Post-harvest losses of produce during marketing were maximum in case of spinach followed by coriander and minimum in case of french bean. The green leafy vegetables *viz.,* spinach and coriander were kept in bundles and were more prone to spoilage. The losses in tomato were also considerably high (4.11%) because the tomato fruit is delicate and soft and even a minor injury spoilt the whole fruit. Bala (2013) also found that the post-harvest losses incurred ranged between 0.15 to 5 per cent and these were highest in tomato followed by capsicum and cauliflower in Kullu and Mandi districts.

Factors affecting marketed surplus: The importance of marketed surplus becomes even greater in view of the compulsion of small cultivators who resort to distress sale to meet urgent cash requirements. In the present analysis, total production, losses, prices and family size were considered to be important factors influencing the marketed surplus of vegetable crops. The result of multiple regression analysis reveals that total production turns out to be the most significant factor (Table 2). The marketed surplus was found to be positively related to the quantity of production and average price received by the producers whereas, size of family and losses showed inverse relationship with marketed surplus. Bala *et al.* (2013) observed that the losses incurred

Table 1. Production and utilization pattern of polyhouse produce on different categories of polyhouse units (per cent)

Vegetables		Total production (q farm^{-1})	Utilization (home consumption)	Marketable surplus	Losses	Marketed surplus
Tomato						
	Small	9.43	5.19	94.81	4.61	90.21
	Large	14.48	4.42	95.58	3.84	91.74
	Overall	12.16	4.69	95.30	4.11	91.19
Capsicum						
	Small	13.79	5.58	94.42	2.52	91.89
	Large	24.94	3.97	96.03	1.78	94.24
	Overall	19.81	4.49	95.51	2.02	93.49
Cucumber						
	Small	8.07	5.96	94.04	2.96	91.08
	Large	8.65	3.15	96.85	3.43	93.43
	Overall	8.38	4.39	95.61	3.22	92.39
Coriander						
	Small	0.01	4.00	96.00	4.00	92.00
	Large	0.01	2.78	97.22	5.56	91.67
	Overall	0.01	3.28	96.72	4.92	91.80
French bean						
	Small	0.09	5.00	95.00	2.50	92.50
	Large	0.87	3.19	96.81	1.06	95.74
	Overall	0.51	3.33	96.67	1.18	95.49
Spinach						
	Small	0.01	4.00	96.00	8.00	88.00
	Large	0.02	2.22	97.78	6.67	91.11
	Overall	0.01	2.86	97.14	7.14	90.00
All vegetables						
	Small	31.40	5.56	94.44	3.27	91.18
	Large	48.97	3.95	96.05	2.67	93.38
	Overall	40.88	4.51	95.49	2.88	92.61

varied from 1.6 to 6% and about 96-98.5% of the total produce was marketable surplus because very less proportion was retained for home consumption.

A close examination of results indicated that in case of tomato, the regression coefficients associated with production, losses and size of family were statistically significant implying that these variables had a significant impact on the marketed surplus. Total production was positively correlated with marketed surplus and thereby every quintal increase in total production would increase marketed surplus by 0.97 quintals. However, size of family and losses showed negative relationship to marketed surplus of tomato as the regression coefficient of size of family indicated that one member increase in family would reduce marketed surplus by 0.04 quintals keeping all other factors constant at their arithmetic mean levels. Similarly, regression coefficient of losses indicated that 1 per cent losses would reduce marketed surplus by 0.89 quintals. Prices were found to be statistically non-significant suggesting that there was no effect of this variable on the marketed surplus of tomato.

In case of capsicum, regression coefficient of total production was significant and positively related to marketed surplus and suggested that every quintal increase in total production would increase marketed surplus by 0.97 quintal. However, losses showed negative relation with marketed surplus that would reduce the marketed surplus by 0.99 quintals with one per cent increase in losses. Size of family and prices were found to be statistically non-significant showing less impact on marketed surplus of capsicum.

In case of cucumber, regression coefficient of total production and losses showed significant values while other factors included in the study were found to be non-significant. Total production was positively correlated with marketed surplus and with every quintal increase in production, there would be increase in marketed surplus of cucumber by 0.98 quintals. However, losses were negatively related with the marketed surplus and suggested that with one per cent increase in losses marketed surplus would reduce by 0.69 quintals.

The regression equation fitted for different polyhouse produce revealed high values of R^2 implying that the variables included in the model explained high variation in the marketed surplus (dependent variable). The values of R^2 in different equations were, by and large above 90 per cent, showing high explanatory power of the linear regression model applied.

Problems and constraints in success of protected cultivation: Most of the growers reported that the construction of polyhouses was faulty because of which the very purpose of polyhouses, to keep the pests away, was defeated. Lack of knowledge about the management of polyhouses was also one of the major constraints in the success of protected cultivation. Inadequate supply of recommended seed/inputs and inadequate help from service provider were other big problems faced by the farmers because the service providers could not reach each and every farmer when required urgently. Provision of subsidy for repair and insurance of polyhouses were lacking as per all the sampled farmers. Bala *et al.* (2013) opined that high cost of inputs, unfair weighing practices, lack of cooperatives and cold storage facilities were also some of the problems of vegetable growers.

Policy implications: The study implies that under protected cultivation, high quality vegetables can be produced with greater efficiency as compared to open farm cultivation. Thus, significantly high resource-use efficiency for all the inputs viz., land, labour, water, power etc. can be obtained under this technology, which paves the way for sustainable

Table 2. Estimated regression equations of marketed surplus of polyhouse produce

Vegetable	Intercept	Total Production	Losses	Prices	Size of Family	R^2
Tomato	-0.9226*	0.9668*	-0.8925*	0.0002	-0.0428*	0.9997
	(0.4125)	(0.0092)	(0.2965)	(0.0002)	(0.0270)	
Capsicum	-0.0746	0.9724*	-0.9904*	0.0001	-0.0103	0.9996
	(0.3484)	(0.0038)	(0.1626)	(0.0002)	(0.0190)	
Cucumber	-0.9528	0.9814*	-0.6857*	0.0001	-0.0126	0.9998
	(0.6376)	(0.0105)	(0.3199)	(0.0004)	(0.0345)	

* Significant at 1% level. Figures in parentheses indicate standard errors

Table 3. Problems and constraints faced by poly house producers

Problems/constraints	Response of farmers (%)		
	Small	Large	Overall
Seeds of recommended varieties/assured quality not available	78.26	77.78	78
Inadequate supply of recommended inputs	78.26	77.78	78
No agency for regular soil testing	43.45	55.55	50
Lack of plant clinics for problem diagnosis and solution	73.91	74.07	74
Lack of knowledge	86.9	74.10	80
Inadequate help from service provider	82.61	81.48	76
Faulty construction of polyhouse	88.90	76.10	82
Improper design of poly house structure	43.45	55.55	50
Improper site selection & water logging	26.07	33.33	30
Insufficient help from extension agencies	45.50	76.10	62
Inadequate water/ power supply	30.45	25.90	28
Polyhouse structure insurance not available	100	100	100
Timely credit not available	60.90	51.80	56
Polyhouse is damaged	17.38	14.82	16
No provision of subsidy for repair of polyhouse	100	100	100

growth. The production in polyhouses can be enhanced by improving the services with respect to implementation and extension. Proper construction of the polyhouses and their scientific management needs to be ensured. Suitable technologies need to be disseminated with utmost precision and full sincerity so that the technologies function successfully and the farming community gets encouraged to adopt more and more of them. Efficient and on the spot advisory services should be made available to the farmers to tackle various insect pest and other problems related to protected cultivation. The officials of state department of agriculture should also be imparted advanced trainings on protected cultivation so that they are able to provide proper advice to polyhouse beneficiaries. Post-harvest losses need to be checked by providing modern storage facilities to the farmers. Provision of insurance and subsidy for repair of polyhouses should be mandatory for promotion and success of the technology. Encouraging marketing strategies that enhance the producers'.

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Factors Affecting the Productivity of Rapeseed Mustard in Sub-tropics of Jammu

P. S. Slathia, L. K. Sharma, Rajinder Peshin, Rakesh Nanda and Raj Kumar

Division of Agricultural Extension Education
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha-180 009, India
E-mail: slathia2007@gmail.com

Abstract: Rapeseed mustard is an important edible oilseed crop in India but its production and productivity is low in India, and Jammu and Kashmir (J&K) state in particular. A study was conducted in Kathua and Samba districts of J&K to ascertain the factors impacting productivity of oilseed crops. The major findings of the study revealed that 68.38% of the total cultivated area of the sampled farmers was rain-fed. The area under rapeseed mustard crops was 19.65% of total cultivated area, and out of that 84.51% was rain-fed. Area under toria *(Brassica rapa)*, raya *(Brassica juncea)* and gobhi sarson *(Brassica napus)* was 71.31%, 10.22% and 18.47% of the area under rapeseed mustard, respectively. The extent of adoption of chemical fertilizers with respect to percentage of farmers was 52, 55 and 53 for urea and 82, 82 and 47 for diammonium phosphate (DAP) for toria, raya and gobhi sarson, respectively. The factors driving the oilseed productivity were analyzed and (DAP) significantly affected the productivity, causing a variation of 11, 36 and 62% in the productivity of toria, gobhi sarson and raya. Rest of the selected production factors namely application of urea, seed rate and sowing time were not causing any variation in the productivity of the sampled mustard growers.

Key Words: Gobhi sarson, Productivity, Rainfed, Raya, Toria

Among the nine edible oilseed crops in India, rapeseed mustard possesses a significant position. Rapeseed mustard group mainly consists of toria *(Brassica rapa)*, raya *(Brassica juncea)* and gobhi sarson *(Brassica napus)*. In India, it contributes nearly 80% of the total *rabi* oilseed production. Area under rapeseed mustard is 6.3 million ha with a production of 7.4 metric tonnes and productivity of 11.76 q ha^{-1} (DRMR, 2013). In terms of rapeseed mustard productivity, global ranking of India is 28th (Bhardwaj, 2013). There are variations in the production and productivity of rapeseed mustard in different states of the country. The productivity of rapeseed mustard in Jammu and Kashmir (J&K) is 6.98 q ha^{-1}, which is 41% less than the national average (DoA, 2013). In the subtropical areas of Jammu region rapeseed mustard is mainly cultivated in rain-fed areas. In rain-fed areas, area under toria crop is maximum, followed by gobhi sarson and raya. Farmers practicing wheat–maize crop sequence grow toria as an additional crop with judicious and utmost use of available natural resources. Keeping in view the low productivity of rapeseed mustard crops in the rain-fed areas of subtropics of Jammu, a study was undertaken to identify the factors affecting its distribution, choice and productivity.

MATERIAL AND METHODS

Samba and Kathua districts were selected because of maximum subtropical area under rapeseed mustard is in these two districts. A list of rapeseed mustard growers of these two districts was obtained from the state Department of Agriculture, Jammu. Out of the available list of 656 mustard growers, 120 mustard growers were selected by random sampling technique by using random number generator. The data was collected with pretested interview schedule consisting of both open and close ended questions. The collected data of 119 respondents was analyzed using SPSS software. Factors affecting productivity of rapeseed mustard crops were analyzed by linear regression method.

Linear regression model: Regression analysis is an important tool to analyze major factors impacting the productivity and to predict the contribution of these variables on productivity. The linear regression model was used to identify the independent variables impacting the dependent variables where dependent variable is continuous (yield). The result of this type of regression can be expressed as follows:

$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 \ldots b_kx_k$--------------------------------(1)

where, Y represents the continuous dependent variable (yield in q/ha) whose values are being modeled. The average yield of toria was 6.23 q ha^{-1} (S.D 3.26) with a minimum and maximum yield of 1.33 q ha^{-1} and 22 q ha^{-1}, respectively. The average yield of raya was 5.39 q ha^{-1} (S.D 3.14) with a minimum and maximum yield of 1.60 q ha^{-1} and 11 q ha^{-1}, respectively. The average yield of gobhi sarson was 8.64 q ha^{-1} (S.D 6.36) with a minimum and maximum yield of 2 q ha^{-1} and 35 q ha^{-1}. b_0 is the y-intercept and x_1 to x_k represent the k independent variables (where, x_1 is seed rate in kg ha^{-1}; x_2 is recommended sowing time; x_3 application of urea as 1st top dressing in kg ha^{-1}; x_4 application of urea as second top dressing in kg ha^{-1} and x_5 application of DAP in kg ha^{-1} in the model. The linear regression model was used to measure variation caused by independent variables namely: seed rate, sowing time, urea, and DAP on dependent variable yield of rapeseed mustard crops. The analysis was carried out by using SPSS 16.0 software. The importance of various factors (predictors) in the model was judged on the basis of standardized regression coefficients. For the validation of each model, model ANOVA and F value was there. The adjusted R^2 was used as a measure of determination of variation caused by predictors. The significance of model indicates that independent variables in the model cause significant variation in dependent variable.

RESULTS AND DISCUSSION

Descriptive statistics of the sampled farmers: Analysis of the data in Table 1 reveals that average age of the farmer was 54 years, majority of them were matriculate with average family size of 7 members. The data further showed that only respondent farmer himself was associated with farming in 56 percent of sampled farm households. From sampled farm households, only 17 per cent were exclusively dependent on on-farm income and rest of the farm households (83% percent) were also involved in other economic activities. This may be due to the fact that small and unirrigated land holding are not economically sustainable as seventy-three per cent of the respondents were having marginal and small landholding with average land holding of 1.38 ha ± 1.047 (Table 1). Thus for a majority of farm households (83%) farming is a secondary economic activity. In developing countries, besides farming, farm families are also engaged in non-farm economic activities, and their production patterns and input use depends on agro-ecological conditions (FAO, 2014; Peshin *et al.,* 2015). Seven per cent of the farmers had leased in the land with average leased in area of 0 .05ha. The total cultivated area of the respondent farmers was 169.25 ha out of which 20 per cent area was under the cultivation of rapeseed mustard crops, comprising of 71, 19, and 10 per cent under toria, gobhi sarson and raya, respectively (Table 2).

Table 1. Descriptive statistics of the sampled farmers (n=119)

Parameter	Statistics
Average age (years)	53.9 ±14.906
Education (% farmers)	
Illiterate	24
Primary	8
Middle	24
Matriculate	33
10+2	7
Graduate & above	4
Family size (No.)	6.9 ±3.964
Family members associated with farming (%)	
Farmer himself only	56
Farmer + one family member	26
Farmer +2 family members	8
Farmer + more than 2 family members	11
Farm households exclusively dependent on farm income (%)	17
Average land holding	1.38±1.047
Size of landholding (% farmers)	
Marginal (<1 ha)	39
Small (1-2 ha)	34
Semi-medium (2-4ha)	27

± is S.D.

Table 2. Total area under rapeseed mustard crops (n= 119)

Crops	Area (ha)
Total cultivated area under different crops	169.25
Area under rapeseed mustard crops	33.25
Toria	23.71
Gobhi sarson	6.14
Raya	3.40
Per cent area under rapeseed crops	19.65
Percent irrigated area under rapeseed mustard	16.00

Adoption of the cultivation practices: One hundred nine framers (92%) had cultivated toria, 29 per cent cultivated gobhi sarson, whereas a small percentage of 9 had cultivated raya. Only 3 (toria), 36 (raya) and 21 (gobi sarson) per cent farmers had cultivated Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST-Jammu) developed and recommended varieties (namely toria: RSPT-1, gobhi sarson: GSL-1, GSL-2 and DGS-1) . Data presented in Table 3, further shows that farmers using recommended seed rate in case of toria (5kg), raya (5kg) and gobhi sarson (5kgs) were 34, 45 and 68 per cent, respectively. Farmers had used seed rate as high as 20 kg ha^{-1}. The main reasons for using higher seed rate than recommended were: lack of knowledge about recommended seed rate and thinning of the crop for the purpose of green vegetable by the farmers. As for as mixed cropping is concerned only 17 per cent farmers had cultivated toria as mixed crop with gobhi sarsoon and raya. 36 per cent of farmers had cultivated raya as mixed crop with other oilseed crops. Gobhi sarson was cultivated as a mixed crop by 41 per cent.

A large majority of farmers, 89 per cent had sown toria on recommended dates of sowing (mid of September) and 82% of farmers had sown gobhi sarson within recommended period of sowing (5th-15th October). Only 18 per cent farmer had cultivated raya within recommended period of sowing (upto 15th October).

Urea was applied in toria, raya and gobhi sarson by 52, 55 and 53% of the sampled farmers, respectively (Table 4). The analysis of data in Table 4 shows that 26, 18 and 15 per cent farmers applied basal dose of urea in toria, raya and gobhi sarson, respectively. About 9, 9 and 12 per cent respondents applied urea after sowing, whereas,18, 45 and 26 per cent farmers applied urea in the first top dressing in toria, raya and gobhi sarson, respectively. Only 3 per cent of the farmers had applied urea as second top dressing in toria and gobhi sarson and rest of the farmers did not give second top dressing of urea. DAP was applied by 82, 82 and 47 per cent farmers in toria, raya and gobhi sarson, respectively. There was negligible use of MOP. The average quantity of DAP in toria, raya and gobhi sarson application was 73.95, 52.45, 43.33 kg, against a recommended dose of 40, 65 and 65 kg ha^{-1}, respectively. There was lot of variation in use of different fertilisers. The results are in conformity with Lakhera *et al*. (2011) from Bharatpur district of Rajasthan and Dudi *et al.* (2012) from Pali district of Rajasthan where farmers apply more than recommended urea and DAP fertilizers, thus incurring wasteful expenditure on fertilizers.

Factors affecting productivity of rapeseed mustard crops: Average productivity of toria, raya and gobhi sarson was 6.23, 5.39 and 8.64 q ha^{-1}, respectively (Fig.1). This is

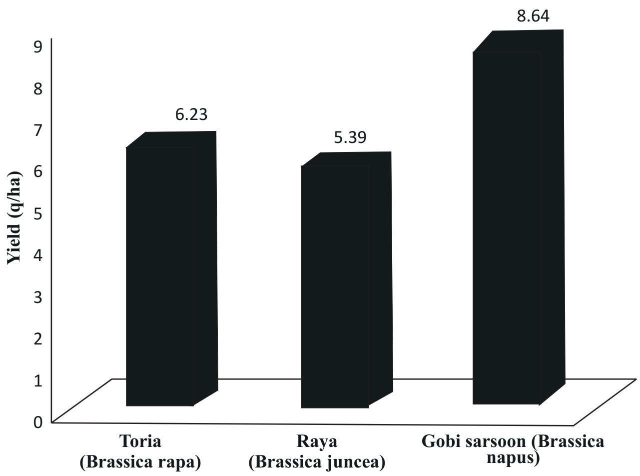

Fig.1. Productivity of rapeseed mustard in sub-tropics of Jammu

Table 3. Cultivation practices adopted by the sampled farmers (n=119)

Practice	Toria (n=109)	Raya (n=11)	Gobhi sarson (n=34)
Cultivation of recommended varieties (% farmers)	3	36	21
Low seed rate (kg ha^{-1})	3.12	3.00	1.50
Max. seed rate (kg ha^{-1})	20	20	20
Recommended seed rate (5 kg ha^{-1})			
As per recommendations (%)	34	45	68
More than recommendation (%)	64	28	21
Less than recommendation (%)	2	27	11
Sown as mix crop (%)	17	36	41
Sown as sole crop (%)	83	64	59
Sown on recommended time (%)	89	18	82

Table 4. Use of chemical fertilizers in oilseed crops (n=119)

Particulars	Toria (n=109)	Raya (n=11)	Gobhi sarson (n=34)
Urea application (% farmers)	52	55	53.00
Basal dose	26	18	15
After sowing	9	9	12
First top dressing	18	45	26
Second top dressing	3	0	3
DAP (% farmers)	82	82	47
MOP (% farmers)	1	0	0
Average fertilizers use (kg ha^{-1})			
Urea	33.74(±41.34)	0.0	28.17(±32.70)
DAP	73.95(± 48.95)	52.45(±37.31)	43.33± (47.20)
MOP	0.36± (3.83)	0.0	0.0

Figure in parentheses indicate standard deviation

Table 5. Factors affecting productivity of rapeseed mustard crops

Variable	Toria				Gobhi sarson				Raya			
	B	Std. Error	t value	Sig.	B	Std. Error	t value	Sig.	B	Std. Error	t value	Sig.
Constant	3.851	0.925	4.162	0.000	7.056	2.620	2.694	0.012	4.406	2.667	1.652	0.150
Seed rate	0.138	0.086	1.599	0.113	-0.230	0.318	-0.722	0.477	0.228	0.155	1.475	0.196
Date of sowing	0.529	0.458	1.154	0.251	0.133	0.751	0.177	0.861	-1.730	1.073	-1.612	0.158
Urea 1st topdressing	-0.012	0.014	-0.901	0.370	-0.067	0.040	-1.669	0.107	-0.013	0.028	-04.6	0.699
Urea 2nd topdressing	-0.033	0.030	-1.117	0.267	0.009	0.073	0.125	0.902	-	-	-	-
DAP	0.015	0.006	2.349	0.021*	0.083	0.023	3.570	0.001*	0.104	0.042	2.459	0049*

R^2 (toria) 0.112; R^2 (gobhi sarson) 0.357; R^2 (raya) 0 .617

nearer to state productivity of oilseed crops (6.98 q ha^{-1}). The productivity of rapeseed mustard crops mainly depends upon adequate and timely application of different inputs. Effective management of natural resources, integrated approach to nutrient and pest management and increase of area under rapeseed-mustard cultivation under different cropping systems. The factors impacting productivity were analysed by general linear regression model.

Application of DAP was significantly affecting the productivity of all three rapeseed mustard crops under study namely toria, raya and gobhi sarson. Rest of the selected production factors namely application of urea, seed rate and sowing time were not significantly affecting the productivity of toria raya and gobhi Sarson (Table 5). Though, other studies have shown that application of nitrogenous fertilizers in split doses (Reager *et al.,*2006) and application of phosphatic fertilizers increases productivity (Shekhwat *et al.,* 2013), however, in the study the variable selected for finding the factors affecting productivity, application of DAP was found affecting the productivity of rape seed crops.

Dutta (2014) conducted a study at Pulses and Oilseed Research Station, West Bengal, Kolkata and found that one of the major constraints for low productivity of rapeseed mustard crop was due to non-adoption of recommended package of practices mainly the variety of the crop. Akbar (2011) also found that the productivity of rapeseed mustard per unit area can be increased by adopting recommended scientific and sustainable management practices and by using suitable high yielding varieties. Though irrigation is a limiting factor in productivity, number of farmers cultivating oilseed crops under irrigated conditions being low, it did not cause any variation when entered in the linear regression model.

CONCLUSION

Majority of the farmers were cultivating non-recommended toria varieties under un-irrigated conditions and applying higher seed rate. Toria crop attained early maturity resulting in enough time for sowing of succeeding wheat crop. The farmers used to apply urea and DAP but variations have been observed from the recommended dosages. However, horizontal and vertical intensification of rapeseed-mustard production needs to be done for self-sufficiency in oilseed production. Besides, training interventions for farmers should be organized frequently about production recommendations of rapeseed mustard for increasing productivity. The researchers need to be prioritize their research on toria for rain-fed areas in J&K.

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Scientific Rationality and Adoption of Indigenous Field Bean (*Lablab purpureus (L.) Sweet*) Cultivated by Tribal Farmers of Tamil Nadu

P. Venkatesan, M. Sundaramari[1] and Surya Rathore

National Academy of Agricultural Research Management, Rajendranagar, Hyderabad -500 030, India
[1]Gandhigram Rural Institute, Gandhigram, Dindigul-624301, India.
E mail: venkatesan@naarm.ernet.in

Abstract: The tribes of the Kolli hills of Namakkal district in Tamil Nadu possessed rich tradition, heritage and experience in agriculture. Their rich wisdom in, Indigenous Tribal Agricultural Practices (ITAPs) of field bean *(Lablab purpureus (L.) Sweet)* can effectively be utilized for sustainable agricultural development of tribal areas. Ten ITAPs on field bean, in different clusters of villages of Kolli hills were documented. For assessing the rationality, the selected ITAPs were sent to 50 horticulturists and 50 plant protection scientists. Out of 10 selected ITAPs, 8 ITAPs were rational and 2 ITAPs were irrational. Overall extent of adoption of ITAPs was found to be more than 75 per cent as they were practiced for quite long time. The rational and effective ITAPs should be blended into the technology package for transfer of technology for sustainable agricultural development.

***Key Words*:** Adoption, Field beans, Indigenous, Rationality, Tribal Agricultural Practices, Tribal farmers

Tamil Nadu State in India is a treasure land of indigenous tribal technical knowledge in agriculture and allied activities. The Malayali tribal groups in Tamil Nadu, mostly found in Kolli Hills, have rich cultural and agricultural heritage which is situated in the Namakkal district of Tamil Nadu, South India, spread over an area of 441 sq.km at the tail end of the Eastern Ghats in the state of Tamil Nadu. The tribes in Kolli Hills were more traditional in nature having faith in the practices of the local communities. They managed their livelihood through agriculture and maintained a traditional life style through their indigenous knowledge system. They cultivated indigenous field beans (*Lablab purpureus* (L.) Sweet). The contribution of indigenous communities to the conservation and sustainable use of biological diversity goes far beyond their role as natural resource managers, their skills and techniques provide valuable information to the global community and a useful model for biodiversity policies. As on-site communities with extensive knowledge of local environments, indigenous and local communities are most directly involved with conservation and sustainable use, their rigid social structure with lesser social mobility had kept them away from scientific and technological progress. The on-going practice of using such indigenous knowledge on field beans cultivation by ethnic communities established the belief that traditional knowledge used was fruitful for the people. Hence, studying Indigenous Tribal Agricultural Practices (ITAPs) of tribes on Field beans cultivation in Kolli Hills will be helpful for proposing an action paradigm for preservation and diffusion of desirable cultivation aspects for the benefit of the tribal farming community. Keeping this in view, a study on scientific rationality and adoption of Indigenous Tribal Agricultural Practices on Field beans was carried out. This paper discusses about the indigenous Field beans adopted by tribal farmers in Kolli hills of Tamil Nadu.

MATERIAL AND METHODS

Kolli Hills is situated in the Namakkal district of Tamil Nadu, South India (78° 17' 05" E to 78° 27'45" E and 11° 55' 05" N to 11° 21'10" N) are a low ranging hills of Eastern Ghats spread over an area of 441 sq.km. Kolli Hill has an area of 282. 92 sq.km. It stretches 29 kms from north to south and 19 km from east to west. The Mean annual temperature ranges from 14°C to 28°C.The area receives an average of 1440 mm of annual rainfall distributed fairly over the two seasons. The elevation ranges between 1000 and 1350 meters MSL. The soils are deep to very deep, non- calcareous and developed from weathered genesis. Each village of the settlement is called 'oor'. A group of ten to fifteen 'oor' constitutes a 'nadu', clusters of villages. For this study seven clusters of villages were selected from the total 14 clusters of villages (Nadu), in Kolli hills of Namakkal district. Seven cluster villages *viz*., *Ariyur Nadu, Bail Nadu, Gudini Nadu, Gundur Nadu, Selur Nadu, Thinnanur Nadu and Valappur Nadu* were selected based on the geographical area covered in agriculture under the farming systems.

In each of the selected villages, 20 aged and experienced farmers were contacted through informal interview method for collecting indigenous practices associated with field beans cultivation there. Thus, a total of 140 farmers were contacted. ITAPs were also collected from secondary sources *viz*., M.S. Swaminathan Research Foundation, State Department of Agriculture and previous studies, apart from the above mentioned farmers. Thus, a total of 10 Indigenous Tribal Agricultural Practices on field beans were collected. The collected ITAPs were then classified systematically based on the four cropping systems and eight technological dimensions.

Rational means explainable with scientific reasons or established facts, based on long time experience; irrational means something/practice that cannot be scientifically explained or supported with long time experience (Sastikannan, 2002). In this study, rationality refers to the degree to which Indigenous Tribal Agricultural Practices can be explained or supported with scientific reasons, or established based on long time experience. Similarly, irrationality refers to the degree to which Indigenous Tribal Agricultural Practices cannot be explained or supported with scientific reasons, or cannot be established based on long time experience. Testing the rationality of the indigenous knowledge items is essential, as it has been envisaged to test the adoption of such knowledge by the farmers. For assessing the rationality, the selected 10 indigenous field beans cultivation practices were referred to the 50 horticulturists and 50 plant protection scientists, by rating them on a four point continuum ranging from 4 to 1.

The rationality of indigenous technologies was assessed by using the scoring procedure adopted by Sakeer Husain (2010) i.e., indigenous technologies which were rational based on scientific evidence, experience; irrational based on experience and scientific evidence was given the score of 4,3,2 and 1, respectively.

To find out the rationality of an Indigenous Tribal Agricultural Practices (ITAPs), the total score given by all the scientists to individual ITAP was calculated and based on the mean score, the indigenous technologies were classified into two categories *viz.*, rational and irrational. If an ITAP scored a mean score of 2.5 and above, it was considered as a "rational" and The ITAPs with a mean score of less than 2.5 were considered as "irrational".

Having identified and selected the list of ITAPs with their rationality scores, further analysis was undertaken to test verify their extent of adoption. Thirty farmers were selected using proportionate random sampling from the above clusters of villages; proportionate to the area. The selected ITAPs were narrated to thirty respondents one by one, each time enquiring whether they had adopted the practice, in the previous years. If the answer was 'Yes', a score of one was assigned and if the answer was 'No', zero score was given. The scores obtained for all the practices were summed up for each respondent and adoption score was arrived at. Then the adoption quotient for each individual was worked out by using the following formula (Sundaramari *et al*., 2003).

Table 1. Rationality and adoption of ITAPs on field beans cultivation

ITAP	ITAPs on field beans cultivation	Rationality score	Adoption	
			No.	%
A.	Crop production			
1.	Local land races of field beans, such as Karuppu mochai (black beans) and Sem mochai (red beans) are generally grown.	1.80 IR	30	100.00
2.	Field beans (Karupu mochai and Sem mochai) is suited only for rain fed or upland cultivation.	1.90 IR	27	90.00
3.	Field beans can be raised thrice a year during May-June (Vaikasi) September-October (Purattasi) and (Thai-Masi) January-Febrauary provided if good rainfall has occurred, otherwise it is raised for two times only.	3.20 R	26	86.67
4.	Black field beans (Karuppu mochai) as well as red field beans (Sem mochai) comes to bearing on 3rd month onwards with a total duration of is 4 months with an average yields about 2-3 kg.	3.70 R	27	90.00
5.	Field bean is sown behind to the country plough and covered by the return plough (marusaal).	3.20 R	27	90.00
6.	Field bean is mixed cropped with mustard, finger millet, italian millet, kodo millet, common millet and castor.	2.70 R	29	96.67
7.	Dry pods are harvested for grain purpose when they turn straw yellow in colour.	3.90 R	28	93.33
8.	Unopened field bean pods as such are stored for longer time.	2.68 R	24	80.00
B.	Crop protection			
9.	Mixing 2.5 kg. of red earth slurry with 50kg. of field bean seeds and drying them before storage. Seeds coated with red earth acts as pest repellent.	3.34 R	23	76.67
10.	A mixture of extracts of nochi (*Vitex negundo L.*) leaves and neem cake is sprayed to control the shedding of flowers and pre mature fall of pods in field bean.	2.98 R	24	80.00

$$\text{Adoption Quotient} = \frac{\text{Number of indigenous tribal agricultural practices adopted}}{\text{Number of indigenous tribal agricultural practices applicable}} \times 100$$

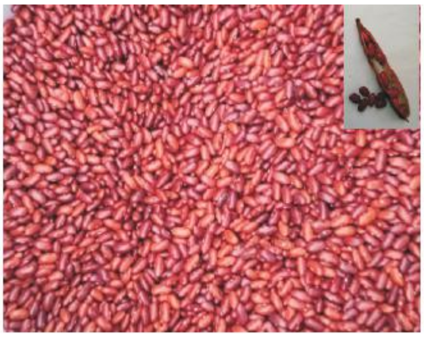
RESULTS AND DISCUSSION

The selected 10 ITAPs (by 1,2,3,4,5,6,7,8,9 and 10) on field bean cultivation were adopted by more than 75 per cent of the farmers, of which 8 ITAPs were rational and 2 ITAPs were (1 and 2) irrational. Local land races of field beans, such as Karuppu mochai (Black beans) and Sem mochai (Red beans) are generally grown (Fig.1). The major difference between black bean and white bean is the taste and energy which is comparatively high in the earlier then the later. Same is the case with red beans. Though this ITAP was irrational, it was followed and adopted by cent percent of the respondents, since these indigenous field beans are locale specific found only in Kolli hills and were much suitable for upland cultivation.

Field bean is mixed cropped with mustard (*Brassica juncea* (L.) *Vassilii Matveievitch Czernajew*), finger millet (*Eleusine coracana* Gaertn.), italian millet (*Setaraia italica* (L.) P.Beauvois), kodo millet (*Paspalum scrobiculatum* L.), common millet (*Panicum miliaceum* L.) and castor (*Ricinus communis* L.) and was adopted by 96.67 per cent of the respondents (Fig.1), to get maximum utilization of the land holding with maximum profit. Moreover, if one crop fails, other crop may fetch income to the farmers. Dry pods are harvested for grain purpose when they turn straw yellow in colour. This practice was adopted by 93.33% of the tribal farmers, since this traditional variety of field beans has been the oldest crop of the study area by which this ITAP would have been test verified for its harvest quality over generations.

Three ITAPs (2,4 and 5) were adopted by 90% of the respondents. Though the ITAP 2 (Field beans (Karupu mochai and Sem mochai) is suited only for rain fed or upland cultivation) was rated as irrational, it had higher adoption since a vast majority of the cultivated area is under rainfed condition. ITAP 4, black field beans (Karuppu mochai) as well as red field beans (Sem mochai) comes to bearing on 3rd month onwards with a total duration of is 4 months with an average yields about 2-3 kg) was rationale with higher adoption, as the indigenous locale variety is well known to them. ITAP 5 (field bean is sown behind to the country plough and covered by the return plough (marusaal) possessed higher adoption as it is the most common practice in the rainfed dry lands and also it is traditionally practiced by the farmers and accepted by the scientists. About 86.67 per cent of adoption was noted towards raising field beans thrice a year during May-June (Vaikasi) September-October (Purattasi) and (Thai-Masi) January-February because

Removing seeds from the pods



Red field beans (Sem mochai)

Black field beans (Karuppu mochai)

Intercropping of field beans with tapioca

Intercropping of field beans with millets

Unopened field bean pods are stored

Fig.1. ITAPs on field beans cultivation

these months coincide with the onset of monsoons and the rainfed crop has to necessarily depend on the monsoon. The ITAP 8, unopened field bean pods are stored as such for longer time (Fig.1) also had higher adoption because it helps in retaining the moisture content of the seeds. The two crop protection aspects selected were rational with the adoption of more than 75 per cent each.

A mixture of extracts of nochi (*Vitex negundo*.L.) leaves and neem cake is sprayed to control the shedding of flowers and pre mature fall of pods in field bean was with 80 per cent adoption, since *Vitex negundo* leaves have polyalcohol and IAA which acts as growth regulator and as neem cake induces cell division and proliferation, with inhibition over biotic senescence. Mixing 2.5 kg of red earth slurry with 50kg of field bean seeds and drying them before storage was adopted by the 76.67% of the farmers, as coating of field beans seeds with red soil prevents the seeds from storage insect pest attack and facilitates in easy sowing. All the 10 ITAPs on field bean cultivation aspects were adopted by more than 75% of the respondents. The studies of Esther *et al.* (2012) and Sakeer Husain (2010) support the above finding.

More than 75 per cent of tribal farmers adopted all the 10 ITAPs on field beans. The tribes of the Kolli hills possessed rich tradition, heritage and experience in indigenous field beans cultivation. Their rich wisdom in ITAPs in indigenous field beans cultivation can be effectively utilized for sustainable agricultural development of tribal areas. It could also be concluded that the farmers have experiential wisdom which they use to conserve and select location specific indigenous varieties of field beans for obtaining sustainable yield. Such stabilizing qualities of traditional practices must be supported and complemented by agro-ecological practices that enhance the soil, water and germ plasm conservation potential of traditional technologies.

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Adoption of Recommended Wheat Production Technology Among the Farmers of Jammu Region

J. S. Manhas, Rakesh Nanda, P. S. Slathia, L. K. Sharma and Rakesh Kumar

Division of Agricultural Extension Education
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India
E-mail: drjsmanhas@gmail.com

Abstract: The present study was conducted in Rajouri district of Jammu and Kashmir to find out the adoption of recommended wheat production technology. The analysis of information collected by personal interview method revealed that 47% of respondents had medium level of adoption, whereas 19% and 34% of respondents had high and low levels of adoption respectively regarding recommended wheat production technology. Among the selected 12 recommended practices of wheat; respondents had high extent of adoption of field preparation (89 MPS), sowing time (79 MPS), seed rate (76 MPS) and manure application (62 MPS), whereas, low extent of adoption was observed in plant protection measures (6 MPS), water management (12 MPS), seed treatment (16 MPS), weed management (17 MPS) and methods of sowing (21 MPS). There was a significant difference between tribal and non-tribal farmers about adoption of recommended wheat production technology. Age, education, size of land holding, extension personnel contact, participation in extension programme and mass media exposure of the respondents were found to be positive and significantly correlated with the adoption behaviour of the wheat growers.

Key Words: Adoption, Mean per cent score, Recommended wheat production technology

India has achieved an impressive growth in food production after adoption of green revolution technology which made the country self sufficient in basic foods (Chand, 2009). Wheat is the major *Rabi*-cereal sown in J&K state, cultivated in an area of 292380 hectares with the production of 46160 quintals (Anonymous, 2013a). In India, the average annual productivity of wheat crop during 2012-13 was 31.18 quintals ha^{-1} (Anonymous, 2015), whereas for the same period it was 15.95 quintals ha^{-1} in J&K state (Anonymous, 2013b). The productivity of wheat crop during 2012-13 in Rajouri district was 17.07quintals ha^{-1} (Anonymous, 2013b). Lack of adoption of recommended wheat production technologies may be reason for low productivity of wheat in J&K State in general and Rajouri district in particular as compared to the national productivity. Though the extension functionaries have concentrated their efforts towards dissemination of generated technology at farmers' fields, still there is wide gap between the potential yield and farmer's yield. The adoption of technology varies from farmer to farmer depending upon the socio-economic characteristics of an individual. In view of the facts stated, the present study was undertaken in Rajouri district of Jammu and to study the level and extent of adoption of production recommendations of wheat by the farmers and impact on socio-economic and communication factors with the adoption level of the farmers.

MATERIAL AND METHODS

The present study was conducted in purposively selected Rajouri district of Jammu and Kashmir. There are 9 blocks in Rajouri district, out of which one block namely Rajouri was selected on the basis of maximum area under wheat cultivation and ten villages were selected on the basis of maximum area under wheat cultivation. From each selected village 12 tribal and 12 non-tribal wheat growers were selected randomly. Thus in all, 240 farmers (120 tribal and 120 non-tribal farmers) were included in the sample of the study.The data were collected through personally interviewing the respondents with the help of a pre-tested and structured interview schedule consisting of 12 recommended practices of wheat. To measure the extent of adoption of wheat growers, twelve recommended practices viz. high yielding varieties, field preparation, sowing time, seed rate, seed treatment, methods of sowing, manure application, fertilizer application, weed management, water management, plant protection measures and harvesting and post harvest-technology were considered. These recommended practices were supplemented by assigning marks. The quantification was done on the basis of given responses. The score of 2,1 and 0 were given to fully adopted, partially adopted and not adopted at all respectively. The total score obtained by the respondent from all the practices was the adoption score of an individual respondent. The respondents were divided into three categories viz., low, medium and high levels of adoption on the basis of mean and standard deviation of adoption scores obtained by them. Frequency and percentage of respondents in each category were calculated. Further, to determine the extent of adoption, mean per cent score for each item was worked out and ranked accordingly.

To find out the variation or similarity in the adoption of recommended wheat production technology between tribal and non-tribal farmers; Z-test was applied. Further, correlation coefficient was worked out to find the relationship between selected independent variables and level of adoption of wheat growers.

RESULTS AND DISCUSSION

The majority (47%) of the total respondents were in the medium adoption group, whereas, 34% were in the low adoption group and remaining 19% wheat growers were observed in the high level of adoption group about recommended wheat production technology. Similar findings were also reported by Avinashilingam (2013) in Uttarkashi district of Uttrakhand and Singh (2013) in Jodhpur, Pali, Bikaner and Jaisalmer districts of Rajasthan for wheat crop.

Table 1. Distribution of respondents on the basis of their adoption level of recommended wheat production technology (n=240)

Level of Adoption	Tribal Farmers	Non-Tribal Farmers	Total
	%	%	%
Low (Below 52)	38	30	34
Medium (52 to 66)	49	45	47
High (Above 66)	13	25	19
Total	100	100	100

F= frequency,%= per cent, n= sample size

The high adoption group (13% respondents) were in tribal farmers' category and 25% respondents from non-tribal farmers' category. In the medium adoption group, 49% respondents belong to tribal group and 45% to non-tribal farmers group. In the low adoption group 38% and 30% respondents were in tribal and non-tribal farmers groups, respectively. From the above results it can be concluded that non-tribal farmers possessed more level of adoption of recommended wheat production technology than tribal farmers. Furthermore, exactly 70% respondents from non-tribal category were in medium to high adoption group, whereas, 87% tribal farmers were in lower to medium adoption group.

Extent of adoption of recommended wheat production technology: The extent of adoption of high yielding varieties of wheat among tribal farmers was 40% while in case of non-tribal farmers it was 66% (Table 2). Less education, less extension contacts and low social participation were the plausible reasons among tribal farmers for their low adoption of recommended wheat varieties. The extent of adoption of field preparation was 88% and 90% in tribal and non-tribal farmers, respectively. This high adoption was attributed to the awareness of the recommended method of field preparation. The extent of adoption of recommended sowing time was 73% and 85% in tribal and non-tribal farmers, respectively. Majority of respondents had high knowledge regarding sowing time of wheat which resulted in its high adoption among both the categories.

The extent of adoption regarding seed rate among tribal and non-tribal respondents was 75% and 77%, respectively. This aspect was ranked IIndby tribal and IIIrd by non-tribal farmers, respectively. The extent of adoption of seed treatment among tribal and non-tribal farmers was 6% and 26% and was ranked Xth and VIIIth by them. The farmers of the study area were not aware of the agro-chemicals used for controlling diseases and insect-pests. The extent of adoption of methods of sowing was 20% among tribal and 22% among non-tribal farmers and was placed at VIIIth and Xth

Table 2. Extent of adoption of recommended wheat production technology among the respondents (n=240)

Recommended practices	Tribal farmers		Non-tribal farmers		Total	
	MPS	Rank	MPS	Rank	MPS	Rank
High yielding varieties	40	VII	66	IV	53	VI
Field preparation	88	I	90	I	89	I
Sowing time	73	III	85	II	79	II
Seed rate	75	II	77	III	76	III
Seed treatment	6	X	26	VIII	16	X
Methods of sowing	20	VIII	22	X	21	VIII
Manure application	60	IV	64	V	62	IV
Fertilizer application	51	V	59	VI	55	V
Weed Management	10	IX	24	IX	17	IX
Water management	5	XI	19	XI	12	XI
Plant protection measures	3	XII	9	XII	6	XII
Harvesting and post harvest-technology	43	VI	49	VII	46	VII

MPS=Mean per cent score; n= Sample size r_s=0.21^{NS}
NS= Non-significant; r_s= rank order correlation

ranks in the ranking hierarchy. It is pertinent to mention here that during data collection it was observed that majority of the respondents were practicing broadcast method of sowing which is unscientific and hence they should be properly educated to discontinue such practice and follow scientific methods of sowing. The adoption of manure application was 60% and 64% among tribal and non-tribal wheat growers and was placed at IVth and Vth ranks by both the categories. Whereas, with regard to fertiliser application the extent of adoption was 51% and 59% among tribal and non-tribal respondents, respectively. The extent adoption of weed management was 10% and 24% among tribal and non-tribal farmers and the respondents had poor knowledge regarding herbicides and their application.The extent of adoption of water management was 5% and 19%, respectively among tribal and non-tribal farmers. Poor extent of adoption of water management among respondents was attributed to the reason that the study area was rainfed and hilly.It was found that extent of adoption of plant protection measures among tribal (3%) and non-tribal farmers (9%) was also weak. Poor extension contacts, poor socio-economic condition and poor knowledge of plant protection chemicals were the plausible reasons for low adoption regarding this aspect.The extent of adoption of tribal and non-tribal farmers about harvesting and post-harvest technology was 43% and 49%, respectively and was placed at VIth and VIIthranks in the ranking hierarchy by them. From the above discussion, it can be concluded that the extent of adoption of recommended wheat production practices among tribal farmers was 3% to 88%, while in case of non-tribal farmers the extent of adoption was 9% to 90%. Hence from the above results,it was observed that non-tribal farmers had more extent of adoption than tribal farmers about recommended wheat production technology. Further analysis of Table 2 clearly shows that the calculated value of rank order correlation (r_s) was 0.21, which is statistically non-significant at 5% level of significance. This leads to the conclusion that there is no correlation between the ranks assigned by the tribal and non-tribal farmers with respect to different aspects of recommended wheat cultivation technology. Similar findings were also reported by Sharma and Choudhary (2014), Singh (2013) and Avinashilingam (2013) for wheat crop.

The z-value was greater than its tabulated value at 1% level of significance. It means that there was significant difference between tribal and non-tribal farmers about adoption of recommended wheat production technology. Further analysis shows that mean score value of non-tribal farmers is more than tribal farmers which clearly indicates that non-tribal farmers had more adoption level than the tribal farmers about recommended wheat production technology. It might be due to the fact that non-tribal farmers possessed more knowledge, higher socio-economic status, more extension contacts and active social participation than tribal farmers.

Table 3. Comparison between tribal and non-tribal respondents about recommended wheat production technology

Category of respondents	Mean	S.D.	Z- value
Tribal farmers	55.67	9.21	
Non-tribal farmers	64.49	4.33	9.47**

**Significant at 1 per cent level

Relationship between selected independent variables and level of adoption of wheat growers: The age, education, size of land holding, extension personnel contact, participation in extension programme and mass media exposure of the respondents were positive and significantly related with the adoption of wheat production technology (Table 4). The contacts with extension personnel who are engaged in agricultural development and participation in extension programme help an individual farmer to overcome the problems and guide him to achieve the desired goal. The involvement of an individual in mass media programmes has shown a significant relationship. This may be owing to the fact that through radio and television, the agricultural messages can go rapidly and timely to far off and remote places. Variables like social participation, socio-economic status, caste, family size and family type did not show any significant relationship with adoption behaviour of wheat growers. The non-significant relationship between social participation and adoption behaviour may be due to total absence of the social institutions. The occupation of the respondents was negative but significantly associated with

Table 4. Correlation between selected independent variables and level of adoption of wheat growers

Selected independent variables	'r' value
Age	0.263**
Education	0.243**
Size of land holding	0.282**
Social participation	0.018
Extension personnel contact	0.213*
Participation in extension programme	0.221*
Mass media exposure	0.340*
Socio-economic status	0.075
Caste	0.172
Family size	0.057
Family type	0.062
Occupation	-0.273**

* and ** Significant at 0.05 and 0.01 level of probability, respectively

the adoption behaviour. Deviation of interest to other subsidiary occupations might be the reason behind it. Similar findings were also reported by Kher (1992) and Singh (2013). On the basis of results it is, therefore, recommended that location specific information rather than general information for the entire region should be provided to the farmers. Information should be provided to the farmers about complete package of practices through various extension methods for better uptake and utilization. Training and message through mobile phones etc. can help in the present era. Blending of traditional (personal contact, demonstrations etc.) and latest methods (expert system, portals, radio and T.V. talk, video films, magazines, newspapers, etc.) should be used to communicate the message timely and repeatedly to ensure that the farmers adopt the technology.Progressive farmers should be encouraged to help the extension workers in delivering the latest message to fellow farmers. Farmers' organizations, NGOs operating in the region should also be encouraged to send the messages to other farmers.

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Factors Affecting Productivity of Wheat Crop in Jammu Region

Y. S. Bagal, L. K. Sharma, Lakhvinder Singh, Pawandeep Kour
Divya Sharma and Apporva Gupta

Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, India
E-mail: ysbagal@gmail.com

Abstract: The present study was conducted with the objective to find out the factors affecting the productivity of wheat and its relationship with socio-personal and biophysical variables of wheat growers. The outcomes of the study indicated that age, education, fragmentation of landholding, total number of fragments, irrigation applied, number of irrigations applied, source of seed, quantity of urea, basal dose of urea, quantity of Murate of Potash (MoP), time of sowing, land preparation had positive and significant relationship with the productivity of wheat crop. There was significant difference in productivity of wheat crop in case of irrigation facility, method of land preparation, source of seed and sowing time. Quantity of basal dose of urea applied and quantity of MoP applied (R^2 = 0.572, p= 0.004) significantly affect the productivity of wheat crop of the respondents.

***Key Words*:** Biophysical, Fragmentation, Landholding and Irrigation, Productivity

India is the second largest producer of wheat (*Triticum spp.*) in the world after China with about 12% share in total world wheat production. In India, wheat is grown in an area of about 30 million ha with a production of 95.91 million tons and the national productivity is about 3 tonnes/ha (Directorate of Wheat Research, 2014). In Jammu and Kashmir, wheat is grown on an area of about 0.3 m ha with production of 0.5 m tonnes and productivity of about 15.35 kg/ha (Directorate of Economics and Statistics 2013). Thus the productivity of wheat in J&K is lower than the national productivity. To find the factors affecting the productivity of wheat in the Jammu region, the present study was conducted.

The normal annual rainfall of Jammu division is about 1331mm, and average normal temperature ranges from 17.9 to 29.6 ^{O}s C (India Meteorological Department, 2013). Sowing of the wheat offers considerable advantage when mean temperature is 20^{0}C. According to the package of practice of SKUAST-Jammu the main varieties that are grown in irrigated conditions are PBW-550, HD-2967, Raj-3077, etc. and in rainfed area the main varieties are PBW-175, HD- 3043, PBW-396, etc. The recommended dose of urea, DAP, MOP and $ZnSO_4$ in irrigated is 175 kg ha^{-1}, 100 kg ha^{-1}, 42 kg ha^{-1} and 20kg ha^{-1}, respectively. Whereas, in un-irrigated conditions the recommended doses are 100 kg ha^{-1} of urea, 88 kg ha^{-1} of DAP, 42 kg ha^{-1} of MOP and 10 kg ha^{-1} of $ZnSO_4$.

Jammu, Udhampur and Rajouri districts were purposively selected from Jammu division for the study. From each selected district, one block was selected (R.S. Pura, Ramnagar and Nowshera). Thereafter, from the selected three blocks, one village from each block was selected randomly. Among the selected three villages, 20 farmers each were selected randomly making a total sample size of 60 wheat growers. The data were collected through personal interview method using a pretested interview schedule during 2015.

The data with respect to various personal and socioeconomic characteristics of the respondents have been studied and furnished in Table 1. Majority of the respondents fall in the middle age group, with an average age of 52 years. In case of education, only 13 per cent respondents were illiterate. Majority of the respondents had family size of 4 to 6 members. 55 per cent respondents had agriculture as their main occupation, with an average farming experience of 26 years.

The average operational landholding of the respondents was 0.95 hectares with an average irrigated area of 0.49 hectares, and an average un-irrigated area of 0.47 hectares. Relatively higher proportion of the respondents (51 %) belonged to marginal land holding category, followed by 43 per cent per cent of the respondents, who had small (1-2ha) and 6 percent respondents had semi-medium (2 to 4 ha) land holding. 45 per cent farmers had fragmented landholding.

The average area under wheat was 0.74 hectares. Irrigation being an important input for wheat crop was adopted by 53.3 per cent wheat growers. 81.25 per cent of the respondents apply irrigation two times. 15.63 per cent apply one time while 3.12 per cent apply irrigation three times. For source of seed of wheat, majority (73.3%) of the respondents had seed from the department of agriculture. whereas 26.7 per cent of the respondents used their own seed. The average quantity of seed rate applied by the

Table 1. Distribution of the respondents according to their characteristics

Characteristic	Mean ± S.D	Category	Respondents (N = 60)	
			Frequency	Percentage
Age	51.85 ± 13.8	Young (20 - 45 yrs.)	23	38.33
		Middle (46 – 63 yrs.)	28	46.67
		Old (64 - 90 yrs.)	9	15
Education	8.68 ± 4.5	Illiterate	8	13.33
		Below Primary	0	0
		Primary	7	11.67
		Middle	12	20
		Matriculation	18	30
		10+2	5	8.33
		Graduation and above	10	16.67
Family size	5.95 ± 2.3	Small (1-3 members)	3	5
		Medium (4-6 members)	40	66.67
		Big (above 6 members)	17	28.33
Main Occupation		Agriculture	33	55
		Other	27	45
Farming experience	25.87 ± 13.4	5-22	30	50
		23-40	21	35
		41-75	9	15

respondents was 1.33 quintals ha^{-1}. 65 per cent of the wheat growers used farm machinery for land preparation, while 35 per cent used animal power for land preparation. All the respondents sow the seed by the method of broadcasting.

Table 2. Distribution of the respondents according to their land holding

Parameter	Mean± S.D
Average operational land holding (ha)	0.95 ± 0.5
Categorization of farm size (% farmers)[1]	
Marginal (<1ha)	36(51.43)
Small (1-2ha)	30(42.86)
Semi medium (2-4ha)	4(5.71)
Medium (4-10ha)	0
Large (>10ha)	0
Average irrigated area (ha)	0.49±0.52
Average un-irrigated area (ha)	0.47±0.52
Fragmented land holding	27 (45)

Figures in the parentheses are percentages
[1]Categorization of farm size as per Ministry of Agriculture (2011).

Majority (68.3 per cent) of wheat growers applied FYM in their fields at an average of 43.16 quintals ha^{-1}. In case of urea 93.3 per cent of the respondents apply urea at an average of 128 kg ha^{-1}. Out of which 96.43 per cent apply at an average of 65.6 kg ha^{-1} urea as basal dose, 91.67 per cent apply 50.33kg ha^{-1} as 1st top dressing and 31.67 per cent apply 12.2 kg ha^{-1} as 2nd top dressing. 93.33 per cent of the respondents apply DAP at an average of 64.5 kg ha^{-1} while 33.33 per cent apply MOP at an average of 7.67 kg ha^{-1}.The average yield of wheat crop was 17.73q ha^{-1}. In R.S. Pura block, the average yield of the wheat crop was 23.7 q ha^{-1}, whereas, in Ramnagar it was 15.5 q ha^{-1} and in Nowshera 14 q ha^{-1}(Fig.1).

Out of seventeen variables, age, education, fragmentation of landholding, total number of fragments, irrigation, number of irrigation, source of seed, quantity of urea, basal dose of urea, quantity of MOP, time of sowing, land preparation had positive and significant relationship with the productivity of wheat crop (Table 4). Whereas family size farming experience, agriculture as main occupation, seed rate and quantity of DAP applied by the respondents had not significant relationship with the productivity of the wheat crop. The difference in the average productivity of wheat crop in case of irrigation facility, method of land preparation, source of seed and sowing time were statistically significant (Table 5)

The education, family size, farming experience, agriculture as main occupation, fragmentation of landholding, irrigation, number of irrigations, source of seed, quantity of basal dose of urea, quantity of DAP, quantity of MoP, seed rate, time of sowing, method of land preparation were taken as independent variables. Among all these independent variables, the results revealed that the quantity of MoP and quantity of basal dose of urea had a positive and

Table 3. Distribution of the respondents according to their wheat cultivation practices

Characteristic	Mean ± S.D	Category	Respondents (N = 60)	
			Frequency	Percentage
Average area under wheat crop (ha)	0.74 ± 0.45			
Application of irrigation			32	53.3
Average number of irrigations	1 ± 0.99			
Number of irrigations		Once	5	15.63
		Twice	26	81.25
		Thrice	1	3.12
Source of seed		Own	16	26.7
		Department of Agriculture	44	73.3
Type of sowing		Broadcasting	60	100
		Line sowing	0	0
Average seed rate (q ha^{-1})	1.33 ± 0.59			
Average yield (q ha^{-1})	17.73 ± 5.6			
Land Preparation		Machinery	39	65
		Animal	21	35
FYM application			41	68.3
Quantity of FYM (q ha^{-1})	43.16 ± 4.98			
Application of Chemical Fertilizer			56	93.3
Quantity of Urea (kg ha^{-1})	128 ± 51.9		56	93.3
Basal	65.5 ± 30.38		54	96.43
1st Top	50.33 ± 22.5		55	91.67
2nd Top	12.2 ± 18.6		19	31.67
DAP (kg ha^{-1})	64.5 ± 24.8		56	93.33
MOP (kg ha^{-1})	7.67 ± 11.7		20	33.33

Table 4. Relational analysis with factors affecting the productivity of wheat crop

Predictors	Correlation coefficient	
	Productivity (r value)	*p* - value
Age	0.387**	0.002
Education	0.370**	0.004
Family size	0.072	0.585
Farming experience	-0.101	0.445
Agriculture main occupation	0.254	0.050
Fragmentation of landholding	0.415**	0.001
Total number of fragments	0.289*	0.025
Irrigation	0.500**	0.000
Number of irrigations	0.551**	0.000
Source of seed	0.354**	0.006
Seed rate	0.109	0.409
Quantity of urea	0.450**	0.000
Quantity of basal dose of urea	0.655**	0.000
Quantity of DAP	0.173	0.186
Quantity of MOP	0.710**	0.000
Time of sowing	0.354**	0.006
Land preparation	0.339**	0.008

*, **Significant at $p \leq 0.05$ and ≤ 0.01, respectively

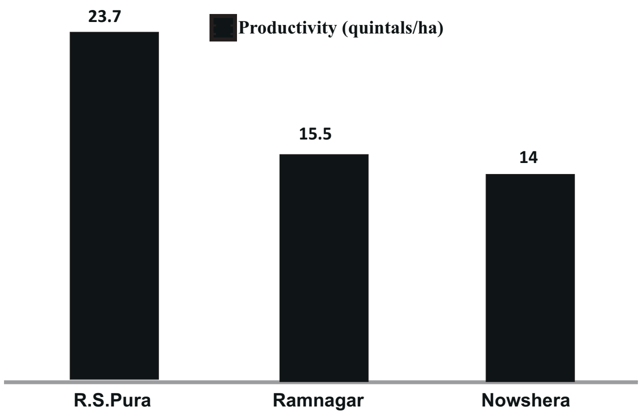

Fig. 1. Productivity of the wheat crop in different blocks

significant imparting the productivity of wheat crop. The model further explained that the variables affecting wheat productivity was quantity of MoP applied (R^2 = 0.504, p= 0.000) and both quantity of MoP applied and quantity of basal dose of urea applied (R^2 = 0.572, p= 0.004) (Table 6). The model explains 50 per cent variation caused in productivity of wheat by only quantity of MoP. The model further explained that total variation due to both quantity of MoP and quantity of

Table 5. Productivity of wheat as affected by different parameters

Parameter	Category	Productivity (q ha^{-1}) Mean± S.D	Mean ifference	df	Statistic
Area	Irrigated	20.31± 5.6	5.5	58	t= 4.402 (0.000*)
	Un-irrigated	14.78± 3.79			
Land preparation	Machinery	19.10± 5.79	3.91	58	t= 2.741 (0.008*)
	Animal power	15.19± 4.09			
Source of seed	Own	14.5± 3.42	4.4	58	t= 3.621 (0.001*)
	Department	18.91± 5.74			
Sowing time	November	18.91± 5.74	4.4	58	t= 3.621 (0.001*)
	December	14.5± 3.42			

Figures in the parentheses are p values; *Significant at $p \le 0.01$

Table 6. Factors affecting the productivity of wheat

ANOVA

Model	Sum of square	df	Mean square	F	Sig.
1 Regression	918.197	1	918.197	58.941	0.000
Residual	903.536	58	15.578		
Total	1821.733	59			
2 Regression	1041.331	2	520.666	38.029	0.000
Residual	780.402	57	12.691		
Total	1821.733	59			

Coefficients

Model	B	Std. Error	T	Sig.
1 (Constant)	15.148	0.611	24.801	0.000
Quantity of MOP	0.337	0.044	7.677	0.000
2 (Constant)	11.879	1.231	9.6447	0.000
Quantity of MOP	234	0.054	4.351	0.000
Quantity of basal dose of urea	0.062	0.021	2.999	0.004

R^2= 0.504 & Adjusted R^2= 0.495
R^2= 0.572 & Adjusted R^2= 0.557
Y= 11.879 + 0.062 (quantity of basal dose of urea) + 234 (quantity of MOP)

basal dose of urea applied was 57 per cent.

Majority of the wheat growers were using the varieties distributed by the Department of Agriculture, 100 per cent of the farmers have broadcasted the wheat seed. The quantity of MoP and urea applied as a basal dose significantly affected the productivity of the wheat crop Productivity of wheat was affected by the irrigation, method of land preparation, source of seed and its sowing time significantly.

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Knowledge and Adoption of Plant Protection Practices in Rice in Jammu

Avinash Panigrahi, Rakesh Nanda, Rajinder Peshin and Fatima Bano
Division of Agricultural Extension Education
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180009, India
E-mail: rakeshnanda2@rediffmail.com

Abstract: A study was carried out on 120 rice growing farmers of Jammu district (J&K) state to find out the knowledge and adoption of plant protection practices by farmers in rice. The results show that majority of the farmers (93%) possessed knowledge about herbicides. Only three and seven per cent of the rice growing farmers had knowledge of insecticides and fungicides, respectively. Thirty six per cent of the rice growers had applied the recommended dosages of herbicide butachlor, whereas, the insecticide use was negligible (3%). The cultivation of rice in Jammu district is insecticide and fungicide free; therefore, it should be used as a case study for promoting reduction in insecticide and fungicide use in other rice growing states.

Key Words: Adoption, Knowledge, Plant protection practices, Rice

Rice (*Oryza sativa*) is one of the most important cereal crop and staple food for more than half of the world's population. It is one of the most important crops of India in terms of area, production and consumer preference. Among the rice growing countries, India has the largest area of 42.41 million ha under rice in the world, accounting for 28.5 per cent of global rice area and having production of 100 million tonnes (MOA, 2013). In Jammu and Kashmir state, rice is cultivated in an area of 262.17 thousand hectares with an annual production of 5447 thousand quintals (DES 2012). It is the second important crop and staple food for majority of the population in the state (Trag and Rather, 2013). Insect pests, weeds and diseases usually in combination with other stresses **are** severe constraints to rice production and have been one of the reasons for huge losses in production (Litsinger *et al*., 2005). External inputs play a vital role in modern agriculture. Although, scientific research in agriculture is moving fast and new techniques are being added continuously, but so far only 20 per cent of the available technologies have been adopted by farmers and that too only among 10 per cent of farming population (Manjunath, 2010). The present study was undertaken to find out the knowledge and adoption of different plant protection practices in rice crop in the sub-tropical Jammu district.

The present study was conducted in the Jammu district of the J&K state in the year 2013-2014. Multi-stage sampling method was employed for selection of villages and rice farmers. All agricultural sub-divisions of the Jammu district namely R.S. Pura, Marh, Akhnoor and Dansal were taken up for the study. On the basis of area under rice, a proportionate sample of villages was drawn from each sub-division and twelve villages were selected for the study. Out of each selected village, 10 rice growers were selected randomly without replacement. Thus total sample size of the rice farmers was 120. Data were collected by personally interviewing the sampled farmers and analyzed using appropriate statistical tools.

Socio-economic profile of the respondents: The mean age of the respondents was 48.54 years and mean education was 7.68 years with only 18 per cent illiterate farmers. The respondents had a mean farming experience of 32 years (Table 1). The average land holding of the sampled group of farmers was 2.14 ha, which was approximately completely irrigated. About 69 per cent farmers were marginal and small with less than 2ha land holding. However, the average land holding of the sample was double the average land holding of Jammu district which is 0.78 ha. As the sampled farmers were predominately Basmati growers who had larger land holdings, therefore, the difference between mean land holding of sampled farmers and overall average land holding of Jammu district.

Knowledge of farmers regarding agro-chemicals, their use and precautionary measures: Majority of the rice growers (82 %) had knowledge of butachlor 5% granule as a recommended herbicide for weed control. Similarly 50 and 21 per cent respondents had the knowledge of herbicides 2, 4-D and bis-pyribac sodium, respectively. The major insect pests of rice crop in Jammu are stem borer (*Scriophaga innotata and S. incertulas*), grass hopper (*Caelifera*), leaf folder (*Cnaphalocrocis medinalis*) and rice hispa *(Dicladispa armigera).* The recommended insecticides for control of these insect pests are fipronil, malathion, monocrotophos and quinaphos, respectively. Only 3 per cent of the respondents had knowledge of fipronil as a recommended

Table 1. Descriptive statistics of the sampled farmers (n=120)

Parameter	Statistics
Mean age (years)	48.58 ±1.15
Mean education (formal number of schooling years completed)	7.68 ±0.37
Education level (% farmers)	
Illiterate	18
Primary	4
Middle	17
Matriculate	47
10+2	12
Graduate and above	2
Mean farming experience (years)	32.27±1.15
Average family size (No.)	5.60±0.34
Average operational land holding (ha)	2.14± 0.29
Categorization of farm size (% farmers)#	
Marginal (<1 ha)	36
Small (1-2 ha)	33
Semi medium (2-4 ha)	19
Medium (4-10 ha)	10
Large (>10 ha)	2

Note:±Standard Error,
Decimals have been rounded up to nearest whole numbers in case of percent farmers
#Categorization of farm size as per MoA (2014).

Table 2. Knowledge of farmers regarding agro-chemicals

Knowledge about	Percent farmers reporting
Herbicide (n=113)	94
Butachlor 5% GR	82
2,4-D 38% EC	50
Bispyribac sodium 10% SC	21
Insecticide (n=03)	
Fipronil 5% SC	03
Fungicides (n=07)	
Carbendazim 50%WP	06
Toxicity Level	
Red	03
Yellow	00
Blue	00
Green	03
Application(n=120)	
Site specific	09
Whole area under crop	91
Precautionary measures (n= 120)	
Mask	68
Goggle	19
Gloves	45
Shoes	32
Complete clothing	60

insecticide against stem borer. Farmers were not aware about the toxicity levels of pesticides and none were aware about the yellow and blue colours mentioned on the insecticide containers. Precautionary measures during pesticide application namely covering face with mask while applying pesticides and complete clothing was average (68 and 60 per cent, respectively). About 45 per cent sampled rice growers had knowledge of wearing gloves while mixing and spraying of pesticides, 32 per cent had knowledge of wearing shoes and 19 per cent about wearing goggles for protecting their eyes while spraying pesticides (Table 2).

From the results, it can be summarized that majority of the rice growers possess knowledge about herbicides. Respondents had less knowledge about seed treatment and toxicity levels of pesticides, which are important parameter before selecting a particular pesticide and its judicious use. Moreover, majority of the rice growers possess low awareness regarding insecticides for the fact that insecticide use on rice crop is low. The overall knowledge score of the respondents regarding plant protection measures revealed that majority of the farmers (58 %) in Jammu district fall under medium knowledge score (21-26). Whereas, only 12 and 30% respondents fall under high knowledge score of (26-31) and low knowledge score (15-21), respectively. Further, the mean knowledge score of the rice growers was 21.91.

Adoption of plant protection technologies by rice growers: Adoption commonly refers to the decision to use a technology or practice by economic units on a regular basis (Rogers, 2003). Adoption of the plant protection measures is complex one as it involves skills, more risk and depends on various factors such as farmer's knowledge, situational factors, extent of support of change agent efforts, personal and socio-economic characteristics of farmers, the characteristics of innovation itself, complexity of practices, timely availability of inputs, etc. Chemical method of weed control was adopted by majority of the respondents. Overall 94 per cent respondents adopted different herbicides in rice crop, out of which 82 per cent respondents used butachlor 5% granules, 50 per cent of respondents used 2,4-D and 15 per cent of the respondents used bispyribac sodium (Table 3). The practice of treating seed before sowing (seed treatment) was adopted by only 7 respondents (6%). The present study is in conformity with the production oriented survey by Directorate of Rice Research (DRR, 2010), which reported that only few farmers adopt seed treatment practice in rice in Jammu district. Therefore, it is concluded that all those farmers who possessed knowledge about herbicides did apply herbicides. Herbicide application is main weed

Table 3. Extent of adoption of plant protection measures by the rice growers

Pesticide	Percentage
Herbicide (n=113)	
Adoption of herbicide	94
Butachlor 5% G	82
2,4-D 38% EC	50
Bispyribac sodium 10% SC	15
Insecticide (n=03)	
Adoption of insecticide	03
Fipronil 5% SC	100
Fungicide (n=7)	
Adoption of fungicide (Carbendazim)	06

Table 4. Level of adoption of plant protection measures by the rice growers

Particulars	Percentage
Level of adoption of herbicide (butachlor) (n=93)	
Less than recommended	53
Recommended (30 kg ha^{-1})	36.
More than recommended	11
Level of adoption of seed treatment (n=07)	
Less than recommended	0
Recommended (2-2.5g kg^{-1} seed)	86
More than recommended	14

control practice in irrigated wheat and rice crops in the state (Peshin *et al*., 2014).

Recommended dosage of 30 kilograms (kg) of butachlor 5% granule for one hectare (ha) area was applied by 36% of the respondents while more than half of the respondents (53%) applied less than recommended dose. The most important finding of the research was that insecticide use in Jammu district was on the lower side as it was applied by only three per cent of the respondents (Table 4). It is pertinent to mention that out of total adopters, six respondents (86%) had applied the recommended dose of 2-2.5g of seed treating chemical bavistin for one kg of seed and one farmer (14%) applied more than recommended dosage of seed treating chemical.

Sources of information about pesticides: The pesticide retailers were a major source of information on pesticide use (herbicides, insecticides and fungicides). For herbicide, 74 per cent of farmers sought information from the pesticide retailers. The other sources of information were the agriculture officers (6%) and fellow farmers (20%) For insecticides, pesticide dealers were the sole source of information whereas for fungicides, agriculture officer and pesticide dealers were consulted by 71 and 29 per cent of the farmers, respectively.

It is concluded that herbicides are the main weed control method employed by rice growers in Jammu district as it reduces the dependence on labour. The use of seed treating chemicals in rice was on the lower side which urges the need to develop training modules with special focus on seed treatment by State Agricultural University, Krishi Vigyan Kendras and State Agricultural Department. The cultivation of rice in Jammu district is insecticide and fungicide free; therefore, it should be used as a case study for promoting reduction in insecticide and fungicide use in other rice growing states. Plant protection scientists should investigate the pests and natural enemy complex in the rice eco-system of Jammu district to develop ecologically sound integrated pest management module for rice crop.

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Robust Regression Model to Study the Number of Indian Agricultural Workers

Manish Sharma, Banti Kumar, Anil Bhat[1], M. Iqbal Jeelani and Sunali Mahajan
Division of Statistics and Computer Science, Faculty of Basic Sciences
[1]Division of Agricultural Economics and Agri-business Management, SKUAST, Jammu-180 009, India
E-mail: manshstat@gmail.com

***Abstract*:** Multiple regression is a popular statistical technique used by researchers to predict or explain relationships between exogenous and endogenous variables. An attempt has been made to propose a robust model for number of Indian agricultural workers with respect to literacy rate, average size of holding, number of establishments, gross cropped area, net sown area, population density and inflation rate. Moreover, the comparison of the robust M estimates with ordinary least square estimates showed that the size, sign and significance of regression coefficient have been changed for some explanatory variables. The M robust regression model was adequate and showed that literacy rate and average size of holding were negatively and number of establishments was positively, significantly affecting the number of Indian agricultural workers inspite of literacy rate and number of establishments in case of ordinary least square. Further, the values of R^2 and adjusted R^2 have also been improved. Thus, the robust M-regression model was the best for the study in the presence of outliers and influential observations.

***Key Words*:** Agricultural workers, Leverages, M-estimator, Outliers, Robust regression

In today's world the agricultural sector employs half of the world's labour force with an estimated 1.3 billion workers active in agricultural production worldwide. Census of India 2011 reported a bleak picture of Indian agriculture. It rings the alarm on an agrarian crisis as the number of farmers has dipped by over 8.6 million in the past decade. Only 54.6 per cent of total workers in India are now part of the agriculture sector with a decline of 3.6 per cent as compared to 2001. Compared to 2001 census, there has been increase of 44 per cent in the male population of agricultural labourers, while for females the number has increased by 24.5 per cent. The trends for farming show those 14 per cent women and 3.2 per cent of cultivators since 2001 who have abandoned farming. As per the census of 2011, 263 million people are engaged in the agriculture sector and over half of them are now agricultural labourers, a trend observed for the first time in the past 40 years. So, there is need to study the influence on number of Indian agriculture workers due to the factors like literacy rate, average size of holding, number of establishments, gross cropped area, net sown area, population density and inflation rate thorough the model.

In classical multiple regression, the ordinary least squares estimation is the best method if assumptions are met to obtain regression weights when analyzing data. However, if these assumptions are not satisfied, then sample estimates and results can be misleading. Especially, outliers violate the assumption of normally distributed residuals in the least squares regression. The danger of outlying observations, both in the direction of the dependent and explanatory variables, to the least squares regression is that they can have a strong adverse effect on the estimate and they may remain unnoticed. The regression coefficients possess large standard errors and some even have the wrong sign (Gujarati, 2003). Another common problem in a regression model is problem of outlier and non-normality of error term. Therefore, statistical techniques that are able to cope with or to detect outlying observations have been developed. Robust regression estimator is an important estimation technique for analyzing data that are contaminated with outliers or data with non normal error term. It can be used to detect outliers and to provide resistant (stable) results in the presence of outliers. These include M-estimation (Huber, 1973), LTS estimation (Rousseeuw, 1984), S-estimation (Rousseeuw and Yohai, 1984), and MM estimation (Yohai, 1987). But in the presence of outliers, M estimation gives the most reliable results. By taking into consideration above points the study has been taken to study the performance of robust M regression in presence of outliers and to propose the robust model for Indian agricultural workers with respect to explanatory variables

MATERIAL AND METHODS

For the present study, the secondary data of all the states and union territories of India was collected from the latest census survey, socio economic survey, agricultural census and online data portals etc. The explanatory variable used to study the number of Indian agricultural workers (AW), are literacy rate (LR), average size of holding (ASH), number of establishments (EST), gross cropped area (GCA), net sown area (NSA), population density (DEN) and inflation rate (IR). Consider the multiple linear regression model: $Y = X\beta + \varepsilon$ where X is an n x p matrix with full rank, Y is n x 1 vector of dependent variable, is a p x 1 vector of unknown parameters and e is the error term such that E( )=0 and. $E(\varepsilon\varepsilon) = \sigma^2 I$ The OLS estimator is given by $\hat{\beta} = (X'X)^{-1}X'Y$. But, ordinary least squares estimators are sensitive to the presence of observations that lie outside the norm for the regression model of interest. The sensitivity of conventional regression methods to these outlier observations can result in coefficient estimates that do not accurately reflect the underlying statistical relationship.

M-estimation addresses dependent variable outliers where the value of the dependent variable differs markedly. The letter M indicates that M estimation is an estimation of the maximum likelihood type. If estimator at M estimation is

$$= \beta_n(x_1 x_2 \ldots x_n)$$

then $E[\beta_n(x_1 x_2 \ldots x_n) = \beta$

This is an extension of the maximum likelihood estimate method and a robust estimation. In this method, it is possible to eliminate some of the data, which in some cases is not always appropriate. M estimation principle is to minimize the residual function ñ:

$$\hat{\beta}_M = \min_{\beta} \rho\left(y_i - \sum_{j=0}^{k} x_{ij}\beta_j\right)$$

RESULTS AND DISCUSSION

The maximum variability can be seen in population density (207.59%), whereas, the minimum variability (10.31%) in literacy rate (Table 1). The regression estimates of explanatory variables with respect to number of Indian agricultural workers which shows that literacy rate negatively and number of establishment positively, significantly affecting the number of Indian agricultural workers. The estimated regression coefficient values were -207079.18 and 1748.36 respectively with R^2 (0.872), which indicated that 87.2 per cent variation in the data was due to the explanatory variables considered under study. Kumar (2015) showed thorough standardized residual, studentized residual, deleted residual, Cook's distance, weighted sum of squared distance if i^{th} value (WSSDi) value and diagonal element of hat matrix that the outliers and influential observations(states) are 4, 11,13, 22, 25 and 34 (Table 2). So classical multiple regression model may not be effective to study the influence on number of Indian agricultural workers. By keeping this fact, the maximum likelihood regression estimation model has been developed.

The robust M- regression model for the Indian agricultural workers was statistically significant and adequate in order to study the variable understudy with respect to the explanatory variables (Table 3). The estimates of the M- robust regression model of number of Indian agricultural workers with respect to the explanatory variables showed that literacy rate and average size of holding were negatively and number of establishments was positively, significantly affecting the number of Indian agricultural workers. The M-robust estimated values of literacy rate, average size of holding and number of establishments are -1, 45,793.246, -8, 81,251.752 and 1,710.028, respectively. So, in order to increase the number of Indian agriculture workers the government has to give intentions to increase the number of establishments related to agriculture, whereas the literacy rate increasing in India. Further, R^2 is 95.9 per cent which indicated that the total variation in the dependent variable Indian agricultural workers was due to the explanatory variables literacy rate, average size of holding, number of establishments, gross cropped area, net sown area, population density and inflation rate.

The comparison of both the models (least square and robust regression method) were significant (Table 3). The literacy rate was negatively significant in both models. Further, it was observed that average size of holding which was non-significant earlier has now become significant in robust M- regression model. The signs of regression coefficient have been changed for some explanatory variables. In ordinary least square model, net sown area has negative sign and population density has positive sign of

Table 1. Coefficient of variation and regression estimates of explanatory variables with respect to number of India agricultural workers

Explanatory variables		LR	ASH	EST	GCA	NSA	DEN	IR
Coefficient of variation (%)		10.31	108.60	123.26	136.69	134.70	207.59	15.44
OLS estimates	Intercept							
	2.47E+7	-2.07E+5*	-1.94E+5	17.48E+2*	-291.63	963.52	177.18	-5.34E+5
			R^2 =0.872*	F- Value : 26.415*				

*=significant at 5%

Table 2. Outliers and influential observations of explanatory variables with respect to Indian agricultural workers

Outlier and influential observation	Standardized residual	Studentized residual	Deleted residual	Cook's distance	WSSDi value	Diagonal element of hat matrix
4	2.42000	2.82274	11505686.14	0.3530	1.013	0.2617
11	1.05756	1.87053	11587755.96	0.9306	16.702	0.6803
13	-1.40252	-1.76386	-7769548.50	0.2265	1.468	0.3677
22	-1.62477	-1.99831	-8608170.21	0.2559	21.563	0.3389
25	1.71411	2.46460	12411640.05	0.8102	31.389	0.5162
34	2.46114	2.64894	9985786.12	0.1389	3.238	0.4769

Table 3. Comparison of robust M regression coefficients with respect to ordinary least square

Variables	OLS estimates (Standard error)	M estimates (Standard error)
Constant	2,47,08,176.553 (8915233)	1,59,02,516.251** (40,76,167.85)
LR	-2,07,044.143* (94795.47)	-1,45,793.246** (42,447.61)
ASH	-1,93,549.176 (336871.10)	-8,81,251.752** (2,54,689.38)
EST	1,748.612* (640.62)	1,710.028** (312.62)
NSA	-291.621 (777.25)	547.217 (366.98)
GCA	963.505 (584.82)	291.762 (275.39)
DEN	177.188 (298.64)	-4.364 (142.81)
IR	-5,36,851.180 (313429.70)	-1,87,689.751 (1,53,374.34)
R^2 Value	0.872*	0.959*
Adjusted R^2 Value	0.840*	0.950*

*,**=significant at 5 % and 1%, respectively

regression coefficients in presence of outliers. But when robust M regression model was applied, these signs get changed which are feasible and consistent to the situation and result showed that the influence of outliers on the ordinary least square. Also, the value of R^2 has been improved in robust regression model. The R^2, which was 0.872 earlier has now become 0.959. The adjusted R^2 values of classical linear multiple regression model and M-robust regression model are 0.84 and 0.95, respectively, and more in case of M-robust regression model.

The OLS could not perform well in the presence of outliers. The OLS estimators could not correctly estimate the regression coefficients. M estimation is a commonly used method for outlier detection and robust regression when contamination is mainly in the response direction. It was found that the size, sign and significance got affected in the presence of outliers in the data. Finally, it has been concluded that in the presence of outliers robust regression (M - estimation) estimator performs better than the ordinary least square estimator. The proposed model for the number of Indian agriculture workers with respect to explanatory variables is as:

$$\widehat{AW} = 1{,}59{,}02{,}516.25^{**} - 1{,}45{,}793.24\ \mathrm{LR}^{**} - 8{,}81{,}251.75\ \mathrm{ASH}^{**} + 1{,}710.02\ \mathrm{EST}^{**} + 547.21\ \mathrm{NSA} + 291.76\ \mathrm{GCA} - 4.36\ \mathrm{DEN} - 1{,}87{,}689.75\ \mathrm{IR}$$

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Sanjeev K. Chauhan
R. Peshin
R. Sharma

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OBITUARY

Prof. GURMAIL SINGH DHALIWAL was born on July 25, 1944 at village Jhakhepal in Sangrur district ,Punjab. He did his B.Sc. (Agriculture) and M.Sc. (Entomology) from Punjab Agricultural University, Ludhiana in 1966 and 1969, respectively and secured first position in M.Sc. and awarded a Certificate of Honour. He did Ph.D. Entomology in the Indian Agricultural Research Institute, New Delhi in 1972 and secured first position and was awarded the Gurprasad Pradhan Gold Medal. He remained Post Doctorate Fellow for two years (1979-1981) in International Rice Research Institute, Manila, Philippines.

Prof. Dhaliwal started his professional career as lecturer in Ecology in January 1973 and Assistant Entomologist in June 1973 at PAU Ludhiana till 1977 and joined Entomologist (Rice) in 1977 at PAU Rice Research Station, Kapurthala.He was selected as Associate Professor Ecology at main Campus, PAU, Ludhiana in 1983. He joined as Professor Ecology in 1988 and retired in July 2004 at the same post.

Dr Dhaiwal was a well decorated teacher and scientist. He was conferred Best Scientist Award in 1999 by National Environmental Science Academy, New Delhi; Scientist of the Year Award-2000 by National Environmental Science Academy, New Delhi; Fellow of Entomological Society of India; New Delhi, National Environmental Science Academy, New Delhi, Society of Pesticide India, New Delhi and Society of Plant Protection Sciences, New Delhi. Dr Dhaliwal was nominated member of World Food Prize Nominating Academy (2003-04) by the World Food Prize Foundation, Des Moines, Iowa, USA. He was conferred Life Time Achievement Award by International Allelopathy Foundation, Hisar.

Apart from twelve recommendations in the PAU Package of Practices, Dr Dhaliwal monitored pesticide residues in various foodstuffs and found widespread contamination of milk, butter and infant formula with DDT and HCH residues; worked out chemical control measures against various rice pests based on economic thresholds; studied the potential of botanical pesticides against insect pest complex of rice, cotton and vegetables; some neem-based pesticides proved promising against rice stem borer, rice leaf folder, cotton whitefly, cabbage caterpillar and mustard aphid; exploited the potential of *Melia azedarach* L. against *Plutella xylostella* (Linnaeus) and *Helicoverpa armigera* (Hubner); exploited glucosinolates from *Brassica* cultivars for reducing the population of mustard aphid and increasing the efficiency of natural enemies, etc.

Dr Dhaliwal in addition to 165 research papers and 102 popular articles has wrote 22 bulletins, 43 book chapters, 54 review and strategy papers, Co -authored/co-edited 32 books on different aspects of pest management, environment and sustainable agriculture, which have been widely acclaimed as advance reference and textbooks. He guided four M.Sc. and two Ph.D. students on different aspects of insect-pest management He also delivered more than 100 lectures, 30 radio and television talks on different aspects of pest management, environment and sustainable development, and remained actively associated with laboratory to land programme for technology adoption.

Dr Dhaliwal was founder President, Indian Society for the Advancement of Insect Science and Society of Biopesticide Sciences, India, President, Indian Ecological Society, Vice President, Society of Pesticide Science and Indian Society of Allelopathy; Editorial Board Member of many professional societies like Pesticide Research Journal, Allelopathy Journal, Indian Journal of Ecology, Journal of Entomological Research, Pest Management in Horticultural Ecosystems, Indian Journal of Environment and Toxicology, Progressive Farming, etc. He organized more than 15 National/International Conferences/Symposia/Seminars as Chairman/Organizing Secretary/Member, Organizing Committee and participated in more than 60 International and national conferences in India and abroad. He will be remembered as a active Ecologist with vision on sustainable utilization and conservation of natural resources.

His sad demise, on December 31, 2015 after a brief illness, has left a deep void in the fields of Ecology, Entomology and Sustainable Agriculture. The Indian Ecological Society deeply mourns the sad demise of Dr Dhaliwal and pray the almighty for peace to the departed soul.

Prof. AK Dhawan
General Secretary
Indian Ecological Society