INDIAN JOURNAL OF ECOLOGY

ISSN 0304-5250

Volume 43 Special Issue-2 September 2016

THE INDIAN ECOLOGICAL SOCIETY

The Indian Journal of Ecology is an official organ of the Indian Ecological Society and is published six-monthly in June and December. Research papers in all fields of ecology are accepted for publication from the members. The annual and life membership fee is Rs (INR) 600 and Rs 4500, respectively within India and US $ 40 and 600 for overseas. The annual subscription for institutions is Rs 3500 and US $ 150 within India and overseas, respectively. All payments should be in favour of the Indian Ecological Society payable at Ludhiana.

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CONTRIBUTED PAPERS

Indian Ecological Society International Conference 2016

Natural Resource Management
Ecological Perspectives

(February 18-20, 2016)

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Organized by

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 603-610

Summary and Recommendation

Indian Ecological Society International Conference 2016 Natural Resource Management: Ecological Perspectives (IESIC 2016)

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The Indian Ecological Society International Conference (IESIC) 2016 on "Natural Resource Management: Ecological Perspectives" was held at Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India from February 18-20, 2016. The conference provided a forum for review of new information concerning natural resource management in the areas of land and water resources, crop environment interactions, forestry tree plantations, horticulture crops, integrated nutrient management, integrated pest management, eco-responsive livestock and fisheries production, and policies for sustainable development of agriculture. New information and recommendations relating to each of these major topics are summarized in the report that follows.

Natural resource management issues are inherently complex as they involve the ecological cycles, hydrological cycles, climate, animals, plants and geography etc. All these are dynamic and inter-related. In addition to the natural systems, natural resource management also has to manage various stakeholders and their interests, policies, politics, geographical boundaries, economic implications and so on. It is very difficult to deal with all aspects at the same time. The emphasis on sustainability attempts to understand the ecological nature of the agriculture and allied areas.

An integrated approach is needed for recognising and implementing the intertwined social, cultural, economic and political aspects of resource management. A more holistic global perspective evolved from the Brundtland Commission and the advocacy of sustainable development. Most nations subscribed to new principles for the integrated management of land, water and forests in the United Nations Conference for the Environment and Development (UNCED) held in Rio de Janeiro in 1992.

Six hundred eight delegates from eight countries attended the international conference. In total, 708 papers were contributed under different themes. There were five main sessions where 15 keynote speakers presented their expert views. In addition, there were eight concurrent sessions on the themes, where 22 lead lectures on various themes were presented, and one panel discussion. There were 15–23 oral presentations in each concurrent session on different themes.

The issues regarding strategies for natural resource management were reviewed and discussed in detail. Developing location specific, cost effective, eco-friendly conservation and management technologies for higher input use efficiency, agricultural productivity and profitability without deteriorating natural resource base is vital for sustainable management of natural resources to ensure agricultural development. The invited lectures, topical discussions, oral and posters presented at the international conference and the invited and contributed manuscripts that appear in two volumes of extended summaries (*Natural Resource Management : Ecological Perspectives*, Vol.1 and Vol.2, ISBN numbered and CAB indexed) and the *Indian Journal of Ecology,* Vol. 43 (Special Issue 1 and 2: 2016) formed the basis for the following summary and recommendations.

SUMMARY AND RECOMMENDATIONS

1. Land and Water Resources

Water and water saving technologies pose the challenge due to climate change. About four to five decades ago, heavy snowfall used to strengthen the glacier but climate change has put havoc on this process in many areas, like Ladakh region of India.

How to manage wetlands is another challenge that we need to address? The multiple use water bodies (MUWBs) are important and valuable to meet various needs. The issues relating to management are complex due to various characteristics and categories. Wetland ecosystems are multipurpose and multiuse in nature with technical socio-economic-cultural-political and environmental inter-dependencies. As a result wetlands suffer with spatial and temporal externalities due to pollution, congestion, in-fillings, encroachment, natural and created use conflicts, and misspecification of property rights regimes, entitlement systems, institutional hierarchy and mechanism for adjusting allocation of wetlands water resources.

The issue concerning water logging and poor quality water available for irrigation pose problems for crop cultivation in many areas. The problems of over-exploitation of ground water, water-logging and salinization in command areas are looming large in several states. Water quality indexing developed by using nine water quality parameters, turbidity of water is an important parameter while indexing quality of water. Presences of aquatic insects are an important indicator for monitoring the quality of surface water.

Long term option for groundwater sustainability in Indian agriculture is another pressing issue. The overdependence on groundwater under irrigated cropping system has led to its overexploitation, which resulted in decline in water table. Sprinkler irrigation is found to be effective for efficient water management and sustainable crop productivity. Growing high value crops with sprinkle irrigation is beneficial for enhanced economics. The watershed management approach has emerged as a unique integrated model. Empirical models for effective estimation of sediment yield in micro-watersheds should be employed.

Some of the states are switching over to free supply of irrigation water and electricity to the farmers. This policy needs reconsideration so as to avoid misuse of the resource, which is likely to aggravate the problem of degradation of land, and water resources, and the environment.

Recommendations

- For managing wet lands, policies of state departments and *panchayats* need to be examined critically in view of the fact that many departments are loosely linked. A synthesis between traditional institutional mechanism and components of current policies can appropriately be put into operation for distributed or polycentric governance for MUWBs. Environmental costs in addition to management cost of the produce, which otherwise are not accounted, must be accounted for.
- Urgent efforts are required for research, training and capacity building on wetlands and its integration with the overall water resources management, in consonance with the National Water Framework Law. It may be desirable to set up an independent Centre for the purpose.
- The Ministry of Environment, Forests and Climate Change has circulated Draft Wetland Conservation and Management Rules 2016 which will replace the 2010 Rules. While there are many shortcomings in these Rules, the states are empowered to make their own rules and identify wetlands within the state. For the purpose of regulation of activities, a state level policy has to be formulated, followed by the rules and regulations. Many states do not have a state level Wetland Authority even under the 2010 Rules. The 2016 Rules provide that: All state governments shall set up a State Level Wetland Authority entrusted with affairs related to wetland conservation, regulation and management under the relevant state bye-laws.
- The adaptation strategies of rain water harvesting, land degradation management, development of salt and water logging tolerant rice (*Oryza sativa* L.) varieties, suitable water and soil conservation measures and agricultural diversification, which all have benefited the farmers, must be promoted. Subsurface drainage system using perforated PVC pipes is effective in drainage of agricultural land. Eco-friendly bio-amelioration populus based agroforestry systems for saline and alkali soils are needed for problematic areas for optimizing tree-intercrop combinations.
- Irrigation scheduling using sensors, mulching, drip and sprinkle irrigation, laser land leveling etc. should be popularized. The incentives for water saving technologies may help in long term ground water sustainability. Recharging shaft with filtration arrangement is more effective for ground water recharging and improving the quality of water from water harvesting storage like pond, nullah, bund, etc. Roller-compacted concrete (RCC) check dams are very useful for water conservation and ground water recharging. The vertical drainage through shallow tube wells on a large scale should be encouraged including rainwater harvesting.
- There is a need for research on methods of implementation of conservational approach and their judicious use. Remote sensing and Geographical Information System (GIS) tools should be widely used for land and water management.
- The concept of "Watershed Management Society at Local Level" needs to be strengthened for proper implementation. The concept needs to be defined with a view to clarify basic principles of land and water management and linkages with biomass production and ecological safeguards. The empirical models are more effective for the estimation of sediment yield in micro-watersheds.
- Information on the wasteland development through biological means and approaches needs to be reviewed, consolidated and made available for general use.
- The proven technology for development of wasteland, including salt-affected/waterlogged soils needs to be introduced, with required modifications, in the areas lying abandoned.
- Water resource development in the hill areas and micro-levels has emerged as the most potent tool not only at the experimental level but also at field level. Replication of proven examples is important for developing sustainable ecosystems.
- The only way the water can be conserved in the cold deserts is by creating artificial glaciers in cold regions. This can be achieved by diverting the melting water to the northern facing slopes where shade is there and winter sun is blocked. These artificial glaciers can augment social, economic and environmental benefits not only in Ladakh region but also in areas falling in down-stream.
- Recharging shaft with filtration arrangement is more effective for ground water recharging and improving the quality of water from water harvesting storage like pond, nullah, bund etc., need validation and adoption.
- The financial support should be provided to farmers for adopting water conserving technologies and equipments.
- Presences of aquatic insects is an important indicator for

monitoring the quality of surface water.

- Shifting the dynamics and timings of providing canal irrigation for mitigating the negative effects of climate change on productivity need critical evaluation.
- Proper use of land and water resources are key factors for improving the soil health of Jammu region.

2. Integrated Nutrient Management

The role of soil as a living medium and the importance of categorization of organic matter and conservation of agriculture, integrated use of inorganic fertilizers, organic materials like animal manure, piggery manure, poultry manure, biogas slurry, green manure and crop residues should be promoted for sustaining chemical, physical and biological fertility of soils. Also, the balanced fertilizer use should be ensured to avoid negative balance among nutrients in the soil. Indiscriminate use of untreated industrial waste water for irrigation of soils and crops must be discouraged to maintain soil health and sustain yield and quality of the crop produce. Make use of the available technology and evolve newer ones wherever required for the efficient and rational use of normal, brackish (saline/sodic) and sewage waters for irrigation to achieve sustainable water use. Optimum levels of soil organic matter for obtaining desirable crop yields under varying soil situations need to be defined. Half of the recommended dose (10:20:20 N, P_2O_5, K_2O kg ha^{-1}) along with FYM at the rate of 4 tonnes ha^{-1} could be the best option that will not only give sustainable yield but also improve soil health. Application of 241.6 g N + 711.6 g P + 592.42 g K $plant^{-1}$ $year^{-1}$ in split doses is a good approach for high production and yield in pomegranate orchard. N-application can be done by using land capability classification (LCC) index of 4 when inorganic fertilizers are combined with organic manure in rice (*Oryza sativa* L.). CP-2013 potato (*Solanum tuberosum* L.) acc. was found superior than earlier identified best variety Kufri Gaurav at low doses of N. Hyper accumulator accumulates heavy metals in roots/leaves and can be used to clean the environment.

Recommendations

- Integrated and optimum use of inorganic fertilizers, organic materials should be promoted for sustaining chemical, physical and biological fertility of soils. Organic cultivation practices need to be developed for different crops and for varied agro-ecological situations.
- It is essential to use the available technology and evolve new technology wherever required for efficient and rational use of normal, brackish (saline/sodic) and sewage water for irrigation to achieve sustainable water use.
- Inoculation of legumes with efficient strains of *Rhizobium* needs to be promoted to increase the use of atmospheric nitrogen by the crops and to save on nitrogenous fertilizers as well as reducing the pollution hazards. Efficient *Rhizobium* strains need to be identified for solublizing sparingly soluble phosphorous compounds in order to increase phosphorus use for efficiency in soils.
- Indiscriminate use of untreated industrial waste water for irrigation must be discouraged to maintain soil health and sustain yield and quality of the crop produce.
- Fertilizer application based on “Soil Health Card” recommendations though initiated,requires proper application.
- Native beneficial soil microorganisms should be isolated, multiplied and applied for better crop growth and soil health.
- Optimum levels of soil organic matter for obtaining desirable crop yields under varying soil situations need to be defined. Change in cropping pattern in places where resources are depleting and are in high risk zone of un-sustainability need priority.

3. Crop Environment Interactions

Crop genetic diversity, crop residue management, increased biomass production, identification of crops/trees (medicinal, aromatic, petro, edible, cactus, etc.) with high commercial/industrial value and compatibility with the prevailing environment, weather forecasting, crop residue management, climate change and biodiversity, impact of climate change on insect pests and diseases of the crops, vegetation tolerating high temperature, salinity, high CO_2 use efficiency, strategies to mitigate the impact of climate change on productivity, and pest outbreak were covered by the delegates and deliberated upon.

Main source of carbon emission is from energy generation followed by land use change and agriculture. Among the top 10 countries from carbon emission point, India contributes a substantial share but least on per capita basis (1.2 tons/year/head). Climate change in India represents an additional stress and is likely to affect Indian agriculture adversely. Due to likelihood of rise in temperature by 2°C, the coastal areas and North Eastern region of the country face the danger of erosion of native genotypes or wild types endemic to this region. Thus by taking adaptive measures, coping as well as resilience range will improve. Deleterious effect of global environment due to rise in temperature, depletion of ozone layer, loss of biodiversity, degradation of air and water quality, which resulted in upsurge of infectious and non infectious diseases in humans were also discussed. About 23 per cent of global diseases and 24 per cent of deaths are attributed to environmental problems. Heart diseases, cancer, reparatory disorders and many vector borne diseases are also increasing due to change in climate.

Close associations between scientists, public health professionals and administrators is required to attain harmony between man and nature. We should not work in silos but there should be intra-disciplinary and inter-disciplinary integration in research to find answers to crop, human and environment interaction, and emerging researchable issues.

Recommendations

- Need for developing climate resilient technology for management of natural resources, which impacts the sustainability of agriculture.
- Consider all the biotic stresses under the changing pattern of climate change.

- Strategies to mitigate the effect of climate with special reference to pest outbreak need special attention.
- Emphasis must shift from impact assessment to developing adaptation and mitigation strategies. In order to realize the increased production while avoiding the extreme adverse effects, there is a need to reintegrate traditional knowledge into new ecological knowledge for sustainable and intensive crop production. More importance should be given to conservation technologies rather than consumptive technologies.
- Revisit efficacy of current, physical, chemical and bio-control methods including pest resistant cultivars under changing climate. The vegetation tolerating high temperature, salinity and high CO_2 use efficiency could be better than other species.
- Some of the mitigation options for reducing carbon emissions recommended are: reducing the food wastage, adopting agroforestry and reducing area under crops like rice.
- The biomass production should be increased through varieties with early seedling vigour and more leaf area without further addition of agro-chemicals and other inputs.
- Crop residue [rice (*Oryza sativa* L.), maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), sugarcane (*Saccharum officinarum* L.) etc.] management needs special attention keeping in view the associated environmental issues. Crop rotations can be framed keeping in view the negative impacts of crops residues on subsequent crops.
- Unique pulse biodiversity of Andaman and Nicobar islands harbour needs to be conserved and promoted for development of pulse varieties.
- Endophytes have the potential to revolutionize the process of introduction of new traits in plants.
- DNA markers are important tools in establishing the genetic diversity and discrete identity of Kashmiri Nakh (*Pyrus pyrifolia* Nakai)**.**
- *Aprostocetus* has become a key pest in the lac ecosystem in the changing scenario of climate and there is urgent need to develop strategies for its management. Impact of climate change on ecology from farmers' perspectives was also discussed.
- From the farmers' perspective (farmer delegate) sustained effort is needed to weed out or neutralize deleterious internal and external influences on critical agricultural issues.
- Transfer of technology from laboratory to the farms has taken shape and increased the productivity but pace is very slow to realize the required benefits.

4. Horticulture Crops

Horticulture offers not only a wide range of options to the farmers for crop diversification, but also provides ample scope for sustaining large number of agro-industries, which generate huge employment opportunities. The government initiatives like Horticulture Mission for North East and Himalayan States which is a part of Integrated Development of Horticulture (MIDH) have gone a long way in helping diversification. The various constraints impeding growth and productivity include the large area under old/senile plantation, poor quality of seeds/planting material and low rate of replacement of cultivars, lack of irrigation, inadequate storage and cold chain, inadequate processing and marketing infrastructure, and less awareness of balanced and judicious use of agricultural inputs.

Natural resource management for the sustainable development of horticulture sector depends upon exploitation of high yielding varieties, production of quality seeds and planting materials, high density plantation, technology for rejuvenation of old orchards, pollination management, integrated pest management (IPM), organic fruit production and post harvest management. Judicious and sustainable utilization of natural resources and genetic wealth would be the priority in future. To increase the production and productivity sincere efforts are needed to develop and popularize the high yielding varieties, hybrids, high planting densities, cost effective production and protection technology, and post harvest value addition that will provided momentum for the growth of temperate horticulture.

Recommendations

In different presentations, the genetic variations in horticulture crop, nutrients and water management, insect pests, diseases and weed management and value addition to horticulture crop were discussed. The technologies for apple (*Malus domestica*), peach (*Prunus persica* (L) Batsch), pear (*Pyrus pyrifolia* Nakai.), pomegranate (*Punica granatum* L), mango (*Mangifera indica* L.), litchi (*Litchi chinensis* Sonn.), guava (*Psidium guajava* L.), aonla (*Emblica officinalis* Gaertn.) kiwifruit (*Actinida deliciosa*), citrus (*Citrus* spp.) were presented. The scientists shared their views on technologies for fruits and vegetable crops.

- New crops/varieties need evaluation for substitution and intensification of existing cropping systems. Increased availability of quality planting material for horticultural crops is essential for enhanced productivity.
- There is an urgent need for certification and registration of nurseries to ensure adequate production of quality planting material.
- Increased coverage of crops under improved/high yielding cultivars and dissemination of improved production technologies as per agro-climatic zones is utmostly required.
- Promotion of integrated approach for nutrient, insect, pest and disease management and hi-technology interventions for improving production of horticultural crops (e.g. drip irrigation, greenhouse, mulching, etc.).
- Crop diversification in horticulture crops.
- Boosting the productivity by intensive cultivation.
- Improvement in water harvesting and distribution system,

moisture management and soil conservation measures.

5. Integrated Pest Management

Pest management has thrown new challenges to plant protection scientists, extension workers and farmers. Worldwide, integrated pest management (IPM) is the policy decision for pest management. It has been five decades since the development of threshold theory and harmonious control strategies were the domain of pest management research in the USA, Canada, and some parts of Europe. In the 1970s the work on development and validation of IPM technologies started in developing countries. The implementation of IPM and pesticide reduction programmes has been in place in the developed and developing countries for the last three to four decades. There are plausible questions raised about the objectives of IPM, adoption of IPM practices, and pesticide use. Low volume pesticides and insect-resistant transgenic crops both decreased and stabilized pesticide use in the 1990s and early 2000s. Since then, pesticide sales regained an upward trajectory, and their use in agriculture has increased. Besides in 2015 there was an outbreak of pink bollworm (*Pectinophora gossypiella* Saunders) (Gujarat, Maharashtra) and whitefly (*Bemisia tabaci* Gennadius) (Punjab and Haryana) in Bt cotton in India. Thus, transgenic crops alone did not prove to be a perfect technique to save crops from ravages caused by pests. Pesticides alone or in conjunction with transgenic cannot be the sole pest management tactics therefore, IPM is the way forward to manage the pests.

Pesticides have deleterious effects on humans. There are a number of parameters of study that are relevant for testing the deleterious effects of chemical pesticides. The main ones include toxicity, mutagenicity, tumorigenicity and/or carcinogenicity, reproductive disruption, endocrine disruption, DNA damage, necrosis, apoptosis (cell death), and teratoginicity (birth defects). Generally, the most of these categories have a chemical profile that fits them and there is greater likelihood that it is potentially dangerous and carcinogenic. The greater number of species are affected by the chemicals adversely, it is more likely to have a negative impact on living organisms as a whole.

Recommendations

Pest monitoring and surveillance should be undertaken at district, state and country level. To minimize dependence on hazardous chemicals, central and state governments should adopt integrated pest management. Use of information and communication technology (ICT) for pest surveillance and monitoring should be given impetus for database on pests over time and space, and also quickly processes data to facilitate decisions on pest management. Eco-friendly methods of pest management with appropriate and need based interventions are highly effective as they enhance natural enemy activity, reduce insect pest damage and help in sustainable production of quality produce. Data on insect resistant management available in India is rudimentary and we need to generate information on genetic and molecular aspects of bollworm resistance to Bt cotton in India that can result in formulation of effective resistance management strategy.

Micro-organisms can be used for management of diseases, insect pests and phyto-phagous nematodes. Micro-organism can also be used for bioremediation (heavy metal degradation), organic carbon recycling and waste management. Consortia of effective micro-organism with differential properties is ideal way for the replenishment of soil biota and helps in sustainability of agriculture. Concomitant with the development of new, less harmful bio-pesticides, there should be implementation of IPM educational programmes for farmers about proper pesticide use and their application practices. A reduction in the excessive use of certain suspect pesticides at plant growth stages and on fruits that they are not recommended for may also result in the decrease of chemical-related cancer incidence.Some of the insect pest namely whitefly, mealy bugs, thrips, jassids, etc. have become serious problem in different agro-ecosystems. Studies on the eco-friendly and bio-intensive management of these pests have shown better results. Bioi-intensive pest management (BIPM) modules involving yellow sticky traps at the rate of 12 ha^{-1} for monitoring, release of *Chrysoperla zastrowi* at the rate of 1 lakh first instar grub ha^{-1}, release of *Cryptolaemus montrouzieri* at the rate of 10,000 ha^{-1}, application of entomopathogen *Lecanicillium lecanii* at the rate of 2×10^9 Conidia ml^{-1}, application of *Azadirachta indica* A. Juss neem seed kernel extracts (NSKEs) 5% are effective in suppressing the spiraling whitefly. The DNA barcoding generated at BOLD systems based on 28S rDNA nucleotide sequences of thirty dipteran insects were made available for providing valuable information for insect taxonomist to ease identification. The beneficial potential of *L. lecanii* can be increased with adoption of some useful technologies such as mass multiplication and proper delivery methods that are highly effective as they enhance natural enemy activity, reduce insect pest damage and help in sustainable production.

- The clear understanding of the functioning of agroecosystem under different environmental conditions needs intensive research to manipulate the ecosystem to the detriment of the pests and/or in favour of natural enemies.
- Bioagents like parasitoids, predators and pathogens should be thoroughly evaluated in the laboratory and screen house conditions for their adaptability to micro- and macro-environment. These can be used as bioresidual pest management with use of safe chemistry.
- The modern techniques like genetic engineering have a place in IPM, this should not be considered a panacea for solving all pest problems in future. The best of traditional techniques should be exploited to maintain biodiversity in agroecosystems.
- The use of resistant varieties has many ecological advantages over those of insecticidal control. It conserves the population of beneficial insects and micro- organisms

thus strengthening natural control of pests in the agroecosystem. Many resistance sources are identified but not used in breeding programme to develop insect-resistant crop cultivars. This should be given priority.

- Most IPM projects today focus on insects, and insufficient attention is given to diseases, weeds and other organisms that damage the crops. Also, much IPM technology still applies to single pest/crop. A more holistic or ecosystem approach is necessary in future programmes. Impact evaluation of IPM at farm level should be part and parcel of all IPM programmes. The evaluation indicators should include: i) adoption of non-chemical pest management practices , ii) pesticide use by weight (a.i) iii) pesticide use frequency, iv) farmers knowledge about safe use and handling of pesticides, and v) environmental impact.
- Molecular phylogenetic analysis and barcoding of insects can also provide valuable information for insect taxonomist to ease identification.
- Recommendations for use of insecticides as component of IPM lack insecticide resistance management strategies. The lack of effective spray technology may result in low efficacy of insecticide. Label claim of insecticides approved long back are not effective and need policy for review. Surveillance procedure for many insect pests needs standardization to represent actual population in field.

6. Forestry Tree Plantations

Agriculture and industrial agro-forestry : a model for food, fuel and wood security, impact of climate change on forest management and adaptive strategies in future with main emphasis on forests, researchable gaps in short rotation forestry, digitization of forest data , integration of poplar improvement programme with its end-use and thrust areas for future research in forestry were discussed by the delegates. There must be holistic approach in improvement, production and end use in industry based on field experience and farmers perspective.

Agro-forestry (AF) is adopted by small and marginal farmers, which provides better economic returns than pure block tree plantation and can reduce pressure on natural forest for wood, effective option for diversification, and food and wood security. Industrial agroforestry can make large scale reforestation more practical and economical. The grain yield of wheat intercrop under poplar based agroforestry systems was higher (3 t ha^{-1}) in pair row spacing of 18m x 2m x 2m as compared to block plantation of spacing of 10m x 2m and 5m x 4m, respectively under semi-arid ecosystem of India.In bio-saline agroforestry model at The Central Soil Salinity Research Institute (CSSRI), Karnal, the pearl millet (*Pennisetum glaucum*) yield was 11q ha^{-1} under *Eucalyptus* and 13.1q ha^{-1} under *Melia* plantation planted in 2014 against 6.7 q ha^{-1} in open plot. For propagation of *Gloriosa superba*, tubers of >20 g weight were found better to obtain flowering and fruiting in the same year. Highest seed yield (221.95 kg ha^{-1}) was obtained in Nauni source followed by Nandani (211.45kg ha^{-1}) and Giripul (187.08 kg ha^{-1}). Treatment of wood of *Bombax ceiba*, *Pinus roxburghii* and *Celti saustralis* with methanolic extract of *Acoruscalamus* considerably enhanced their dimensional stability. *Simarouba glauca* at the age of 10 years and spacing 6 m x 6m meter had carbon sequestration potential of 374.1 t ha^{-1} of CO_2 equivalents under dryland conditions. *Toona ciliata* was found to have excellent tolerance to air pollution compared to *Ficus carica, Melia azedarach* and *Morus alba*, respectively under mid hill conditions.

Recommendations

- Management of natural forests should be directed in accordance with scientific principles of forest management.
- Need to set up value addition cottage units at village/panchayat levels to enhance marketability of the tree/agroforestry produce, besides employment generation.
- Stakeholder's (Farmer–Industry-Scientist-Financial institution) coordination to attract the adopters and incentives for biomass based renewable energy are the attractive areas of interest.
- The potential of agroforestry and niche area for agroforestry practices on marginal land need to be exploited to meet the targets of tree cover, basic needs and mitigation of climate change.
- Setting up of the region specific working groups of experts including progressive adopters for development and promotion of agroforestry as a viable land use.
- Registration of certified sources ensuring the availability of quality planting material of elite genotypes preferable to indigenous species.
- Sustainable development strategies for plantations to strengthen India's cause and contribution to committed restrictions of COP-21 (The Paris Climate Conference is officially known as the 21st Conference of the Parties or COP-21).
- Public and private sector involvement through financial support to the plantation forestry.
- Quantification of ecosystems services on long term basis and provision of incentives to industry as well as growers would definitely help in adoption of plantations.
- Promotion of export potential for on-farm timber.
- Interface with private and public sector for R&D and forest enterprise development should be promoted. Forestry research is not able to meet the needs with more specialization, rather coordination of research institutions with state forest departments is essential.
- Man-wildlife conflict is increasing and needs consideration to protect human life and livelihood.

7. Policies for Sustainable Agriculture and Success Stories

A three-pronged strategy may be required to deal with the ecological and other problems created by the monoculture of crop rotations:

(i) Searching solutions within the prevalent production pattern,

(ii) Evolving equally or more remunerative alternatives to natural resource exploiting rotations, and

(iii) A medium and long term development plan should be formulated covering relevant aspects. Such a plan should also include appropriate policies, programmes and projects for implementation.

"Sustainability of Himalayan Environment: Issues and Policies" were discussed in the current scenario and steps required for sustainability of this region. In order to promote sustainable farming, achieve sustainable livelihood, the need to judiciously access natural resources is essential. Hill agro-ecosystem has vast potential of exportable commodities. In addition, this region is a vast source of water and biodiversity but requires more efforts for their perseverance, sustenance and also fast response to changes.

Ecological and socio-economic impacts of transplanted and direct wet seeded rice cultivation were discussed by the industry that is supporting this programme in collaboration with the public sector research system. By using holistic lifecycle assessment, the options to improve the socio-economic and ecological performance can be identified. The approaches adopted by various segments within private extension and key elements involved in extension also came up for discussion. One of the main reasons for success is direct and frequent contact with farmers. The increasing use of information and communication tools in private sector has built in dynamic system of information sharing and feedback from users. Six success stories were presented involving directed seed rice technology, aquaculture in inland salt affected waterlogged areas, efficient on and off-farm resource management, sustainable agriculture through integrated farming system, role model for scientific dairying, and crop diversification.

Recommendations

- Introduction of multidimensional changes in terms of knowledge, attitude and skill development, intensive extension approaches for sustainable development of farmers and agriculture in the Himalayas are required.
- Emphasis on shifting from traditional cereal crops to niche crops for higher profits in agriculture.
- Increased investment in infrastructure in rural areas especially on input and product markets.
- Formation of producer companies to mitigate the reduction in size of holdings and scattered marketed surplus.
- Effective integration of public-private partnership in extension system is the need of the hour.
- Documentation and publication of success stories of farmers for replication and up-scaling of innovations. Highlighting the positive side of successes in agriculture in mass media needs more emphasis.
- All development strategies/efforts should focus on natural resource management with effective involvement through empowerment of all stakeholders keeping them farmers centric.
- In order to have rational use of valuable water resources and power, a proper pricing policy may be evolved. "Competitive populism" needs to be avoided by all the political parties in the country.
- The input testing laboratories particularly for fertilizers and pesticides should be strengthened. Strict enforcement measures may also be undertaken to follow the quality standards of these inputs. Users of the inputs should also have the right to get the samples tested. Fertilizer usage based on soil testing be made mandatory.
- Farmers, particularly women, must be involved at various stages of development, evaluation and implementation of technologies regarding sustainable development.
- Key contact fellow in each village should be encouraged for business powers outsourcing and mobile learning module should be encouraged.
- Integrated organic farming system (IOFS) for improving of farming, organic inputs availability and profit. IOFS comprising of cropping system involving cereals, pulses, oilseeds, fruits and fodder with dairy, fisheries, vermin-compost can reduce the cost of market dependency for organic inputs.
- The spending on agricultural developmental programmes has increased and with this the demand for "All India Coordinated Research Project for Evaluation".

8. Promoting Resource Efficient Agriculture System through Public – Private Partnership

- World Wide Fund for Nature – India and Centers for International Project Trust (CIPT) organized a panel discussion on 'Promoting resource efficient agriculture system through public- private partnerships (PPP)' as a part of Indian Ecological Society-International Conference. The discussions pointed out that the current levels of PPP lie in need based requirements and work in service providing mode. For an efficient agriculture system, the complementary strengths of public and private sectors need to be harnessed to add context for a sustainable environment.
- Government should be proactive and urge partners to start PPPs in agriculture. This will ensure more serious participation of private sector.
- In order to improve agriculture production and enhance accessibility of food crops by the consumer, a huge opportunity exists that presents a strategic point in which the private sector, in collaboration with the public sector can pull out the resources to address the issue. No one individual sector can do it all alone. The sooner one starts, the better is the chance of getting there.

Recommendations

- The Indian research institutes, particularly, in dealing issues like impact of climate change in agriculture should enhance accessibility so that the private sectors or non-governmental organizations can reap benefit and percolate the knowledge down to the growers.

- In case of the voluntary global sustainable standards, government role will be important to enforce regulations.
- Research findings as an output from the research institutions should not be restricted to only peer reviewed journals but must also benefit all sectors including private and farmers.
- For states like Punjab which have been aiming towards crop diversification because of the alarming groundwater conditions, there lies an opportunity to shift farmers towards high value crops and integrating them with better market linkages.
- PPPs can make a difference in bringing technology innovation to the highly resource intensive agriculture system. However, installation of devices and digitization of data is a challenge. Public institution like Department of Science and Technology (DST) can play a big role in scaling up projects and providing the technical and financial support.

10. New Initiative

The Indian Ecological Society (IES) will like to be associated with research institutes for more scientific interaction among scientists from India and abroad. To achieve this objective IES will shortly initiate following activities:

- Lecture Series: Lectures by eminent scientist from India and abroad at various state agricultural universities/ institutes,
- Initiative for young scientist for documentation of work in theme area of ecology to be presented at conferences of the Indian Ecological Society,
- The Indian Ecological Society travel grant for post graduate students for participation in conferences of the Indian Ecological Society,
- Constitution of consultative group on theme area for more interaction, and
- Formulation of state/institutional chapters of the Indian Ecological Society.

ACKNOWLEDGEMENTS

We are sincerely grateful to Prof. Dinesh Marothia and Dr. Keshav R. Kranthi for their critical comments on the draft recommendations and their valuable inputs for improving the draft.

APPENDIX

Panel chairpersons and co-chairpersons keynote lectures

Technical session I: Dr. Narayana Gowda and Dr. B.L. Jalali

Technical session II: Dr. N. K. Krishna Kumar and Dr. Nazeer Ahmed

Technical session III: Dr. U.C. Sharma and Dr. B. Gangwar

Panel chairpersons and co-chairpersons concurrent technical sessions

Technical session IV- Land and Water Resources: Dr. Dinesh Marothia and Dr. U.S. Walia

Technical session V- Integrated Nutrient Management: Dr. Sushil Kumar Saxsena and Dr. R.K. Nanwal

Technical session VI- Integrated Pest Management: Dr. A. Sabalpara and Dr. K.K. Sharma

Technical session VII- Crop Environment Interactions: Dr. U.C. Sharma and Dr. S.K. Gupta

Technical session VIII- Horticulture Crops: Dr. V. K. Wali and Dr. S. C. Negi

Technical session IX- Forest Tree Plantation: Dr. V. Vijay Vardhan and Dr. M.S. Haque

Technical session X- Policies for Sustainable Development of Agriculture and Success Stories: Dr. Narayan Gowda and Dr. Kamal Vatta

Technical session XI- Eco-responsive Livestock and Fisheries Production- Dr. Asha Dhawan and Dr. Meera D. Ansal

Panel discussion

Dr. Birgit Wilhelm, Dr. Kamal Vatta, Dr. Vijay Vardhan, Jagmeet Bal and Murli Dhar

Plenary session chairperson and co-chairpersons

Dr. P.K .Sharma, Dr. K.S.Risam and A. K. Dhawan

Keynote speakers

Padma Shri Chewang Norphel, Dr. N.K. Krishna Kumar, Dr. Nazeer Ahmad, Dr. Chanda Siddoo-Atwal, Dr. Birgit Wilhelm, Dr. Keshav R. Kranthi, Dr. K. Narayana Gowda, Dr. S. Dam Roy, Dr. Anil Kakkar, Dr. Bushan L. Jalali, Dr. Dinesh K. Marothia, Dr. Randeep Guleria, Dr. Kamal Vatta, Dr.Krishan Bir Chaudhary, and Dr. U.C.Sharma

Correct citation: Dhawan, A.K., Peshin,R. and Chauhan,S.K.(2016) Summary and recommendations of the Indian Ecological Society International Conference on Natural Resource Management: Ecological Perspectives. *Indian Journal of Ecology,* **43** (Special issue 2): 603-610.

Indian Journal of Ecology (2016) 43 (Special Issue-2): 611-614

Manuscript Number: 2345
NAAS Rating: 4.47

Popularization of Improved Production Technologies in Oilseed Crops through Frontline Demonstrations under Rainfed Conditions in Punjab

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Abstract: All the improved production technologies (rainfed varieties, sowing with seed drill and recommended fertilizer application) recorded increase in yield for both the crops over farmers' practices. The per cent increase in yield under rainfed condition over local cultivars was 41.1 and 53.3, while 66.9 and 45.4 per cent and 32.0 and 21.7 per cent for drill sowing and fertilizer application over farmers practice in raya & taramira, respectively.. The B:C ratio of the improved practices demonstrated through the FLDs was also higher for both the crops in comparison to farmers' practice. High technology gap and technology index for both the crops was observed. This indicated that productivity of oilseed crops per unit area could be increased by adopting recommended management practices with a suitable high yielding rainfed variety under rainfed conditions.

***Key Words*:** Frontline demonstrations, Improved varieties, *Kandi* region, Oilseed crops

Oilseed crops have significant contribution in Indian agriculture and are second largest agricultural commodity in India after cereals sharing 14% of the gross cropped area and accounting for nearly three per cent of gross national product and 10% value of all agricultural products (Meena *et al.,* 2012). During 2013, globally it was cultivated on an area of 290 m ha with production of 196.7 m tonnes, while in India, it was cultivated on 42 m ha with production of 12.8 mt with an average productivity of 3.03 q ha^{-1} (FAO, 2013), which is less than half of the world productivity (6.78 q ha^{-1}). The oilseed crops are generally cultivated on marginal lands having low soil fertility and under rainfed conditions. Moreover, poor agronomic practice, selection of suitable variety, nutrient management, weed management and irrigation management etc. are responsible for low productivity of oilseed crops in India. The available agricultural technology does not serve the very purpose until it reaches and adopted by its ultimate users the farmers. The extent of adoption of improved agricultural technologies is a crucial aspect under innovation diffusion process and the most important for enhancing agricultural production at a faster rate. Large number of technologies evolved in the field of agriculture is not being accepted and adopted to its fullest extent by the farmers. The gap between recommendations made by the scientists and actual use by farmers is frequently encountered. Frontline demonstration is the new concept with main objective to demonstrate newly released crop production and protection technologies and its management practices in the farmers' fields. Keeping this in view, frontline demonstrations (on farmer's fields) on oilseed crops were conducted to demonstrate the production potential and economic benefits of drought tolerant varieties and latest improved technologies to the farmers.

MATERIAL AND METHODS

Total 102 frontline demonstrations (FLDs) to demonstrate the effect of high yielding varieties, drill sowing and fertilizer application on the productivity of oilseed crops were conducted during *rabi* 2011-12 to 2013-14 on farmers' fields under rainfed conditions in Punjab. The soils of the farmer fields were sandy loam to silty clay loam in texture, neutral to slightly alkaline in reaction with low to medium soil organic carbon and medium to high in phosphorus and potassium. Each demonstration was conducted on an area of 0.2-0.3 ha and adjacent plot (0.1-0.2 ha) to the demonstration plot was kept for assigning farmers practices.

The technologies selected for FLDs were improved high yielding rainfed varieties, drill sowing and fertilizer application. The spacing followed was at 30 cm (row-row) for both the crop. The sowing of raya and taramira was done between last week of October and second week of November. The improved practices adopted for frontline demonstrations for both the crops are given in table 1. The technology gap and technology index were calculated using the formula as suggested by Samui *et al*. (2000).

Technology gap (kg ha^{-1}) = Potential yield (kg ha^{-1}) – Demonstration yield (kg ha^{-1}).

Technology index (%) = {(Potential yield – Demonstration yield) / Potential yield} x 100

RESULTS AND DISCUSSION

Constraints in oilseed production: The availability of suitable high yielding variety (HYV) seed (75%) was given the top most rank followed by low technical knowledge (71%), germination/crop stand, and uncertainty of monsoon rains/drought (52%) were the major constraints to oil seed crops production. Other constraints such as aphid infestation, low fertility and post-harvest management were also found to reduce oilseed production.

Performance of FLD: The productivity of improved raya varieties ranged between 700 to 1300 kg ha^{-1} with a mean yield 1017 kg ha^{-1}, while that of improved taramira variety ranged between 665 to 550 kg/ha with mean value of 610 kg ha^{-1} in comparison to the productivity of 721 kg ha^{-1} and 398 kg ha^{-1}, respectively for local variety (Table 3). The additional mean yield of high yielding raya varieties over local cultivar was 296 kg ha^{-1}, however it was 212 kg ha^{-1} in case of taramira which may be due to non-availability of quality seed and lack of knowledge about the improved high yielding varieties. The productivity of raya and taramira in the FLDs on sowing with seed drill was 898 kg ha^{-1} and 583 kg ha^{-1}, respectively. The additional yield with drill sowing was 360 kg ha^{-1} and 182 kg ha^{-1}, respectively over farmer practice of sowing with broadcasting. This was mainly due to higher per cent germination/crop stand (75-80%) in case of sowing with seed drill as the seed was placed in the soil zone having sufficient moisture for germination in comparison to sowing with broadcasting method (60-65%) which results in uneven/poor germination and ultimately poor crop stand. The productivity of raya and taramira in the FLDs on fertilizer application (as per PAU recommendations) was 746 kg ha^{-1} and 511 kg ha^{-1}, respectively and increase in yield was 32.0 and 21.7 per cent in raya and taramira, respectively over farmer practice (no fertilizer application), which was mainly due to better nutrient management in the FLDs as the basal nitrogen application helps in crop establishment. The variation in the productivity was caused by delay in sowing in some of the farmer's fields due to delayed rains and prolonged dry spell during the growth period (Table 6). Similar enhancement in productivity of different crops in front line demonstration has been documented by Mishra *et al.* (2009); Katare *et al*. (2011); Meena *et al*. (2014) and Singh *et al.* (2014).

Technology gap: The technology gap in the demonstration yield over potential yield and the average value was 283, 402 and 554 kg ha^{-1} for raya and 115, 142 and 214 kg ha^{-1} for

Table 2. Ranks given by farmers for different constraints (n=100)

Constraints percentage ranks	Percentage	Rank
Availability of suitable HYV seed	75	I
Germination/crop stand	68	III
Aphid infestation	35	VI
Low soil fertility	42	V
Low technical knowledge	71	II
Uncertainty of rains/drought	52	IV
Post-harvest management	25	VII

Table 1. Particulars showing the details of oilseeds growing under FLD and farmers' practices

Technology	Farmers practice	Improved practices
FLDs on improved varieties		
Variety	Local/unknown variety	Raya: RLC 1, RLM 619 and PBR 97
Crop production and protection	All the crop management practices as per the package of practices for *rabi* crops by Punjab Agricultural University, Ludhiana (Anonymous, 2011) were followed for raising the crop.	
FLDs on sowing with seed drill		
Variety	Local/unknown variety	Raya: RLC 1, RLM 619 and PBR 97 Taramira: TMLC 2
Spacing	Broadcasting of seed	Spacing was 30 cm between rows and 10-15 cm between plants in the row.
Seed Rate	5.0 – 6.0 kg/ha	Raya and Taramira: 3.75 kg ha^{-1}
Crop production and protection	The other crop management practise was kept same as per farmers' practices for both the crops to demonstrate the impact of sowing with seed drill on per unit yield.	
FLDs on fertilizer application		
Variety	Local/unknown variety	Raya: RLC 1, RLM 619 & PBR 97 Taramira: TMLC 2
Fertilizer application	Only FYM and no fertilizer application	Raya : 37.5 kg N and 20 kg P_2O_5 ha^{-1} as basal application Taramira: 30 kg N ha^{-1} as basal application
Crop production and protection	The other crop management practise was kept same as per farmers' practices for both the crops to demonstrate the impact of fertilizer application on per unit yield.	

taramira, respectively in FLDs on HYVs, sowing with seed drill and fertilizer application. Hence variety-wise location specific recommendation with full package of practices and other pre-requisite appears to be necessary to minimize the technology gap for yield level under different situations. Such steps would boost up the production and bring more prosperity to the farming community.

Technology index (%): Technology index varied from 42.6 to 15.9 % and showed the feasibility of the varieties as well as improved technologies at the farmer's field. The findings of the present study are in line with the findings of Singh *et al.* (2007) and Ahmad *et al.* (2013).The results indicated that performance of improved varieties was better than the local cultivars and farmers were motivated by HYVs and improved technologies demonstrated in the FLDs which will result in adoption of these improved technologies.

Economics: FLDs recorded higher net returns (Table 4 and 5) and B:C ratio in comparison to farmers' practise, these results are in line with the results of Katare *et al*. (2011); Sreelakshmi *et al*. (2012); Meena *et al.* (2014) and Singh *et al.* (2014). The cost of production of oilseeds under improved technologies for both the crops was higher than farmers' practise due to higher cost of inputs and more labour for cultural practices. The results from the present study clearly brought out the potential of improved production technologies in enhancing oil seed production and economic gains in rainfed farming situations.

The frontline demonstrations conducted on oilseeds at the farmers' fields revealed that the adoption of improved production technologies significantly increased the yield and net returns to the farmers. So, there is need to effectively disseminate these improved technologies among the farmers with extension methods like training and demonstrations.

Table 3. Seed yield of different oilseed crops as affected by improved and farmer practices in farmer fields

Improved technology	Demonstration (No.)	Yield ($kg\ ha^{-1}$)		Additional yield ($kg\ ha^{-1}$) over farmer practise	% increase in yield over farmer practise	Technology Gap ($kg\ ha^{-1}$)	Technology index (%)
		Improved technology (IT)*	Farmer practice (FP)				
Improved varieties							
Raya	18	1017 (700-1300)	721	296	41.1	283	21.8
Taramira	12	610 (665-550)	398	212	53.3	115	15.9
Sowing with seed drill							
Raya	21	898 (1060-800)	538	360	66.9	402	30.9
Taramira	18	583 (660-540)	401	182	45.4	142	19.6
Fertilizer application							
Raya	15	746 (940 -670)	565	181	32.0	554	42.6
Taramira	18	511 (650-340)	420	91	21.7	214	29.5

*Values in parenthesis are the range of yield in the FLDs

Table 4. Cost of cultivation (Rs ha^{-1}), net return (Rs ha^{-1}) and benefit: cost-ratio of different oilseed crops as affected by improved and farmer practices

Technology	Cost of cultivation (Rs ha^{-1})		Gross returns (Rs ha^{-1})		Net returns (Rs ha^{-1})		Additional cost of cultivation (Rs ha^{-1})	Additional returns (Rs ha^{-1})	B:C Ratio	
	IT	FP	IT	FP	IT	FP			IT	FP
Improved varieties										
Raya	14,288	13,668	34,448	24,038	20,440	10,840	620	9,600	2.41	1.76
Taramira	10,625	10,610	19,285	12,483	8,660	1,873	15	6,787	1.83	1.17
Drill sowing										
Raya	12,287	11,857	30,287	18,461	18,000	6,605	430	11,395	2.46	1.51
Taramira	9,666	9,020	19,698	13,696	10,032	4,675	646	5,357	2.06	1.59
Fertilizer application										
Raya	11,937	10,357	24,403	18,514	12,466	8,157	1,580	4,309	2.04	1.78
Taramira	8,657	8,164	16,949	13,873	8,292	5,709	885	2,483	1.95	1.67

Market rate of raya and taramira: Raya = 30.00 Taramira 35.00 (2011-12), Raya = 35.00, Taramira = 30.00 (2012-13), Raya = 35.00, Taramira = 30.00 (2013-14)

Table 5. Cost of different inputs used for FLDs

Particulars of input	Rate (Rs.)		
	2011-12	2012-13	2013-14
Hiring of tractor for ploughing etc. (Rs ha^{-1})	1500/-	1800/	1800/-
Seed (Rs 80 kg^{-1})	80/-	80/-	100/-
Urea (Rs kg^{-1})	5.31/-	5.36/-	5.44/-
DAP (Rs kg^{-1})	10.75/-	12.00/-	22.50/-
SSP (Rs kg^{-1})	9.60/-	12.00/-	16.80/-
FYM (Rs q^{-1}))	43.50/-	50.00/-	50.00/-
Herbicide (Rs kg^{-1})	600/-	600/-	600/-
Insecticide (Rogar) (Rs kg^{-1})	315/-	315/-	315/-
Labour charge (Rs $manday^{-1}$)*	147.73/- and 164.04/-	210.00/- and 219.20/-	250.64/- and 258.34/-

* Minimum wages to labour changed in the month of March every year

Table 6. Detail of dry spells during the *rabi* seasons during three years

Year	Seasonal rainfall (mm)	Date of first rainfall	Duration of dry spell
2011-12	133.0	8th Dec.	82 days (17th Sept. to 7th Dec.) 22 days (9th Dec. to 30th Dec.) 16 days (18th Jan to 4th Feb.) 33 days (5th Feb. to 10th March)
2012-13	199.6	11th Dec.	94 days (18th Sept. to 10th Dec.) 25 days (13th Dec. to 8th Jan.) 15 days (18th Jan. to 3 Feb.) 15 days (27th Feb. to 14th March)
2013-14	223.6	30th Oct.	43 days (8th Nov. to 22nd Dec.) 17 days (30th Dec. to 16th Jan.)

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Received 04 February, 2016; Accepted 12 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 615-618

Manuscript Number: 2346
NAAS Rating: 4.47

Effect of Different Land Configurations, Irrigation Regimes and Potassium Levels on Consumptive Use, Water Use Efficiency and Yield of Summer Groundnut *(Arachis hypogaea* L.*)*

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Abstract: The field experiment was laid out in split - split plot design replicated thrice with 27 treatment combinations comprising of three main plot treatments consisting of land configurations *viz.,* Flat Bed, Broad Bed Furrow (BBF), and Broad Bed Furrow (BBF) + Polythene mulch (black), three subplot treatments of irrigation regimes *viz.,* 0.6, 0.8 and 1.0 IW/CPE ratios and three sub-sub plot treatments of potassium levels *viz.,* 20, 40 and 60 kg ha^{-1} K_2O. The BBF+Polythene mulch recorded significantly higher dry pod and haulm yield. Irrigation at 1.0 IW/CPE ratio produced significantly higher dry pod and haulm yield However, it was at par with 0.8 IW/CPE ratio. The potassium application 60 kg ha^{-1} K_2O produced significantly higher dry pod and haulm yield. However, it was at par with application of 40 kg ha^{-1} K_2O. The consumptive use of water was recorded higher in combination of 1.0 IW/CPE ratio coupled with BBF+ polythene mulch while lower consumptive use of water was in combination of 0.6 IW/CPE ratio with flat bed. However, water use efficiency was higher in combination, recorded of 0.6 IW/CPE ratio with BBF + polythene mulch, followed by 0.8 IW/CPE ratio with BBF + polythene mulch. The lower water use efficiency was in 0.6 IW/CPE ratio with flat bed. The gross monetary returns, net monetary returns and B:C ratio were significantly higher in the treatment of broad bed furrow + polythene mulch. In irrigation levels, significantly higher gross monetary returns, net monetary returns and B:C ratio were recorded in the irrigation regime at 1.0 IW/CPE ratio. It was followed by and at par with application of irrigation at 0.8 IW/CPE ratio. Incase of potassium levels, gross monetary returns, net monetary returns and B:C ratio were significantly higher at application of potassium @ 60 kg K_2O ha^{-1} followed by and at par with application of the 40 kg K_2O ha^{-1}.

***Key Words*:** Consumptive use, Irrigation regimes, Land configurations, Polythene mulch, Potassium levels, Water use efficiency, Yield of groundnut

Among all oilseed crops, groundnut (*Arachis hypogaea* L.) is premier and one of the most important money minting legumes-cum oilseed crops of India. In crop production, irrigation water is one of the most important input which is a scarce and expensive input. Mulching is useful for moderating soil temperature, conserving soil moisture and for controlling weed growth. Solar heating of the soil by mulching the bare soil with polythene films during hot summer months, immediately before planting of the crop can effect excellent control of weeds, nematodes and soil borne pathogens. Application of mulch not only helps in realizing higher yields, but also contributes in reducing water requirement by 40 per cent and eliminates crop weed competition (Basu, 2008) . The low average yield of the crop is mainly due inadequate nutrient and irrigation. The fertilizer application is the most important factor contributing to the crop production. The medium black soils in the intensive cropping area started depleting in potassium on long run from high to medium and to low levels. In such conditions groundnut crop may respond to potassium application (Patil *et al.,* 2003). In view of this, the field experiment was conducted to evaluate the irrigation requirement for polythene mulch summer groundnut with potassium levels.

MATERIAL AND METHODS

The field experiment was conducted in 2011 and 2012 at Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was laid out in split - split plot design with three replications. The treatments comprised of three main plot treatments of land configurations *viz.,* Flat bed, Broad Bed Furrow (BBF), and Broad Bed Furrow (BBF) + Polythene mulch (black), three subplot treatments of irrigation regimes *viz.,* 0.6, 0.8 and 1.0 IW/CPE ratios and three sub-sub plot treatments of potassium levels *viz.,* 20, 40 and 60 kg K_2O ha^{-1} and replicated thrice. The gross plot size was 5.10 x 3.60 m^2 and net plot size was 4.50 x 3.00 m^2 for flat bed and 4.50 x 2.40 m^2 for BBF and BBF + polythene mulch. Recommended dose of fertilizer (25:50 NP kg ha^{-1}) was applied to all treatments and K was applied as per treatments. The polythene mulch used was of 7 micron thickness. The variety used for experimentation was '*RHRG 6083*'.

RESULTS AND DISCUSSION

Consumptive use and water use efficiency: The higher consumptive use of water 732.19 mm and 728.92 mm was in the year 2011 and 2012, respectively, in 1.0 IW/CPE ratio with flat bed followed by 0.8 IW/CPE ratio with flat bed. The lower consumptive use of water was in combination of 0.6 IW/CPE ratio with BBF + polythene mulch. However, higher water use efficiency was recorded in 0.6 IW/CPE ratio with BBF + polythene mulch, followed by 0.8 IW/CPE ratio with BBF + polythene mulch. The lowest water use efficiency was observed in 0.6 IW/CPE ratio with flat bed (Table 1).

Land configurations: The test weight was significantly higher in BBF + polythene mulch (43.92 g). Similar trend was observed in respect of dry pod yield plant^{-1} (Table 2). It was followed by broad bed furrow and the lowest dry pod yield plant^{-1} was recorded in flat bed. The BBF + polythene mulch recorded significantly higher dry pod yield (4915.84 kg ha^{-1}) and haulm yield (9189.21 kg ha^{-1}). It was followed by broad bed furrow without polythene mulch. This might be because of higher moisture retention through out the growth period in BBF + polythene mulch which enhanced the moisture and nutrient availability, induced and created conducive environment (micro-climate) for rapid germination and early establishment of seedlings which resulted in vigorous growth of the crop. The increase in soil microorganisms accelerates the decomposition and transformation of organic matter in the soil, thus increasing the level of available nutrients in the soil. It also prevents weed seed to germinate hence no weed competition for moisture and nutrients with the crop (Basu *et al.,* 2008). BBF + polythene mulch increases physical condition of the soil with increased porosity of soil resulting into increased root mass, which altogether produced higher dry pod yield. The results are in conformity with Subrahmaniyan *et al*. (2008), Zagade and Chavan (2010) and Bure *et al*. (2011).

Irrigation regimes: Scheduling of irrigation at 1.0 IW/CPE ratio caused significantly higher dry pod yield per plant 27.33 g) and test weight (42.24 g), dry pod yield (4278.84 kg ha^{-1}) and haulm yield (8676.09 kg ha^{-1}) . However, it was at par with 0.8 IW/CPE ratio (Table 2). This might be due to optimum moisture status with the application of irrigation at 0.8 and 1.0 IW/CPE resulting in to enhanced nutrient availability to the crop favoring yield contributing parameter and higher dry pod yield.

Potassium levels: The yield contributing characters *viz.,* test weight (42.11g) was significantly higher with application of 60 kg ha^{-1}K_2O. Similarly, application of potassium 60 kg K_2O ha^{-1} exhibited significantly maximum dry pod yield (4123.47 kg ha^{-1}) and haulm yield (8441.22 kg ha^{-1}). However, the yield attributes and yield was at par with application of 40 kg K_2O ha^{-1} (Table 2). This might be due to the involvement of potassium in physiological and biochemical functions of plant growth i.e. enzyme activation, water balance, protein synthesis, starch synthesis etc. Its application in legumes, improves nitrogen fixation capacity of plants and availability of all nutrients. These favorable effects might have resulted in higher dry pod yield and haulm yield. The results are in conformity with the Singh (2007) and Salve *et al*. (2010).

Interaction effect: The irrigation at 1.0 IW/ CPE ratio with broad bed furrow + polythene mulch recorded significantly higher dry pod yield (4953.75 kg ha^{-1}) and haulm yield (9238.88 kg ha^{-1}) on pooled mean basis. However, it remained at par with treatment combination of BBF + polythene mulch with irrigation at 0.8 IW/ CPE and BBF + polythene mulch with 0.6 IW/CPE ratio (Table 3).

Cost of cultivation : The cost of cultivation was significantly higher in BBF + polythene mulch. It was followed by broad bed furrow without polythene mulch. As regards, irrigation levels, the irrigation at 1.0 IW/CPE ratio recorded significantly

Table 1. Consumptive use and water use efficiency as influenced by land configurations and irrigation regimes

Treatment	Moisture depletion (mm)		Effective rainfall (mm)		Consumptive use (mm)		Dry pod yield (kg ha^{-1})		WUE (kg ha^{-1}-mm)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
I_1 - 0.6 IW/CPE										
Flat bed	555.67	554.37	53.4	52	609.07	606.37	2974.9	2696.9	4.88	4.45
Broad bed furrow (BBF)	487.26	484.37	53.4	52	540.66	536.37	3029.5	2897.4	5.60	5.40
BBF + poly mulch	394.63	407.35	53.4	52	448.03	459.35	4999.4	4756.8	11.16	10.36
I_2 - 0.8 IW/CPE										
Flat bed	611.28	616.25	53.4	52	664.68	668.25	3650.7	3548.0	5.49	5.31
Broad bed furrow (BBF)	537.34	564.51	53.4	52	590.74	616.51	5301.0	4127.3	7.28	6.69
BBF + poly mulch	452.99	498.21	53.4	52	506.39	550.21	5026.1	4805.3	9.93	8.73
I_3 - 1.0 IW/CPE										
Flat bed	678.79	676.92	53.4	52	732.19	728.92	3704.3	3558.9	5.06	4.88
Broad bed furrow (BBF)	608.03	626.00	53.4	52	661.43	678.00	4351.6	4150.7	6.58	6.12
BBF + poly mulch	513.51	546.67	53.4	52	566.91	598.67	5070.5	4836.9	8.94	8.08

Table 2. Pooled data of yield contributing characters, dry pod and haulm yield of groundnut and economics as influenced by land configurations, irrigation regimes and potassium levels

Treatments	Dry pod yield plant^{-1} (g)	Test (100 kernel) weight (g)	Dry pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Cost of cultivation	Gross monetary returns	Net monetary returns (Rs ha^{-1})	B:C ratio
A. Land configurations (P)								
Flat bed	24.70	38.57	3355.67	7537.02	67626	132384	64757	1.95
Broad bed furrow (BBF)	25.33	40.24	3809.60	7958.22	69939	149796	79857	2.13
BBF + poly mulch	28.75	43.92	4915.84	9189.21	74451	192302	117851	2.58
CD (p = 0.05)	1.47	3.39	106.24	212.29	-	9016	8509	0.06
B. Irrigation regimes (I) - IW/CPE								
0.6	24.66	38.86	3559.16	7510.99	68527	139944	71417	2.02
0.8	26.78	41.63	4243.12	8497.37	70646	166535	95888	2.35
1.0	27.33	42.24	4278.84	8676.09	72845	168004	95159	2.30
CD (p = 0.05)	0.64	0.61	56.80	134.31	-	3607	3608	0.03
C. Potassium (K_2O) levels (F) - kg ha^{-1}								
20	25.69	39.41	3842.28	7945.70	70390	151048	80658	2.13
40	26.18	41.20	4115.36	8297.53	70554	161504	90950	2.27
60	26.90	42.11	4123.47	8441.22	71073	161930	90857	2.26
CD (p = 0.05)	0.21	0.45	45.62	75.74	-	1485	1486	0.02
Mean	26.26	40.91	4027.04	8228.15	70672	158161	87488	2.22

Table 3. Interaction effect between land configurations and irrigation regimes on dry pod yield and haulm (pooled mean)

Land configuration Irrigation regimes (IW/CPE)	Dry pod yield (kg ha^{-1})			Haulm yield (kg ha^{-1})		
	Flat bed	BBF	BBF + polymulch	Flat bed	BBF	BBF + polymulch
0.6	2835.90	2963.48	4878.09	6590.51	6824.37	9118.09
0.8	3599.48	4214.17	4915.70	7822.50	8458.94	9210.66
1.0	3631.61	4251.15	4953.75	8198.04	8591.35	9238.88
CD (p= 0.05)						
Between irrigation (I) means at same level of land cofiguration (P) means			98.38			232.63
Between P means at same level of I means			114.03			255.33

higher cost of cultivation. In respect of potassium levels, cost of cultivation were recorded significantly higher in the application of potassium @ 60 kg K_2O ha^{-1} (Table 2).

Gross monetary returns : The gross monetary returns (Rs. 192302 ha^{-1}) were obtained significantly higher in the treatment of broad bed furrow + polythene mulch. As regards, irrigation levels, significantly higher gross monetary returns (Rs. 168004 ha^{-1}) were recorded in the irrigation regime at 1.0 IW/CPE ratio. It was followed by and at par with application of irrigation at 0.8 IW/CPE ratio. In case of potassium levels, gross monetary returns (Rs. 161930 ha^{-1}) was obtained significantly higher at application of potassium @ 60 kg K_2O ha^{-1}. It was followed by and at par with application of the 40 kg K_2O ha^{-1} (Table 2).

Net monetary returns: The significantly higher net monetary returns (Rs.117851 ha^{-1}) in pooled mean basis was obtained in broad bed furrow + polythene mulch. In respect of irrigation levels, significantly higher net monetary returns (Rs. 95888 ha^{-1}) was recorded in the application of irrigation at 0.8 IW/CPE ratio. As regards, potassium levels, significantly higher net monetary returns (Rs. 90950 ha^{-1}) were obtained at application of potassium @ 40 kg K_2O ha^{-1}. (Table 2).

Benefit : cost ratio: The benefit : cost ratio (2.58) was recorded significantly higher in the treatment broad bed furrow + polythene mulch. In respect of irrigation levels, significantly higher benefit : cost ratio (2.35) was recorded in the irrigation application at 0.8 IW/CPE ratio. The benefit : cost ratio (2.27) was significantly higher where the potassium was applied @ 40 kg K_2O ha^{-1} (Table 2).

It is concluded that summer groundnut should be cultivated on broad bed and furrow (BBF) with polythene

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Received 26 March, 2016; Accepted 10 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 619-623

Manuscript Number: 2347
NAAS Rating: 4.47

Agricultural Resource Management Using Optimization Techniques – A Case Study

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***Abstract*:** Application of optimization techniques play important role for utilizing of agricultural resources efficiently. In view of optimization of agricultural resources, most popular optimization technique, linear programming was used in Kharagpur block-1 of district Midnapur (W.B), India for management of agricultural resources with the objective function of maximization of the net return. A linear programming model was formulated considering twelve major crops of the study area. Consumptive use of every crop was calculated by pan evaporation data. It was found that net profit of the block was increased by 42.82 per cent with existing one using available resources optimally.

***Key Words*:** Consumptive use, Linear Programming, Net profit, Optimization

In India the agriculture alone sustains the livelihood of around 60 per cent of the population and contributes nearly 25 per cent of nation's gross domestic product (GDP) and 15 per cent of export. With the explosion of population the demand of food, feed and fiber are increasing which can be achieved by increasing production through intensive cropping and by enhancing productivity. Land availability being limited, leaving little scope for horizontal expansion and the aspiration level of farming community is on the increased. The efficient management of the agricultural resources is becoming the key issue for feed the increasing population from the limited resources. In modern concept efficient management of agricultural resources for maximizing the out put from any piece of land, it is necessary to find out the best possible allocation of land under different crops considering the constraints like water, fertilizer and labour.

Indian agriculture has a vast potential and can feed an even larger population provided targets are met with the land and managed judiciously. The potential for growth and diversification can be fully exploited taking the holistic view of climate, soil type, topography, water resources and irrigation facilities and relating them to the output and employment. This underline the importance of micro level planning. In order to meet the needs of agricultural industry, national, nutritional and regional goals, farmer's interest food and nutritional requirement of the population and judicious utilization resources, a case study in Kharagpur-1 block was under taken. Attempt has been made to develop linear programming model for appropriate allocation of land under different crops. The study was conducted keeping the objective function maximization of the net profit considering all the constraints like land labour and availability of water resources in the study area, nutritional food area fertilizer.

MATERIAL AND METHODS

The project area Kharagpur block-I is located at latitude of 22^{o} 22'N and at a longitude of 87^{o} 20'E. It is situated at about 8 km in the south of Midnapur (West Bengal), India. The total geographical area of Kharagpur block-1 is 32600 ha the net cultivated area is 18500 ha. The dally rainfall data of 20 years and evaporation data of 15 years were taken from Indian Institute Technology (IIT) Kharagpur observatory and converted on weekly basis to predict the expected weekly rainfall and evaporation at different probability level using Weibull's plotting position formula. Consumptive use of various crops was calculated from pan evaporation data. Twelve crops were considered for land allocation so as to maximization of net benefit within the constraints. Parameters were estimated by taking maximum yields of all crops at optimum levels of water and fertilizer inputs. Only area is taken as the as the decision variable. For optimal resources, the whole block is considered a compact and self-sufficient unit and resources were considered to be transportable within the block. Planning was done keeping in view the farmer's benefit under the constraints of nutrition and food for the socio-economic upliftment of the block.

Keeping the economic food nutritional needs in view, twelve crops (Table 1) are considered for land allocation so as to maximize net benefit within the constraints, the selected crops like paddy wheat, mustard, groundnut, greengram, sesamum, sugarcane, brinjal, chilli . potato, tomato and lady's finger. Linear programming technique was used for optimization for net benefit.

Table 1. Major crops of Kharagpur Block-1 considered model

Notation	Crop	Type of cultivation
A_1	Paddy (Local)	Kharif & Rainfed
A_2	Paddy (HYV)	Kharif & Irrigated
A_3	Paddy(HYV)	Rabi, Irrigated (Boro)
A_4	Wheat	Rabi & Irrigated
A_5	Mustard	Rabi & Irrigated
A_6	Groundnut	Kharif & Irrigated
A_7	Greengram	Rabi & Irrigated
A_8	Greengram	Summer & Rainfed
A_9	Sesamum	Summer & Rainfed
A_{10}	Sugarcane	Summer & Irrigated
A_{11}	Brinjal	Rabi & Irrigated
A_{12}	Chilli	Rabi & Irrigated
A_{13}	Potato	Rabi & Irrigated
A_{14}	Tomato	Rabi & Irrigated
A_{15}	Lady's finger	Kharif & Rainfed

Assumed that: *Kharif*-28^{th} to 42^{nd} standard week; *Rabi*- 43^{rd} to 11^{th} standard week: Summer:12^{th} to 27^{th} standard week

Theoretical approach: The assumptions made in developing the present model were soil of the bock is homogeneous, farm resources such as land, labour and capital are divisible, each unit of land receives the same management practices for a particular crop, time and period of the crop is same in every year, amount of water and fertilizer applied during different physiological crop growth stages for a particular crop is based on recommendation of the department of agriculture government of West Bengal and all the relationships in the objective function and in the constraints are linear

Objective function

Maximization of net benefit (Zb): The net benefit from each crop should be maximised and can be expressed as

$$\text{Maximization } Zb = \sum_{i=1}^{15} \text{Bi Ai}$$

Constraints: The constraints are as under

(a) Area constraints

The total summation of the area under all the crops in any given season should not be greater than the total area available for the cultivation, mathematically it can be expressed as:

(I) Kharif season: $\sum_{i=n}^{n} Ai \leq TA$

(ii) Rabi season- $\sum_{i=n}^{n} Ai \leq TA$

(iii) Summer season- $\sum_{i=n}^{n} Ai \leq TA$

(b) Target constraints

Government of west Bengal has propose some minimum area under different crops for the block. Accordingly,

$$\sum_{i=n}^{n} Ai \geq Ati$$

(c) Labour requirement

The limited number of labour available in the block should be utilized effectively to meet the labour requirement in a season so that no labour is imported from outside. Hence, total labour requirement should not exceed the total labour available in that season. Mathematically,

(i) Kharif season- $\sum_{i=n}^{n} LiAi \leq Lk$

(ii) Rabi season- $\sum_{i=n}^{n} LiAi \leq Lr$

(iii) Summer season- $\sum_{i=n}^{n} LiAi \leq Ls$

(d) Weekly water constraints

The peak weekly water demand of the cropping pattern should be less than the weekly water supply from all the existing sources in a particular week, i.e. water requirement for the different crops in a given week must be less than the total available water in that standard week. Mathematically,

$$\sum_{j=1}^{52} WijAi \leq TW$$

(e) Food constraints

The crop yield obtained from the block should be sufficient for the food requirement of the population in order to have self- sufficiency in terms of food grains (cereals & pulses) potato and vegetables. These are considered under food constraints. The total production of these items should meet the annual requirements of the population, which is based on the minimum per capita requirement recommended by ICMR (Indian Council of Medical Research). These constraints are mathematically expressed as:

(i) Cereal constraints- $\sum_{i=n}^{n} YiAi \geq TCr$

(ii) Pulse constraints- $\sum_{i=n}^{n} IiAi \geq Pr$

(iii) Potato constraints- $\sum_{i=n}^{n} IiAi \geq Tpo$

(iv) Vegetable constraints- $\sum_{i=n}^{n} IiAi \geq Tvr$

(f) Nutritional constraints

(i) Energy requirement- $\sum_{i=n}^{n} EiAi \geq Te$

(ii) Protein requirement- $\sum_{i=n}^{n} PrAi \geq Tp$

(iii) Iron requirement- $\sum_{i=n}^{n} IiAi \geq TI$

(iv) Calcium requirement- $\sum_{i=n}^{n} CiAi \geq Tc$

(g) Fertilizer constraint

The major plant nutrients supplied to the crops through fertilizer are nitrogen, phosphorus and potassium. In order to prevent procurement of fertilizer from outside , the total fertilizer applied to crops should not exceed its availability in the season. Hence,

(i) Nitrogen requirement: $\sum_{i=n}^{n} NiAi \leq Tn$

(ii) Phosphorous requirement: $\sum_{i=n}^{n} PiAi \leq Tp$

(iii) Potassium requirement : $\sum_{i=n}^{n} KiAi \leq Tk$

(h) Affinity constraints

Due to strong affinity of the local people towards rice , it is assumed that a minimum of 50 percent and 7.5 percent of the cultivable area must be allocated to paddy in kharif and rabi season respectively . it can be mathematically expressed as

(i) Kharif Paddy: $A_1+A_2 \geq 0.5$ TA

(ii) Boro Paddy: $A_3 \geq 0.075$ TA

(a) Economy constraints: Considering risk involved in working demand, high capital investment and other economic factor, crops like oilseeds, pulses, sugarcane and potato have been restricted in their allocation values. A minimum 6% ,10%, 0.9% and 2.5% of total area allocated for the oil seed, pulses, sugarcane and potato.

(i) Oil seeds: $A_5+A_6+A_9 \leq 0.06$ TA

(ii) Pulses: $A_7+A_8 \leq 0.1$ TA

(iii) Sugarcane: $A_{10} \leq 0.009$ TA

(iv) Potato: $A_{13} \leq 0.025$ TA

Where,

Bi	=	net return from the cultivation of i^{th} crop, Rs ha^{-1}
Ai	=	area under i^{th} crop ha,
i	=	index of crop under consideration of respective season
TA	=	total available cultivation area of the block, ha,
Ati	=	targeted area for i^{th} crop by govt. of W.B
Li	=	labour requirement for th i^{th} crop, man days/ha required in different season
Lk	=	total availability of labour in the kharif season
Lr	=	total availability of labour in the rabi season
Ls	=	total availability of labour in the summer season
Wij	=	weekly water demand of the i^{th} crop in j^{th} week cm,
j	=	index for the standard weeks
TW	=	weekly water supply capacity ha-cm.
T_{cr}	=	total cereal requirements of the block, quintal,
T_{pr}	=	total pulses requirements of the block, quintal,
T_{po}	=	total potato requirements of the block, quintal,
T_{vr}	=	total vegetable requirements of the block, quintal,
T_e	=	total energy requirement of the block ,k cal,
E_i	=	energy available from the i^{th} crop, k cal ha^{-1}
C_i	=	calcium available from the i^{th} crop, g ha^{-1}
Tc	=	total Calcium requirements of the block,g
T_n	=	represents the total amount of the nitrogen available in the block in kg,
T_p	=	represents the total amount of the phosphorous available in the block in kg
T_k	=	represents the total amount of the potassium available in the block in kg

Field determination: Agricultural resources management of a particular region would need to include those crops, which were locally and economically important keeping the economic, food nutritional needs in view, twelve crops were considered for land allocation so as to maximize net benefit within the constraints .the selected crops were paddy (three category) wheat, mustard, green gram, tomato, potato, brinjal, chilli, lady's finger ,sugarcane, ground and sesmum. Parameters were estimated by taking maximum yields of all crops at optimum levels of water and fertilizer inputs. Only area is taken as the as the decision variable.

RESULT AND DISCUSSION

The hydrological analysis shows deficit in the whole year except in kharif season. The overall evaporation rate is significantly high and reasonable amount of water is lost due to evaporation. the large deficit in most of the period calls for planning to optimize the use of water to satisfy the requirement for the entire cropping period. The water becomes constraint under independent Linear Programming (LP) strategy. Fertilizer availability of fertilizer is increase to obtain the optimal values. The per capita income of the agricultural labour in the block is surprisingly low and inadequate to meet even the minimum needs. Existing cultivation practices show that around 57 per cent of the total geographical were is used for cultivation.

The excess deficit water table (Table 2) were computed from the values of rainfall at 60% and evaporation at 40% probability level. The excess deficit table shows that surplus water is available during 25^{th} to 33th and 35^{th} to 37^{th} standard weeks only. In rest of the period the deficit condition prevails. It can be inferred that surplus condition is only during kharif season. The large deficit in most of the period calls for planning to optimize the use of water to satisfy the crop requirement for entire cropping period.

Kharagpur block-1 is mainly irrigated by dug wells, shallow tube wells, river lefts tanks, canals and deep tube wells. The existing surface and subsurface resources have been analyzed (Table 3). After analyzing all the existing water resources, it is estimated that weekly water supply during kharif, rabi and summer season is 45066.80, 34334.97 and 21763.97 ha-cm, respectively. Though the water resources seem to be abundant, the water became a constraint.

Computer software package QSB+ (Quantitative System for Business Plus) was used to solve the linear programming model. Optimum allocation of land under maximization of net profit strategy was worked out using optimization software (Table 4). Total net benefit from the crops under the model of the block was increased by 42.82% when compared with existing one. It is due to the allocation of more area under high value crops like tomato, chilli and okra (lady's finger) and reducing area under local rice crop. On the contrary area of sugarcane crop was decreased due to high investment towards its cultivation under optimum allocation of agricultural resources strategy.

The excess and deficit analysis shows that the excess irrigation water is available only during 25^{th} to 33^{rd} and 35^{th} to 37^{th} week. Deficit prevails in rest of the weeks. The net benefit

Table 2. Rainfall excess-deficit analysis

Standard week	Rainfall at 60% probability level (B)	Evaporation at 40% probability level (B)	Excess-deficit B-C
1	00.00	25.20	-25.20
2	00.00	26.00	-26.00
3	00.00	29.00	-29.00
4	00.00	25.30	-25.30
5	00.00	32.40	-32.40
6	00.00	30.10	-30.10
7	00.00	31.90	-31.90
8	00.00	38.70	-38.70
9	00.00	39.50	-39.50
10	00.00	44.10	-44.10
11	00.00	49.90	-49.90
12	00.00	46.90	-46.90
13	00.00	44.10	-44.10
14	00.00	49.18	-49.18
15	00.00	57.56	-57.56
16	00.63	60.00	-59.47
17	02.35	54.60	-52.25
18	01.59	65.10	-63.49
19	06.15	66.00	-59.85
20	11.54	62.06	-50.49
21	08.91	53.40	-44.53
22	11.61	54.86	-43.25
23	14.88	46.90	-30.02
24	26.46	52.30	-26.84
25	34.40	00.00	37.40
26	54.60	00.00	54.60
27	37.58	00.00	37.58
28	70.12	00.00	70.12
29	55.60	00.00	55.60
30	50.20	35.70	40.50
31	52.60	50.40	22.60
32	43.51	37.04	06.47
33	47.68	37.00	10.68
34	32.76	39.90	-07.14
35	49.46	32.20	17.26
36	54.60	37.60	17.00
37	40.81	35.62	05.26
38	20.78	30.24	-09.46
39	25.90	35.60	-09.70
40	12.54	34.62	-22.08
41	04.25	37.60	-33.35
42	00.00	30.00	-29.53
43	00.00	37.70	-34.70
44	00.00	33.60	33.60
45	00.00	34.00	34.00
46	00.00	35.00	35.00
47	00.00	30.80	30.80
48	00.00	36.02	36.02
49	00.00	28.28	28.28
50	00.00	23.92	23.92
51	00.00	29.60	29.60
52	00.00	27.98	27.98

Table 4. Comparison of optimal land allocation under maximization of net profit strategy

Decision	Crop	Area (ha)	
		Maximize net benefit	Existing land allocation
A_1	Paddy (K & Rn, local)	4500	15800
A_2	Paddy (K & Rn, HYV)	5500	2000
A_3	Paddy (R & I)	1500	1400
A_4	Wheat (R & I)	400	370
A_5	Mustard (R & I)	300	270
A_6	Groundnut (K & Rn)	410	350
A_7	Greengram (R & I)	700	670
A_8	Greengram (S & Rn)	1150	1050
A_9	Sesamum (S & Rn)	400	380
A_{10}	Sugarcane (S & I)	10	100
A_{11}	Brinjal (R & I)	160	140
A_{12}	Chilli (R & I)	135	125
A_{13}	Potato (R & I)	462.5	380
A_{14}	Tomato (R & I)	7273.13	4000
A_{15}	Lady's finger (K & Rn)	149.73	100

Kharif (K); Rabi (R); Rainfed (Rn); Irrigated (I); Summer (S)

increased by 42.82% when compared with existing one. It is due to the allocation of more area under high value crop like tomato, chilli and lady's figure and reducing area under local paddy. On the contrary, the area under sugarcane crop decreases because of high investment towards its cultivation.

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Table 3. Existing surface and sub surface water resources within block

Source of Irrigation	No. of Units	Water Availability	Kharif	Rabi	Summer
Deep tube well	5	285.26	285.26	213.94	142.63
River left irrigation	7	1497.63	1497.63	1497.63	------
Dry well	500	28350.00	28350.00	21262.50	14175.00
Tank	310	684.06	684.06	513.05	----------------
Shallow tube well	400	13608.00	13608.00	12206.00	6804.00
Canal	3	641.84	641.84	641.84	641.84
ha-cm week^{-1}		45066.80	45066.80	34334.97	21763.47

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Received 26 April, 2016; Accepted 14 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 624-630

Manuscript Number: 2348
NAAS Rating: 4.47

Importance of Sub Surface Drainage in Amelioration of Salt Affected Soils and Enhancing Crop Productivity

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Abstract: A study on sub surface drainage in amelioration of salt affected soils to enhance the rice productivity, revealed that after laying out the subsurface drainage in 136 acres in farmer's field, totally 1.26 million liters of leachate was discharge to natural canal through 10 outlets of subsurface drains. Through this leachate totally 19.65 tons of salts were removed. Maximum quantity of cations removed was sodium (1.61 t) followed by calcium (1.47 t) and anions removed was bicarbonate (9.13 t) followed by chloride (4.00 t). The installation of sub surface drainage alone helped to increase the rice yield to an extent of 22.99 and 25.13 per cent, whereas application of gypsum in alkali soils based on soil test and stagnating with good quality water and application of sufficient quantity of organic manures and required quantity of NPK nutrients increased the yield to an extent of 35.68 and 38.28 per cent in the first and second year, respectively.

Key Words: Drainage, Gypsum, Leachates, Rice productivity, Salt affected soils

Today India is self-sufficient in food production mainly due to better crop productivity from the irrigated crops. However, no one has concentrated on the ill effects of irrigation. Due to improper drainage facilities in irrigated command areas in semi-arid regions of Karnataka, water table has increased drastically, in addition, high evaporation and low precipitation leads to accumulation of more salts on the soil surface, which leads to salinity and alkalinity in these command areas. Because of this fertile soils have become barren leading to low crop yields there by reducing the economic development of the farmer's. Generally, all soils will be having some amount of salts, of which some salts will be essential plant nutrients for crop growth and production. However, if these salts are in excess, the growth, yield and quality of most crops is adversely affected.

It is estimated that by 2030, in India nearly 15.5 million ha of land will be infested with water logging, salinity and alkalinity (CSSRI, 2011). At present in Karnataka out of 1,28,562 ha irrigated area, totally 12,692 ha area (9.9 %) is infested with water logging, salinity and alkalinity problems. In saline soils, nearly 36 per cent and water logged areas nearly 43 per cent crop yield reduction was noticed (Chinnappa, 2002). In improvement of salt affected soils of command areas, drainage play an important role. Among the different types of drainages open drains and sub-surface drains are important. In open drains nearly 10-12 per cent cultivated land is wasted, which is not affordable by small and marginal farmers of our country and in addition maintenance is required for removal of silt quite often, otherwise they will not be effective. In sub surface drains, perforated clay pipes are very commonly used. However, these clay pipes work effectively only for few years. Because of weathering they break up and block the water seepage. Hence, in recent years corrugated and perforated plastic pipes are used for sub surface drainage. These pipes will perform efficiently for several years there by helps in improving the fertility status of the soil which in turn improve the crop productivity. Hence, a study was taken at subsurface drains installed area to see the changes in water logged and salt affected soils, amount of salts removed and changes in the crop yield.

MATERIAL AND METHODS

For the purpose of management of waterlogged and salt affected soils, 136 acres land infested (72 farmer's field) with these problems was selected in Thyavanige (Tyavangi) village, Davanagere district of Karnataka. This area was selected after surveying the problematic soils of Bhadra command for the severity of water logging and salt infestation. The area belongs to southern transition zone of Karnataka located between 14^{0} 23' 45 to 14^{0} 24' 07 N latitude and 75^{0} 58' 21 to 75^{0} 59' 13 E longitude. The soils of the study area are medium to deep black cotton soils belong to order vertisoils. The mean annual rainfall of the area was 805 mm.

The crop cutting experiment was taken during 2010 *Rabi* in each farmer's field by harvesting 5 × 5 m area of rice crop. Immediately after harvest of crop, scientific survey was taken to study the direction and percentage of slope and finally a contour map was prepared. In addition to this, surface soil samples (0-20 cm) were collected from each farmer's field and analyzed for pH, EC and ESP (Jackson, 1973) to see the severity of salinity/sodicity problems. Based on the contour map and severity of the soil problem, a drainage layout was prepared (Fig 1) for the whole 136 acres area in such a way that totally 10 outlets were connected to natural canal at the low lying area.

On the basis of this layout, lateral drains were laid at 30 m to 50 m interval at a depth of 1 m by maintaining a slope of 0.9 to 1.2 per cent with 3 perforated and corrugated PVC pipes, which were covered with geo-textile polyster to avoid the blocking of perforations of PVC pipes. Then these lateral pipes were connected to 6 corrugated and non-perforated collectors which were finally connected to natural canal as outlets. All the related structures like manholes and outlets were constructed with masonry. After laying out the subsurface drainage, gypsum was applied based on the gypsum requirement to around 54 acres sodic soils, allowed 3-4 of water to stagnate and left it to drain through subsurface drains. 15 days after gypsum application, soil was puddled properly and 30 days old seedlings were transplanted after applying recommended dose of FYM and chemical fertilizers. Standard package of practices were followed for rice cultivation (Anon., 2015) and grain yield data was collected.

Studies on leachate discharged and salt content: Fifteen days after laying out the subsurface drains, leachate samples were collected after recording the discharge rate by using a bucket, measuring cylinder and stop watch from ten outlets which were connected to natural canal, at 15 days interval till the harvest of rice crop for computing the total quantity of leachate drained out from the study area. These leachate samples were analyzed for the concentration of cations and anions (Richards, 1954) to calculate the amount of salts leached out of the study area. This study was carried out till the harvest of second crop.

Soil sampling and chemical analysis: Before installation of subsurface drains soil samples were collected from 136 acres of the study area to see the severity of salinity/alkalinity problems. After installation of subsurface drains, two

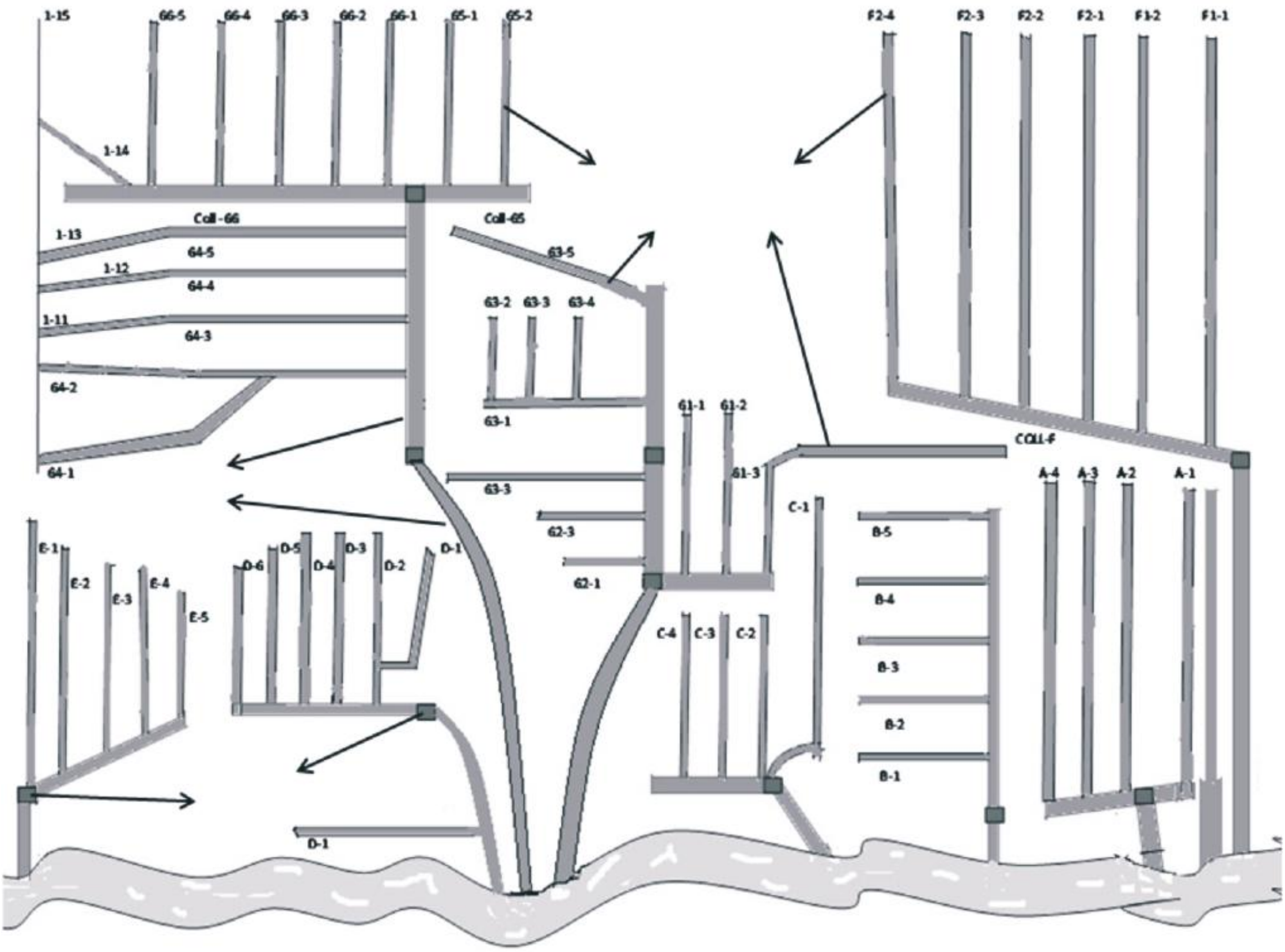

Fig. 1. Sub surface drainage layout (area : 136 acres) at Thyavanige village of Davanagere district

subsequent rice crops were grown and soil samples were collected from the same fields to analyze the changes in pH, EC, per cent of salts present and change in soil fertility.

RESULTS AND DISCUSSION

The data on leachate indicates that totally 1.26 million liters of leachate (water) was drained out to natural canal from the study area (136 acres) through 10 outlets of subsurface drains during two cropping seasons, immediately after installation of subsurface drains. The highest discharge of leachate was recorded (0.253 ML) in outlet 7 and lowest (0.039 ML) was recorded in outlet 2. Through this leachate totally 19.65 tons of salts were removed (Table 2) from the study area. Maximum quantity of cation removed was sodium (1.61 t) followed by calcium (1.47 t) and anions was bicarbonates (9.13 t) followed by chlorides (4.00 t). This clearly indicated that from this salt affected area maximum quantity of sodium, calcium, bicarbonates and chlorides were removed, which helped in improving these salt affected soils. This improvement can be observed through the reduction in pH and EC of these soils. The amount of cations and carbonates present in soil will directly influences the alkalinity of the soil. The presence of soluble Na^{+} increases the pH of the soils by increasing the activity of carbonate and bicarbonate. Sodium

Table 1. Total amount of water (L) discharged/out let/day /interval during different days/interval (15 days) of leachate collection

Out let/Date Days interval	1	2	3	4	5	6	7	8	9	10	Total vol. of water discharge/ out let
10-01-14						5040					5040
17-01-14						216000	144000	216000			576000
22-01-14				48000	43200						91200
23-01-14		7200									7200
24-01-14	1584000					1425600	1584000	1425600			6019200
26-02-14			4800	3085							7885
27-02-14	15428				43200	18000	13090			11368	101087
05-03-14				40500	36000						76500
20-03-14				2400	2160						4560
21-03-14		2400	2160						1800		6360
22-03-14	34560					43200	51840	43200		23563	196363
03-04-14				4320	2541						6861
04-04-14		4320	1878	2400							8598
05-04-14	23563					32400	28800	19938		18514	123216
17-04-14	1878	1661									3539
18-04-14		1800	2273						1728		5801
19-04-14	19365	26742				26742	26742	18720		20800	139114
02-05-14	24685	22539	21600	25287	23563	17875	25920	19200	17875	19938	218486
14-05-14	30857	33230	29793	43200	29793	25411	43200	30857	30857	27000	324200
03-06-14	19938	19200	18514	19200	19938	16722	19938	19938	23563	19938	196892
15-06-14	1270	929	1107	1350	1270	1350	1152	1270	1350	1309	12359
03-08-14	75600	46523	86400	75600	75600	40320	100800	46523	31831	37800	616997
17-08-14	86400	55542	77760	86400	59815	48600	97200	59815	38880	45741	656154
04-09-14	70200	33035	56160	56160	40114	37440	51054	37440	29557	35100	446262
17-09-14	98742	49371	98742	76800	69120	43200	86400	49371	40658	49371	661778
03-10-14	70200	0	62400	74880	80228	53485	93600	80228	56160	51054	622237
16-10-14	92160	0	81317	76800	76800	86400	62836	76800	69120	72757	694991
02-11-14	64800	81000	61714	72000	81000	72000	92571	72000	58909	64800	720794
17-11-14	3756	3085	3927	3756	4547	4320	3927	4320	3927	3927	39495
Total vol. of water discharge/ out let	2317407	388581	610549	712140	688892	2214108	2527073	2221223	406219	502984	12589180

Table 2. Total amount of salts collected in different days/interval from 10 out lets of Thyavanige sub surface drainage installed area (2014)

Total salts collected →	K	Na	Ca	Mg	CO_3	HCO_3	Cl	SO_4	Grand total
Day's interval	Kg of salts removed at different interval								
10-01-14 to 17-01-14	0.01	2.68	0.04	0.03	0.60	1.23	3.22	1.44	9.25
17-01-14 to 26-01-14	2.80	144.46	2.81	1.16	60.55	123.12	184.20	166.51	685.63
26-01-14 to 5-03-14	1.01	113.59	63.36	26.28	31.23	123.54	151.83	54.25	565.08
5-03-14 to 20-03-14	0.23	19.95	15.47	18.59	9.45	35.43	29.81	8.15	137.07
20-3-14 to 3-04-14	0.60	72.81	30.25	71.56	44.80	229.16	119.10	6.30	574.57
3-04-14 to 17-04-14	0.45	54.91	37.53	41.89	26.79	152.20	78.06	8.38	400.21
17-04-14 to 2-05-14	0.42	33.67	23.18	29.40	22.22	126.97	49.38	7.57	292.82
2-05-2014 to 14-05-14	0.64	57.96	66.42	91.91	42.61	251.13	94.89	15.15	620.71
14-05-14 to 3-06-14	2.29	118.30	92.94	140.59	70.12	453.09	166.15	9.19	1052.67
3-06-14 to 15-06-14	0.55	62.61	16.19	17.77	32.20	210.81	101.48	9.63	451.24
15-06-14 to 3-08-14	0.06	3.07	3.08	4.59	2.15	18.51	9.19	2.68	43.34
3-08-15 to 17-08-14	3.04	135.85	144.31	234.67	96.68	352.55	654.69	164.38	1786.18
17-08-15 to 4-09-14	3.13	114.11	283.83	1.01	208.00	669.90	449.79	140.34	1870.11
4-09-14 to 17-09-14	1.81	64.68	45.37	85.02	0.00	730.02	205.55	56.64	1189.07
17-09-14 to 3-10-14	2.80	88.44	71.60	113.72	0.00	1338.74	343.89	94.83	2054.02
3-10-14 to 16-10-14	135.16	154.96	79.33	163.19	0.00	1613.50	324.75	175.02	2645.90
16-10-14 to 2-11-14	170.91	251.38	62.23	92.26	0.00	1221.07	392.02	71.30	2261.17
2-11-15 to 17-11-14	1.89	105.24	416.28	156.22	0.00	1401.68	567.03	145.66	2794.01
17-11-14	0.118	11.523	12.553	22.044	0.000	76.533	79.999	15.103	217.87
Total salts	327.92	1610.17	1466.77	1311.91	647.41	9129.20	4005.01	1152.53	19650.92

carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) are relatively soluble, and their removal by leaching can substantially reduce pH. Thus, the decrease in pH was in part associated with the leaching of TSS (Chi *et al*., 2012). Padalkar *et al*. (2012) carried out the sub-surface drainage treatment for reclamation of saline soil of Kasabe Digraj village in Maharashtra and quantified the salts leached out through discharge water at monthly intervals, they also observed the significant reduction in pH (8.70 to 7.27) and in E.C. (4.50 dS m^{-1} to 2.81 dS m^{-1}) after sub-surface drainage treatment. Therefore, for amelioration of salt affected soils, soluble salts should be removed first through sub surface drains by leaching through good quality water and if sodium is present amendments like gypsum should be used to leach out sodium to desired level from the exchange sites to reclaim the salt affected soils (Kuligod, 2002).

The crop cutting data indicated that by installation of sub surface drainage alone helped to increase the rice yield to an extent of 22.99 per cent (Table 3), whereas with application gypsum in the first crop growing season the rice yield was increased to an extent of 35.68 per cent. Similarly, in second year an increase of 25.13 per cent in water logged and saline soils was recorded. Whereas, in sodic soils gypsum application increased the rice yield to an extent of 38.28 per cent. The increase in yield after installation of sub surface drainage and gypsum application was mainly due to large quantity of salts which were harmful to crop growth have been removed and soil fertility has been increased to supply sufficient quantity of nutrients for crop growth and productivity. A study conducted by Gupta *et al*. (2004) on evaluation of subsurface drainage system under submerged rice in saline environment also revealed the decreased EC of the soil and increased crop yields after subsurface drainage which attests to the drainage induced land reclamation.

The yield increase by application of gypsum was due to the improvement in physico-chemical properties of the soil. The results are in agreement with Sinha *et al*. (2000) and Fageria and Knupp (2014). Gypsum application in different doses (0, 25, 50, 75, 100 and 200 per cent of the gypsum requirement) increased the yield of rice by 9.8 to 25.3 per cent over control (Sabir *et al.,* 2007). This was attributed to improvement in sodicity problems by leaching Na through gypsum application which helped in better utilization of applied NPK nutrients there by increased the rice yields. In addition, installation of sub surface drainage in these soils directly helped in increasing the rice yield, by reducing water logging and removing the slats in the root zone and create favorable conditions in the root zone to take up more

Table 3. Rice yield in crop cutting experiment in sub surface drainage installed problematic farmer's field at Thyavanige village

Latitude	Longitude	Yield (2013) (Before Subsurface drainage)	Rice yield after subsurface installation				Soil properties before installation of subsurface drainage			Soil properties after installation of subsurface drainage		
			2014 first crop		2014 second crop							
		q ha^{-1}	q ha^{-1}	Increased yield	q ha^{-1}	Increased yield	pH	EC (dSm^{-1})	ESP (%)	pH	EC (dSm^{-1})	ESP (%)
14° 14' 11.13"	75° 53' 2.84"	21.60	28.89	33.74	29.23	35.33 (G)	8.48	1.60	17.18	8.02	1.84	11.59
14° 14' 14.59"	75° 53' 5.74"	20.80	26.67	28.21	27.97	34.47 (G)	8.40	0.67	35.80	7.71	1.83	9.28
14° 14' 8.88"	75° 53' 20.34"	21.60	25.78	19.34	30.18	39.70 (G)	8.40	0.90	11.86	7.90	0.35	4.93
14° 14' 15.99"	75° 53' 20.57"	21.60	26.67	23.46	28.56	32.22	8.20	0.50	6.30	7.67	0.29	5.99
14° 14' 20.30"	75° 53' 20.78"	20.80	28.00	34.62	28.63	37.64 (G)	8.30	0.28	12.50	8.14	1.43	5.29
14° 14' 20.58"	75° 53' 15.43"	22.40	26.67	19.05	26.88	20.00	8.68	0.39	10.58	7.66	1.45	9.90
14° 14' 25.66"	75° 53' 17.90"	20.80	25.78	23.93	28.50	37.00 (G)	8.50	0.49	12.10	8.15	1.65	11.98
14° 14' 25.22"	75° 53' 19.37"	20.80	26.67	28.21	28.05	34.85 (G)	8.50	0.33	17.60	8.21	1.84	12.39
14° 14' 21.74"	75° 53' 6.05"	21.60	25.78	19.34	30.40	40.74 (G)	8.70	0.86	18.50	8.17	2.05	12.18
14° 14' 22.32"	75° 53' 9.47"	20.00	27.65	38.24	29.60	42.31 (G)	8.63	0.37	9.74	8.34	0.74	8.73
14° 14' 24.64"	75° 53' 9.04"	20.00	28.40	42.00	27.89	39.44 (G)	8.90	0.87	9.70	7.81	0.87	8.23
14° 14' 27.37"	75° 53' 10.20"	21.60	23.82	10.30	29.50	36.59 (G)	-	-	-	-	-	-
14° 14' 24.63"	75° 53' 4.61"	20.80	34.40	16.48	-	-	-	-	-	-	-	-
14° 14' 24.00"	75° 53' 1.68"	21.60	-	-	28.64	37.69 (G)	-	-	-	-	-	-
			Average data of 66 farmers				8.52	0.66	14.71	7.98	1.30	9.14
Mean % increase in yield		21.42 (65)	26.49 (63)	23.80 (63)	27.38	27.89 (62)						
Mean % increase in yield			26.41 (59)	22.99 (59)	26.97	25.13 (49)						
Mean of gypsum applied farmers			27.67 (4)	35.68 (4)	28.93	38.28 (13)						

*G – Gypsum applied plots; Values in parenthesis – number of farmers (average data) nutrients from the soil for optimum plant growth. Similar findings were reported by Manzoor *et al*. (2006), Lal Bahadur *et al.* (2013) and Vijay Kumar (2015).

The soil samples collected before and after installation of subsurface drainage and application of gypsum (Table 3) clearly indicated that before installation of subsurface drainage pH values varied from 8.20 - 8.90 and this pH was reduced to 7.66 - 8.34 after sus surface drainage installation. The reduction in soil pH was attributed to displacement of exchangeable Na by calcium ion of gypsum and subsequent formation of sodium sulphate which get leached out of soil through drainage. Similar decrease in soil pH from the initial value due to application of gypsum was observed by Vijay Kumar (2015) in saline sodic soils of Cauvery command, Karnataka. The electrical conductivity increases from 0.28 – 1.60 to 0.29 - 2.05 dS m^{-1} after installation of subsurface drainage. The increase in electrical conductivity in gypsum amended plots is normally expected, since gypsum is a source of salts to soil solution. Vijay Kumar (2015) observed the salinity increase by application of gypsum in sodic soils. Acidic nature of gypsum along with good amount of calcium helped in solublization of free lime content of soil which replaced the sodium on exchange complex might also have contributed for increase in electrical conductivity of soil. Addition of amendments also increases the mineralization of the applied nutrients by improving the soil condition which results in the increased salt concentration and consequently increases the soil ECe (Yadav and Chippa, 2007). Whereas, ESP values varied from 6.30 to 35.80 per cent and 4.93 to 12.39 per cent before and after installation of subsurface drainage, respectively. The maximum ESP reduction (35.80 to 9.28 %) was observed in study area. This might be due to exchangeable Ca was exchanged for sodium and converted to sodium sulphate which was leached by drainage and there by reduces the ESP of the soil. Mohamed and Abdel-Fattah (2012) while studying the efficiency of gypsum, rice straw compost and their different combinations on reclamation of clay saline-sodic soils, indicated that all the amendments used either, singly or in combination decreased the ESP markedly compared to control. Hence, gypsum treatment is considered optimum for reducing the ESP to a desired level under field conditions. The results are in accordance with the findings of Chhabra and Thakur (2000) and Rai *et al*. (2010). These soil properties indicate that the soils of the study area have been improved with reduction in pH and ESP.

Thus, the results of this study clearly indicated that by installation of sub surface drainage in water logged/saline/alkali soils and application of gypsum in alkali soils based on the soil test and stagnating with good quality water to leach out salts and application of sufficient quantity of organic manures and required quantity of NPK nutrients will helps to get better yield of rice crop in problematic soils.

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Received 20 April, 2016; Accepted 14 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 631-636

Manuscript Number: 2349
NAAS Rating: 4.47

Antifungal Potential of *Inula racemosa* Root Extract and *Vetiveria zizanioides* Root Essential Oil against Some Phytopathogenic Fungi

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Abstract: The effectiveness of *Inula racemosa* root extract and vetiver root essential oil; their non-polar and polar fractions was tested against three fungi of rice and wheat *i.e. Dreschlera oryzae*, *Fusarium moniliforme* and *Alternaria triticina* using spore germination inhibition method. The ED_{50} values of root extract of *I. racemosa* and essential oil of vetiver roots were 100 and 450; 360 and 120; 650 and 220 ìg mL^{-1} against *D. oryzae, F. moniliforme and A. triticina,* respectively. Vetiver oil showed maximum effectiveness as compared to its fractions and was most active against *F. moniliforme* out of three fungi tested. The non-polar fraction of *I. racemosa* root extract was most effective as compared to root extract and polar fraction. *I. racemosa* root extract and its fractions were most active against *D. oryzae* out of three tested fungi. The study revealed that vetiver oil and *I. racemosa* root extract may be useful in developing botanical fungicides against these phytopathogenic fungi.

Key Words: *Alternaria triticina, Dreschlera oryzae*, *Fusarium moniliforme*, *Inula racemosa,* Spore germination inhibition

Rice and wheat are the important cereal crops in the world. Their production is largely effected by many biotic and abiotic stresses. Among biotic stresses fungal diseases have played an important role in reducing the yield of crops (Perelló and Sisterna 2006; Paster *et al*., 1993). Out of various fungal diseases *Dreschlera oryzae*, *Fusarium moniliforme* and *Alternaria triticina* are pathogenic fungi causing brown leaf spot of rice, foot rot of rice and leaf blight of wheat, respectively. Generally these phytopathogenic fungi are controlled by synthetic fungicides like Bavistin and Tilt; however, the continuous, incorporate and indiscriminate use of chemical fungicides to control the diseases is known to cause residual toxicity, development of pathogen resistance, environmental pollution, health hazards to humans and animals and increased expenditure for plant protection. Hence in agricultural practice, plant pathologists have focused their attention to replace synthetic hazardous chemical fungicides by natural phytochemical extracts and essential oils to combat fungal diseases of crops. Plant metabolites and plant based pesticides appear to be one of the better alternatives as they are known to have minimal environmental impact and danger to consumers in contrast to synthetic pesticides (Verma and Dubey, 1999). A number of plant species have been reported to possess compounds that are toxic to many fungi causing plant diseases (Amadioha, 2000; Ranaware *et al*., 2010; Dwivedi and Shukla, 2000). The systematic search of higher plants for antifungal activity revealed that plant extracts have the ability to inhibit spore germination and mycelial growth in many fungal species (Natarajan and Lalithakumari, 1987; Singh and Dwivedi, 1987). During recent years, use of plant extracts for the control of plant diseases is gaining importance due to their antifungal and antibacterial properties (Yin and Cheng, 1998). Many plant extracts are reported to specifically inhibit the germination of fungal spores (Babu *et al.,* 2001).

The genus *Inula*, belonging to family Asteraceae (Abid and Qaiser, 2003), consists of about 100 species widely found in Europe, Asia and Africa, mostly in the Mediterranean. *Inula racemosa* (*Pushkarmoola*) is a medicinally important herb of North Western Himalayas. The aromatic essential oil from its roots contains about 60% sesquiterpenes, 22% aplotaxene and 2% phenylacetonitrile (Bokadia *et al*., 1986) and also one of the richest sources of sesquiterpenoid lactones, having strong anthelminthic activity and the potential to induce detoxifying enzymes (Livermore, 2002; Jeon *et al*., 2005). Roots of the plant are known to exhibit wide range of biological properties (Liu *et al.,* 2006; Lokhande *et al.,* 2007; He *et al*., 2014). Vetiver grass *(Vetiveria zizanioides* (L.) Nash commonly known as *khas-khas* in India, is a perennial grass belonging to the family Poaceae. The essential oil is extracted from the roots of the vetiver grass. Over 150 compounds have been isolated and characterized from vetiver oil mainly consisting of sesquiterpenes and their oxygenated derivatives. The vetiver oil is known to possess insecticidal (Pangnakorn 2009; Sujatha, 2010), fungicidal (Jayashree *et al*., 2011; Dubey *et al*., 2010) and herbicidal (Mao *et al.,* 2006) properties.

The present work was aimed to study the antifungal potential of *I. racemosa* root extract and vetiver essential oil; their non-polar and polar fractions against three phytopathogenic fungi, *D. oryzae*, *F. moniliforme* and *A. triticina* using spore germination inhibition method.

MATERIAL AND METHODS

The roots of *Inula racemosa* were procured from laboratory stock, dried and powdered. The powdered roots were subjected to Soxhlet extraction for 6-8 hrs using chloroform as the solvent. The extract was concentrated with a rotary evaporator under reduced pressure at 40ºC to afford crude extract. The resulting chloroform extract was then partitioned into petroleum ether (60-80ºC) and acetonitrile to have non-polar and polar fraction, by liquid-liquid partitioning (Bahl and Bahl, 1992). Vetiver oil obtained from laboratory stock was subjected to column chromatography over silica gel (60-120 mesh size) to have non-polar (petroleum ether) and polar (acetone) fractions.

Fungal strains: Pure cultures of *D. oryzae, F. moniliforme and A. triticina* were obtained from the department of plant pathology, PAU, Ludhiana, Punjab, India. The isolates were collected from the diseased samples and maintained on Potato Dextrose Agar (PDA) slants and plates were stored in refrigerator for further use.

Preparation of stock solution: The stock solution (2000 µg mL^{-1}) of each component was prepared by dissolving 20 mg of each component in distilled water with Tween 80 (polyoxyethylene sorbitan) as emulsifier. The required dilutions of 1000, 500, 250, 100, 50, 25 and 10µg mL^{-1} were subsequently made from the stock solution by adding required amount of distilled water. Different concentrations (10-1000 µg mL^{-1}) of standard fungicide *i.e.* Carbendazim (Bavistin 50 WP) were prepared.

Spore germination inhibition method: Antifungal activity was tested by means of spore germination inhibition method (Nene and Thapliyal, 1993). Spore suspension was prepared from ten days old culture of the test fungi (*D. oryzae, F. moniliforme* and *A. triticina*) with sterilized water. In order to remove mycelial and agar bits, the suspension was filtered through three layers of sterilized cheese cloth after shaking the tube thoroughly under aseptic conditions. Spore density of 10^6 spores mL^{-1} was adjusted with the help of haemocytometer. Small droplets (0.02 mL) of test solution and spore suspension in equal amount were seeded in the cavities of the cavity slides. Experiment was replicated three times for each concentration as well as control. A negative control containing only drop of water was also maintained. These slides were placed in petri plates lined with moist filter paper and incubated at 24±1°C. The number of spores germinated were counted and per cent spore germination inhibition was calculated by using the formula:

$$\text{Per cent spore germination inhibition} = \frac{\text{Spore germination in control-Spore germination in treatment}}{\text{Spore germination in control}} \times 100$$

The fungicide Carbendazim was used as standard for comparison of the activity. The antifungal activity was expressed in terms of ED_{50} and ED_{90} values, respectively.

RESULTS AND DISCUSSION

D. oryzae: There was positive correlation between concentration and antifungal activity (Table 1). Root extract, its non-polar and polar fraction showed 50% inhibition of spore germination (ED_{50}) at concentrations 100, 60 and 110 µg mL^{-1}, respectively. At very low concentration (10 µg mL^{-1}) polar fraction was more effective but with increase in concentration non-polar fraction was found to be most effective followed by root extract whereas polar fraction was least effective. At higher concentrations (50 and 100 µg mL^{-1}), there was slight difference in antifungal activity between the components tested. The ED_{90} values of the root extract, its non-polar and polar fraction are 450, 220 and 330 µg $mL^{-1,}$ respectively (Table 3).

Vetiver oil, its non-polar and polar fraction showed 50% inhibition of spore germination (ED_{50}) at concentrations 450, 610 and 550 µg mL^{-1}, respectively. Polar fraction of vetiver oil was more effective as compared to non-polar fraction (Table 3). The vetiver oil showed 90% (ED_{90}) inhibition at 950 µg mL^{-1}, while the polar and non-polar fractions showed inhibition at concentration higher than 1000 µg mL^{-1}. Statistical analysis of data showed that antifungal activity of all the components increased with increase in concentration and there was a positive correlation between components and concentrations (Table 2).

***F. moniliforme*:** There was positive correlation between concentration and antifungal activity (Table 1). Nearly 50% inhibition of spore germination (ED_{50}) for root extract, its non-polar and polar fractions were at concentrations 360,120, 240 µg mL^{-1} and ED_{90} values at 900, 420 and 760 µg mL^{-1} , respectively (Table 3). At lower concentrations (10 and 25 µg mL^{-1}), the polar fraction and root extract showed comparable effect against test fungi but with increase in concentration non-polar showed increased effectiveness. The per cent spore germination inhibition at all concentration revealed that vetiver oil, its non-polar and polar fractions showed 50 % inhibition of spore germination (ED_{50}) at concentrations 120, 200 and 180 µg mL^{-1} and 90 % inhibition at concentrations of 320, 850 and 600 µg mL^{-1}, respectively (Table 3). The statistical analysis of data showed that all the components were statistically different from each other and the antifungal activity increased with increase in concentration (Table 2).

***A. triticina*:** Per cent spore germination inhibition values showed a positive correlation between concentration and antifungal activity (Table 1). Root extract, its non-polar and

Table 1. Effect of *I. racemosa* root extract and its fractions on spore germination inhibition against three fungi

Components	Concentrations (µg mL^{-1})						
	10	25	50	100	250	500	1000
D. oryzae[a]							
Root extract	10.50 (18.89)	27.67 (31.72)	36.85 (37.36)	48.91 (44.36)	79.77 (63.26)	91.34 (72.90)	91.32 (72.85)
Polar fraction	18.47 (25.44)	30.45 (31.73)	43.05 (40.15)	51.46 (43.31)	87.10 (66.38)	95.09 (77.35)	96.32 (78.92)
Non-polar fraction	16.74 (24.08)	27.69 (33.44)	41.60 (40.98)	47.086 (45.83)	83.96 (69.10)	95.09 (77.35)	96.32 (78.92)
F. monilliforme[b]							
Root extract	10.30 (18.71)	18.10 (5.16)	29.23 (32.71)	32.30 (34.61)	40.73 (39.64)	58.40 (49.81)	95.96 (78.40)
Polar fraction	10. 53 (18.88)	18.50 (25.45)	24.80 (29.85)	35.43 (36.51)	50.63 (45.34)	79.66 (63.17)	95.50 (77.75)
Non-polar fraction	14. 73 (22.55)	21.76 (27.79)	35.86 (36.77)	43.76 (41.40)	75.76 (60.48)	91.56 (73.11)	98.00 (81.83)
A. triticina[c]							
Root extract	12.28 (20.49)	21.22 (27.41)	25.00 (29.95)	32.30 (34.59)	41.51 (40.09)	44.67 (41.92)	65.22 (53.84)
Polar fraction	5.44 (13.47)	17.15 (24.45)	24.86 (29.88)	30.42 (33.45)	40.49 (39.50)	78.85 (62.59)	96.00 (78.43)
Non-polar fraction	7.53 (15.91)	19.27 (26.02)	36.50 (37.15)	45.61 (42.46)	75.89 (60.56)	93.31 (74.98)	100.00 (89.96)

Figures in parentheses are arc sine transformed values, [a]CD (p=0.05) = Components: 2.53; Concentrations : 1.66; Interaction: 1. 90; [b]CD (p=0.05) = Components: 0.84; Concentrations: 0.55; Interaction: 1.46 ; [c]CD (p=0.05) = Components: 1.44; Concentrations : 0.95; Interaction : 2.50

Table 2. Effect of Vetiver oil and its fractions on spore germination inhibition against three fungi

Components	Concentrations (µg mL^{-1})						
	10	25	50	100	250	500	1000
A. Triticina[a]							
Vetiver oil	0.00 (0.00)	11.84 (20.04)	24.94 (29.92)	34.99 (36.25)	53.85 (47.19)	82.86 (65.56)	100.00 (89.96)
Non-polar fraction	0.00 (0.00)	5.57 (13.64)	14.07 (22.02)	29.88 (33.10)	40.20 (39.32)	77.32 (61.54)	93.44 (75.26)
Polar fraction	0.00 (0.00)	8.44 (16.75)	16.16 (23.70)	31.67 (34.23)	44.33 (41.72)	79.65 (63.16)	93.73 (75.48)
D. oryzae[b]							
Vetiver oil	0.00 (0.00)	0.00 (0.00)	10.40 (18.78)	22.30 (28.09)	40.00 (39.21)	52.53 (46.43)	94.87 (77.86)
Non-polar fraction	0.00 (0.00)	0.00 (0.00)	5.733 (13.75)	19.13 (25.57)	29.67 (32.71)	41.13 (39.79)	79.13 (63.29)
Polar fraction	0.00 (0.00)	0.00 (0.00)	6.50 (14.73)	19.33 (25.94)	30.37 (33.35)	46.37 (42.90)	81.47 (64.48)
F. moniliforme[c]							
Vetiver oil	7.69 (16.04)	17.40 (24.63)	25.53 (30.30)	43.20 (41.06)	82.87 (65.54)	96.97 (80.01)	100.00 (89.96)
Non-polar fraction	3.80 (11.21)	8.70 (17.14)	17.20 (24.47)	30.60 (33.44)	56.87 (48.95)	79.17 (62.89)	94.93 (77.32)
Polar fraction	4.93 (12.77)	11.07 (19.42)	18.63 (25.52)	34.90 (36.18)	58.97 (50.14)	86.20 (89.96)	100.00 (89.96)

Figures in parentheses are arc sine transformed values, [a]CD (p=0.05) Component: 1.967, Concentrations: 1.287, Interaction: 3.406; [b]CD (p=0.05) Components: 4.352, Concentrations: 2.849, Interaction: 5.483; [c]CD (p=0.05) Components: 3.071, Concentrations: 2.010, Interaction: 5.320

Table 3. ED_{50} and ED_{90} values of *I. racemosa* root extract, vetiver oil and their non-polar and polar fractions, carbendazim against tested fungi

Fungus	Components		ED_{50}	ED_{90}
D. oryzae	*Inula racemosa*	Root extract	100	450
		Non-polar fraction	60	220
		Polar fraction	110	330
	Vetiver oil	Vetiver oil	450	950
		Non-polar fraction	610	1000
		Polar fraction	550	>1000
	Standard	Carbendazim	18	60
F. moniliforme	*Inula racemosa*	Root extract	360	900
		Non-polar fraction	120	420
		Polar fraction	240	760
	Vetiver oil	Vetiver oil	120	320
		Non-polar fraction	200	850
		Polar fraction	180	600
	Standard	Carbendazim	15	38
A. triticina	*Inula racemosa*	Root extract	650	1540
		Non-polar fraction	130	400
		Polar fraction	300	760
	Vetiver oil	Vetiver oil	220	650
		Non-polar fraction	320	850
		Polar fraction	290	810
	Standard	Carbendazim	08	20

polar fraction showed 50% inhibition of spore germination (ED_{50}) at concentrations 650,130 and 300 µg mL^{-1}, respectively whereas 90% inhibition (ED_{90}) was at concentrations 1540,400 and 760 µg mL^{-1} (Table 3). At low concentrations (10 and 25 µg mL^{-1}) root extract showed more effectiveness whereas at higher concentrations non-polar fraction was most effective. Percent spore germination inhibition increased with increase in concentration for each of the component. Vetiver oil, its non-polar and polar fraction showed 50% inhibition of spore germination (ED_{50}) at concentrations 120, 180 and 130 µg mL^{-1}, respectively. The ED_{90} values of vetiver oil, non-polar and polar fraction were 650, 850 and 810 µg mL^{-1}, respectively. Vetiver oil was found to be more effective as compared to its fractions at all tested concentrations. The statistical analysis of data showed that there was a positive correlation between components and concentrations (Table 2).

The standard fungicide Carbendazim was more effective as compared to all the components tested against all the three fungi. The results showed that the non-polar fraction of *I. racemosa* root extract was more effective than *I. racemosa* root extract and polar fraction against all the three tested fungi. The overall order of effectiveness of *I. racemosa* root extract and its fractions against all the three tested fungi was: Non-polar fraction > Polar fraction > *I. racemosa* root extract

The basis of varying degree of sensitivity of test fungi may be due to the intrinsic tolerance of microorganisms, the nature and combinations of phytochemicals present in the root extract. Non-polar fraction of the root extract showed remarkable antifungal activity against three tested fungi. Although ED_{50} values were not much low as compared with that of standard fungicide, Carbendazim but the results are of interest since they have been obtained with the extract and it is widely accepted that plant extracts that are active at ED_{50} values less than 100 ìg mL^{-1} could be considered to have a good potency level. Wang *et al*. (2004) reported the antifungal potential of non-polar and polar extracts of dried leaves of *I. viscosa* may be used as an herbal source for fungicidal preparations against foliar diseases caused by pathogens belonging to the families Oomycetes, Ascomycetes, and Basidiomycetes. The behaviour of *I. falconeri* extract against plant pathogens and non-polar fraction (concentration gradients of 1.25, 2.5, and 5 mg/disc) revealed significant zones of inhibition against *A. triticina* and *Rhizoctonia solani* whereas only an insignificant effect against *F. oxysporum* was observed (O'Shea *et al.,* 2009).

The antifungal activity of vetiver oil was more as compared to polar and non-polar fractions against three fungi tested. The overall order of effectiveness of the all the tested components of *V. zizanioides* was:Vetiver oil > Polar Fraction > Non-polar Fraction

The results are in consonances with earlier studies conducted on the fungicidal potential of vetiver oil against *Rhizocotonia bataticola* and *Sclerotium rolfsii* (Sharma *et al.,* 2009). The antifungal activity of root and shoot extracts of vetiver oil against two potent pathogenic fungi, *Candida albicans* and *Cryptococcus neoformens* showed the minimum inhibitory concentration (MIC) of 10000 ìg mL^{-1} against pathogens and IC_{50} of these fractions varied between 5000 -7500 ìg mL^{-1} (Jayashree *et al*., 2011). Similarly, antifungal potential of two types of Indian vetiver oils (Dubey *et al*., 2010), namely North and South Indian types were evaluated against *Rhizoctonia solani* and found that fungal toxicity of South Indian vetiver oil (ED_{50} = 297 µg mL^{-1}) was slightly higher than North Indian oil (ED_{50} = 352 µg mL^{-1}). Further, the steam distilled vetiver oil exhibited the highest fungicidal activity (ED_{50} = 474 µg mL^{-1}) against *R. solani* followed by essential oils obtained from solvent extraction (ED_{50} = 387 µg mL^{-1}) and *Deg Bhapka* methods (ED_{50} = 534 µg mL^{-1}) (Dubey *et al*., 2010, 2011). The antifungal activity of vetiver oil was further screened against certain pathogenic microorganisms using Flucanozole as positive control. Among the tested fungal cultures, *Aspergillus niger* exhibited a highest mean zone of inhibition (30 and 32 mm) against vetiver leaves and root extracts (Sangeetha and Stella, 2012). The antifungal activity of vetiver oil may be attributed to the presence of sesquiterpenes and their oxygenated derivatives. However, lower activity of fractions of vetiver oil as compared to vetiver oil suggested the synergistic effect of various compounds in non-polar and polar fractions of the vetiver oil. Sesqui-terpenoids present in vetiver oil were chemically modified and tested for their antifungal activity against two phytopathogenic fungi i.e. *A. alternata* and *F. oxysporum* using spore germination inhibition technique. Out of various compounds tested khusinodiol monobrosylate was found to be effective antifungal agent against both the fungi (Dikshit and Husain, 1984). Similar studies conducted to evaluate the bioefficacy of the synthesized Schiff bases of sesquiterpenoid i.e. N- (Khusilidene)-*p*-methoxy aniline and N-(Khusilidene)-*p*-bromo-aniline. It was found that N-(Khusilidene)-*p*-methoxy aniline inhibited the growth of *A. alternata* upto 84.7% whereas N-(Khusilidene)-*p*-bromo-aniline inhibited the growth of *F. oxysporium* upto 74.5% at 1000 ìg mL^{-1} level (Kaushal and Chahal, 2008).

In conclusion, *I. racemosa* root extract and vetiver oil possessed significant antifungal activity against three fungi *D. oryzae, F. moniliforme and A. triticina.* There is a great potential to develop new natural fungicides from *I. racemosa* root extract and vetiver oil against these three phytopathogenic fungi.

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Received 22 May, 2016; Accepted 11 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 637-644

Manuscript Number: 2350
NAAS Rating: 4.47

Impact of Climate Variability and Crop Phenology on Abundance of Mango Thrips Complex

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***Abstract*:** Impact of climate and crop phenology on abundance of mango thrips (*S. dorsalis, S. mangiferae* and *Rhipiphorothrips cruentatus*) was observed in mango cv. Alphonso at Agriculture Experimental Station, Navsari Agricultural University, Paria, Gujarat from 2004 to 2014. Overall thrips population (irrespective of crop stage) was 12.16/twig or panicle. The highest thrips population was 18.96 (peak 61 at 6th standard week)/twig or panicle during 2010-2011 when maximum, minimum and average temperatures were 32.05, 18.75 and 25.40 °C, respectively. Relative humidity during the same year were 89.62 (morning), 57.74 (evening) and 73.68 (average) per cent, respectively. Rainfall, rainfall days, sun shine and wind velocity during this period were 55.68 mm, 1.81 days, 7.79 hours and 4.13 km/hour, respectively. During this period, thrips population exhibited significant positive correlation with sun shine. While, it indicated significant negative correlation with minimum and average temperature, evening and average relative humidity, rainfall, rainfall days and wind velocity. Total contribution of all the abiotic factors on fluctuation of thrips population during 2010-2011 was 65.48 per cent. Thrips population during the peak activity year remained highest on peak flowering stage of the crop (56.00/panicle). So, it may be the most critical weather condition for peak abundance of thrips population. During peak activity year, there was slight increase in temperature, relative humidity, rainfall, rainfall days, sun shine, wind velocity which became conducive for sharp rise in thrips population.

***Key Words*:** Crop stage, Mango, Thrips, Weather

Mango (*Mangifera indica L.*) is one of the most important fruit crops of tropics and sub tropics. In India, it is cultivated in 23.12 lakh hectares with annual production of 150.25 lakh metric tonnes. In Gujarat, it is cultivated in 1.25 lakh hectares with 8.56 lakh tonnes of fruit production (Anonymous, 2010). Its cultivation is principally distributed in South Gujarat as well as in pockets of Junagadh. The popular varieties grown in Gujarat are Alphonso, Kesar, Rajapuri and Banarasi Langra.Though, there is tremendous increase in area and distribution of mango at national level and in Gujarat however, the level of productivity has not reached up to the expected level of 10 t/ha. There are many reasons attributed to this fact. One of the main reasons is incidence of major pests and diseases. Amongst major insect-pests, the abundance of sucking pests *viz;* mango hopper and mango thrips in South Gujarat in particular have caused greatest threat to the mango industry.The thrips complex (*S. dorsalis, S. mangiferae,* and *Rhipiphorothrips cruentatus*) remain present in the mango ecosystem of South Gujarat almost throughout the year and damage every crop stage i.e. from emergence of new flush to fruiting stage. Significant impact of major abiotic factors and appropriate crop stages on their dominance as well as continuation of their respective life cycles inflict severe damages resulting into enormous crop losses. Due to these reasons, a study was planned in late nineties and carried out during 2004-2014 to establish relationship between major abiotic factors and abundance of mango thrips.

MATERIAL AND METHODS

Seasonal abundance of mango thrips was studied in relation to weather factors and crop stages in mango cv. Alphonso under field condition from July 2004 to June 2014 at Agriculture Experimental Station, Navsari Agricultural University, Paria, Valsad, Gujarat. For recording thrips population, ten trees of mango cv. Alphonso were selected randomly in one hectare plot in **"W" design** representing every part of the orchard. The trees were kept unsprayed during the period of investigation (2004-2014). Thrips population was recorded at standard week wise interval from 27th standard week of 2004 to 26th standard week of 2014. Ten twigs from lower canopy of each tree were selected for recording thrips population during vegetative, emergence of new flush, new twig, fruiting, initiation of ripening, ripening cum harvest and harvest stages of the crop. Similarly, thrips were also recorded on ten panicles per tree during bud/bud burst stage, initiation of flowering, peak flowering, pea/marble and stone sized fruit stages of the crop. Thrips were counted on each randomly selected twig or panicle by visual count method (tapping technique on a piece of white paper) without disturbing the plant part. Weather parameters *viz;* temperature (maximum, minimum and average), relative humidity (morning, evening and average), rainfall, rainfall days, sun shine and wind velocity of the preceding week (26th standard week of 2004 to 25th standard week of 2014) was observed at standard week wise interval.

Relationship of abundance of thrips in relation to major weather factors and crop stages was studied using correlation and regression method.

RESULTS AND DISCUSSION

Impact of major abiotic factors as well as appropriate crop stages on abundance of mango thrips has been studied during ten years spread over 2004-2014 i.e. July 2004 - June 2014. The whole period was divided into three distinct crop stage regions *viz*; vegetative which on an average spread over 21 standard weeks (27-47) followed by bud burst cum flowering cum fruit set stage spread over 23 standard weeks (48-18) and lastly, fruiting cum harvest stage spread over 8 standard weeks (19-26).

(I) Seasonal abundance of mango thrips (Ten years impact)

(a) Seasonal abundance: Thrips population varied from 6.31 (2008-2009) to 18.96 thrips per twig or panicle (2010-2011). Average thrips population was 12.16 per twig or panicle. The first peak (29.70 /panicle) was of thrips species *S. dorsalis* and *S. mangiferae* at 9th SW (26 February – 4 March) followed by another period of higher activity (28.90) at 8th SW (Table 1).

(b) Impact of weather factors: The overall average thrips population indicated significant positive correlation with maximum temperature ('r' = 0.1182) and sunshine ('r' = 0.4153) and significant negative correlation with temperature (minimum and average) ('r' = -0.5189 and -0.4279), relative humidity (morning, evening and average) ('r' = - 0.2203, - 0.4809 and – 0.3649), rainfall ('r' = -0.2944), rainfall days ('r' = -0.4410) and wind velocity ('r' = -0.2143) (Table 4). The total contribution of all the abiotic factors was 29.73 per cent (Table 5).

Regression equation of overall thrips population was:

$$\hat{Y} = 17.2716 – 100.3820 (X_1) – 101.2408 (X_2) + 200.5991 (X_3) + 0.0040(X_4) – 0.0646(X_5) + 0.1936 (X_6) – 0.0041 (X_7) - 0.3549(X_8) + 0.7500 (X_9) – 0.1717 (X_{10})$$

Where,

Y	=	Thrips/twig or panicle
X_1	=	Maximum temperature
X_2	=	Minimum temperature
X_3	=	Average temperature
X_4	=	Morning Relative humidity
X_5	=	Evening Relative humidity
X_6	=	Average temperature
X_7	=	Rainfall
X_8	=	Rainfall days
X_9	=	Sun shine
X_{10}	=	Wind velocity

(II) Seasonal abundance of mango thrips during peak activity year

(a) Seasonal abundance: During ten years of experimental period, the highest thrips population was noticed during 2010-11 which was thus considered as period or year of highest activity. Thrips population varied from 0 to 61.00 thrips per panicle (average 18.96/panicle). The maximum thrips population was during during 5-6th SW (Table 2).

(b) Impact of weather factors: Overall thrips population during peak year of activity (2010 - 2011) was noticed when weather variables indicated temperature (maximum, minimum and average) of 32.05, 18.75 and 25.40 °C, relative humidity (morning, evening and average) of 89.62, 57.74 and 73.68 per cent, rainfall of 55.68 mm, rainfall days of 1.81, sunshine of 7.79 hours per day and wind velocity of 4.13 kms/hour (Table 2). The thrips population during peak year exhibited significant positive correlation with sunshine while, it was significant and negative with temperature (minimum and average), relative humidity (evening and average) ('r' = -0.6453 and 0.5965), Rainfall ('r' = -0.5275), rainfall days and wind velocity (Table 4). The total contribution of all the factors on fluctuation of thrips population was 65.48 per cent (Table 5). Regression equation of thrips population during peak activity year was:

$$\hat{Y} = 114.8857 + 2.5991 (X_2) + 0.0193 (X_3) + 1.2214 (X_5) – 1.5413 (X_6) – 0.0206 (X_7) – 0.0274 (X_8) + 0.5983 (X_9) – 1.9620 (X_{10})$$

(III) Overall assessment of thrips population v/s peak year activity

It is evident from the above results that slight increase in maximum temperature from 32.04 to 32.05 °C (0.01), minimum temperature from 18.67 to 18.75 °C(0.08), average temperature from 24.67 to 25.40 °C (0.73), morning relative humidity from 87.84 to 89.62 per cent (1.78), average relative humidity from 71.15 to 73.68 per cent (2.53), rainfall from 43.90 to 55.68 mm (11.78), rainfall days from 1.66 to 1.81 (0.15), sun shine from 7.67 to 7.79 hours (0.12) and wind velocity from 4.07 to 4.13 kms/hours (0.06) and with slight decrease in evening relative humidity from 57.89 to 57.74 per cent (0.15) indicated sharp rise in thrips population from 12.16 to 18.96 per twig or panicle i.e. a rise of 5.97 which is much more than the threshold value (presence of thrips) of the pest under consideration.

During the entire experimental period (2004-2014), there were two active periods of thrips population, first was of foliage thrips (*R. cruentatus*) between 41-50 SW (8 October – 16 December) which had its peak (19.30 thrips/twig in pooled observation) on 49th SW (3-9 December) coinciding with bud burst stage of the crop, whereas second active period was of

Table 1. Incidence of mango thrips at Agriculture Experimental Station, NAU, Paria (2004-2014)

Standard	Standard	Thrips Population/twig or panicle										Mean
		2004 -05	2005- 06	2006- 07	2007 -08	2008 -09	2009 -10	2010 -11	2011 -12	2012- 13	2013- 14	
27	July 2-8	0	0	0	6	0	0	0	0	0	0	0.60
28	9-15	0	0	0	0	0	0	0	0	0	0	0.00
29	16-22	0	0	0	4	0	0	0	0	0	0	0.40
30	23-29	0	0	0	0	0	0	0	0	0	0	0.00
31	30-5	0	0	0	0	0	0	0	0	0	0	0.00
32	Aug 6-12	0	0	0	0	0	0	0	0	0	0	0.00
33	13-19	0	0	0	0	0	0	0	0	0	0	0.00
34	20-26	0	0	0	0	0	0	0	0	17	0	1.70
35	27-2	0	0	0	0	0	0	0	0	19	8	2.70
36	Sept 3-9	0	0	0	0	0	0	9	7	24	10	5.00
37	10-16	0	0	0	0	0	0	13	11	23	14	6.10
38	17-23	0	0	0	0	0	0	19	16	19	17	7.10
39	24-30	0	0	0	0	7	7	19	17	16	19	8.50
40	Oct 1-7	0	0	0	0	0	10	20	20	13	20	8.30
41	8-14	0	0	0	13	45	11	23	28	19	23	16.20
42	15-21	0	0	0	0	23	19	21	28	17	25	13.30
43	22-28	0	0	11	0	28	23	21	30	13	17	14.30
44	29-4	5	13	17	0	10	0	22	27	19	10	12.30
45	Nov 5-11	8	7	19	2	0	16	23	27	14	12	12.80
46	12-18	10	4	24	0	0	16	21	23	13	13	12.40
47	19-25	15	13	29	6	0	4	23	21	19	17	14.70
48*	26-2	23	19	32	6	13	5	23	22	13	17	17.30
49*	Dec. 3-9	29	27	32	16	15	2	21	13	19	19	19.30
50*	10-16	20	31	33	11	7	3	12	9	13	10	14.90
51*	17-23	10	13	15	14	0	5	6	21	16	8	10.80
52*	24-31	9	10	4	10	0	9	11	46	19	9	12.70
01*	Jan 1-7	5	13	4	25	0	5	17	39	11	7	12.60
02*	8-14	15	16	5	31	0	9	49	25	13	7	17.00
03*	15-21	17	36	6	19	2	1	45	21	9	8	16.40
04*	22-28	23	33	3	21	3	7	45	29	6	11	18.10
05*	29-4	33	19	13	34	4	8	51	29	13	15	21.90
06*	Feb 5-11	37	21	8	35	5	14	61	20	19	16	23.60
07*	12-18	40	41	2	63	6	10	49	13	19	19	26.20
08*	19-25	42	48	10	33	23	13	45	35	17	23	28.90
09*	26-4	53	56	11	44	17	17	32	21	19	27	29.70
10*	Mar 5-11	38	16	17	48	20	20	37	21	23	30	27.00
11*	12-18	27	20	19	7	19	23	36	58	34	33	27.60
12*	19-25	11	37	24	9	7	21	37	43	39	37	26.50
13*	26-1	8	39	4	11	14	19	37	18	39	37	22.60
14*	Apr 2-8	8	10	11	7	0	14	38	19	36	43	18.60
15*	9-15	7	5	8	2	19	11	24	23	33	40	17.20
16*	16-22	5	16	24	8	19	4	19	19	29	35	17.80
17*	23-29	3	11	42	5	12	3	11	17	36	33	17.30
18*	30-6	1	10	43	6	4	0	6	11	29	21	13.10
19	May 7-13	0	0	13	6	0	0	4	10	23	15	7.10
20	14-20	0	0	10	3	0	0	7	9	19	9	5.70
21	21-27	0	0	14	11	6	0	9	7	16	9	7.20
22	28-3	0	0	19	14	0	0	9	0	11	7	6.00
23	June 4-10	0	0	23	0	0	0	7	0	9	4	4.30
24	11-17	0	0	27	0	0	0	4	0	9	2	4.20
25	18-24	0	0	19	0	0	0	0	3	0	0	2.20
26	July 25-01	0	0	19	0	0	0	0	1	0	0	2.00
	Average	9.65	11.23	11.81	10.19	6.31	6.33	18.96	16.48	16.08	14.54	12.16

*Observations on 10 panicles

Y_1: Thrips population/twig or panicle (Dependent variable)

X_1: Maximum Temperature (°C)
X_2: Minimum Temperature (°C)
X_3: Average Temperature (°C)
X_4: Morning Relative Humidity (%)
X_5: Evening Relative Humidity (%)
Independent variables

X_6: Average Relative Humidity (%)
X_7: Rainfall (mm)
X_8: Rainfall day
X_9: Sunshine Hour
X_{10}: Wind Velocity (km / hr)
Independent variables

Table 2. Abundance of mango thrips during peak year of activity in relation to major weather factors (2010-11)

SW	Standard	Dependent	Independent Variable									
		Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
27	July 2-8	0	29.27	24.55	26.91	94.00	83.85	88.93	377.10	5.00	3.32	5.98
28	9-15	0	30.08	24.35	27.22	92.71	85.57	89.14	398.00	6.00	5.52	5.29
29	16-22	0	29.50	24.60	27.05	95.00	85.42	90.21	152.00	7.00	3.54	6.52
30	23-29	0	29.21	24.78	27.00	96.14	84.85	90.50	220.00	7.00	2.07	5.54
31	30-5	0	28.60	24.50	26.55	94.93	87.00	90.97	338.40	7.00	1.12	8.85
32	Aug 6-12	0	29.72	24.47	27.10	95.71	84.00	89.86	190.00	6.00	3.14	7.11
33	13-19	0	28.52	24.14	26.33	96.42	89.85	93.14	188.50	7.00	3.34	4.41
34	20-26	0	29.55	23.85	26.70	94.42	83.00	88.71	50.00	6.00	5.00	9.71
35	27-2	0	30.05	24.01	27.03	93.14	80.28	86.71	158.60	7.00	4.00	6.96
36	Sept 3-9	9	28.51	23.28	25.90	95.42	87.28	91.35	112.90	6.00	2.11	4.93
37	10-16	13	28.88	23.35	26.12	95.28	82.71	89.00	24.60	4.00	5.05	4.05
38	17-23	19	25.92	23.42	24.67	93.28	79.00	86.14	36.60	5.00	6.14	4.76
39	24-30	19	29.01	23.37	26.19	95.57	84.42	90.00	211.30	3.00	4.04	3.39
40	Oct 1-7	20	28.5	23.14	25.82	96.85	83.42	90.14	139.20	7.00	2.77	2.42
41	8-14	23	33.24	21.78	27.51	84.57	64.00	74.29	0.00	0.00	9.52	2.43
42	15-21	21	33.48	21.85	27.67	91.71	56.00	73.86	0.00	0.00	9.08	2.31
43	22-28	21	34.44	18.07	26.26	90.14	44.00	67.07	0.00	0.00	10.22	1.93
44	29-4	22	34.00	15.60	24.80	87.14	39.85	63.50	0.00	0.00	10.00	2.08
45	Nov 5-11	23	35.48	19.50	27.49	89.57	39.85	64.71	0.00	0.00	9.77	2.58
46	12-18	21	34.95	17.67	26.31	90.42	42.42	66.42	0.00	0.00	9.62	2.05
47	19-25	23	33.61	14.67	24.14	91.14	40.14	65.64	0.00	0.00	9.71	2.02
48*	26-2	23	32.78	15.65	24.22	89.57	45.85	67.71	0.00	0.00	9.10	1.80
49*	Dec. 3-9	21	33.17	16.10	24.64	92.14	47.85	70.00	0.00	0.00	9.21	1.72
50*	10-16	12	32.95	14.85	23.90	89.00	32.42	60.71	0.00	0.00	8.94	3.35
51*	17-23	6	31.71	13.28	22.50	89.85	49.57	69.71	0.00	0.00	8.95	2.47
52*	24-31	11	30.22	9.94	20.08	92.42	43.28	67.85	0.00	0.00	9.17	1.91
1*	Jan 1-7	17	30.33	9.99	20.16	89.62	39.62	64.62	0.00	0.00	9.41	3.33
2*	8-14	49	28.44	8.15	18.30	93.28	36.57	64.93	0.00	0.00	9.43	2.46
3*	15-21	45	31.38	10.95	21.17	89.42	38.00	63.71	0.00	0.00	9.45	2.44
4*	22-28	45	31.86	11.00	21.43	91.42	46.71	69.07	0.00	0.00	9.31	1.90
5*	29-4	51	28.21	9.92	19.07	89.28	43.14	66.21	0.00	0.00	10.01	2.97
6*	Feb 5-11	61	29.36	11.43	20.40	83.00	54.28	68.64	0.00	0.00	9.60	3.45
7*	12-18	49	30.91	7.78	19.35	85.85	37.00	61.43	0.00	0.00	10.34	3.11
8*	19-25	45	32.00	11.28	21.64	90.85	47.43	69.14	0.00	0.00	9.83	2.63
9*	26-4	32	31.95	12.21	22.08	93.28	47.71	70.50	0.00	0.00	9.83	2.78
10*	Mar 5-11	37	33.67	12.83	23.25	92.28	42.00	67.14	0.00	0.00	8.91	2.47
11*	12-18	36	36.54	12.26	24.40	80.00	31.00	55.50	0.00	0.00	7.80	2.61
12*	19-25	37	37.96	13.21	25.59	87.71	29.00	58.36	0.00	0.00	8.82	2.68
13*	26-1	37	36.74	15.14	25.94	88.00	43.57	65.79	0.00	0.00	10.22	2.69
14*	Apr 2-8	38	33.48	16.57	25.03	88.28	44.71	66.50	0.00	0.00	9.94	3.11
15*	9-15	24	34.28	18.77	26.53	88.71	50.14	69.43	0.00	0.00	9.10	3.13
16*	16-22	19	34.45	20.17	27.31	86.000	45.42	65.71	0.00	0.00	10.30	4.44
17*	23-29	11	34.81	20.84	27.83	85.28	49.00	67.14	0.00	0.00	10.52	5.97
18*	30-6	6	35.35	22.50	28.93	85.42	56.71	71.07	0.00	0.00	10.14	4.30
19	May 7-13	4	35.95	21.04	28.5	81.28	46.26	63.77	0.00	0.00	10.30	4.74
20	14-20	7	37.21	25.57	31.39	80.28	53.00	66.64	0.00	0.00	7.65	4.68
21	21-27	9	33.71	25.78	29.75	82.71	62.71	72.71	0.00	0.00	9.62	7.77
22	28-3	9	33.81	24.67	29.24	79.57	61.00	70.29	0.00	0.00	10.40	8.17
23	June 4-10	7	34.05	24.50	29.28	83.28	57.71	70.50	0.00	0.00	10.41	7.64
24	11-17	4	33.50	24.65	29.08	79.00	59.57	69.29	42.00	1.00	8.98	5.29
25	18-24	0	32.50	24.38	28.44	90.28	72.42	81.35	133.3	4.00	5.80	5.04
26	Jun 25- Jul 01	0	28.88	24.57	26.73	89.71	81.81	85.76	91.00	2.00	4.61	8.58
Average	18.96	32.05	18.75	25.40	89.62	57.74	73.68	55.68	1.81	7.79	4.13	

Table 3. Overall abundance of mango thrips during in relation to major weather factors (2004-14)

SW	Standard	Dependent	Independent variable									
		Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
27	July 2-8	0.60	30.31	24.76	27.25	91.90	80.87	83.92	295.8	5.40	5.01	6.92
28	9-15	0.00	29.70	24.62	26.93	92.25	83.81	85.16	239.2	5.40	3.07	6.16
29	16-22	0.40	29.42	24.87	26.90	92.00	82.80	84.07	152.1	5.50	3.14	9.20
30	23-29	0.00	30.13	24.69	27.18	92.83	81.33	84.16	149.8	6.00	3.01	6.99
31	30-5	0.00	29.53	24.40	26.71	93.16	83.67	85.73	144.1	6.00	3.07	7.24
32	Aug 6-12	0.00	29.14	24.23	26.40	94.14	86.27	87.50	174.2	5.50	2.30	7.13
33	13-19	0.00	28.42	24.11	26.08	94.96	88.34	88.70	252.0	6.80	1.83	6.71
34	20-26	1.70	28.83	24.13	26.25	93.71	83.41	85.71	100.6	5.80	3.71	6.65
35	27-2	2.70	29.40	23.72	26.27	94.51	82.27	85.45	123.9	6.10	3.49	4.91
36	Sept 3-9	5.00	29.50	23.75	26.36	92.81	81.22	83.99	69.8	4.30	4.53	4.87
37	10-16	6.10	29.80	23.25	26.22	93.95	78.84	83.36	47.9	4.00	4.72	2.83
38	17-23	7.10	29.55	23.04	25.89	93.63	80.31	84.18	52.2	3.70	4.87	3.36
39	24-30	8.50	30.11	22.77	26.07	93.29	78.51	83.43	98.1	3.40	4.66	3.49
40	Oct 1-7	8.30	31.55	23.07	26.83	93.32	73.44	81.55	42.8	3.10	6.40	2.04
41	8-14	16.20	32.83	22.47	27.33	91.34	66.92	77.18	11.2	1.40	7.59	1.97
42	15-21	13.30	33.30	21.94	27.19	90.02	64.48	74.60	11.3	0.80	8.42	1.88
43	22-28	14.30	33.92	19.46	26.01	88.83	54.70	70.11	1.3	0.20	9.18	1.82
44	29-4	12.30	34.30	16.95	24.66	86.22	49.70	66.03	0.0	0.00	9.60	1.90
45	Nov 5-11	12.80	34.32	17.71	25.09	85.76	50.35	66.61	0.0	0.00	8.81	2.12
46	12-18	12.40	34.22	16.87	24.59	88.34	45.26	65.82	0.0	0.00	9.09	1.58
47	19-25	14.70	33.61	15.48	23.49	87.10	43.89	64.33	0.0	0.00	9.33	1.45
48*	26-2	17.30	32.03	13.82	21.85	85.93	40.53	62.20	0.0	0.00	8.98	1.52
49*	Dec. 3-9	19.30	31.89	13.59	21.71	83.87	40.50	61.23	0.0	0.00	8.81	1.75
50*	10-16	14.90	32.34	12.88	21.57	85.30	39.34	61.82	0.0	0.00	8.72	1.98
51*	17-23	10.80	31.95	11.07	20.43	85.75	46.34	63.26	0.0	0.00	8.80	2.03
52*	24-31	12.70	31.30	10.39	19.75	88.65	42.44	64.47	0.0	0.00	8.86	1.62
1	Jan 1-7	12.60	30.68	11.42	20.04	88.53	47.21	66.46	0.0	0.00	9.02	1.94
2	8-14	17.00	29.82	10.92	19.32	88.34	42.11	63.56	0.0	0.00	8.77	2.09
3	15-21	16.40	30.68	10.74	19.69	88.34	46.64	66.04	0.0	0.00	9.06	2.11
4	22-28	18.10	30.68	10.44	19.66	87.27	39.92	62.96	0.0	0.00	9.32	2.03
5	29-4	21.90	29.60	10.67	19.15	88.15	40.21	63.39	0.0	0.00	9.25	2.57
6	Feb 5-11	23.60	30.32	10.84	19.49	85.14	41.32	61.99	0.0	0.00	9.12	2.53
7	12-18	26.20	30.93	10.80	19.84	87.60	41.41	64.14	0.0	0.00	9.77	2.67
8	19-25	28.90	31.89	11.97	20.90	87.33	43.24	64.48	0.0	0.00	9.51	2.51
9	26-4	29.70	31.85	12.35	21.08	86.13	43.81	64.12	0.5	0.10	9.78	2.67
10	Mar 5-11	27.00	33.43	13.09	22.12	84.49	39.48	61.14	0.0	0.00	9.83	3.13
11	12-18	27.60	32.50	12.92	21.67	84.16	41.38	61.51	0.3	0.10	9.31	2.93
12	19-25	26.50	33.51	13.99	22.76	84.83	40.42	61.74	0.5	0.20	9.32	3.22
13	26-1	22.60	34.38	15.09	23.80	84.00	40.75	61.26	0.0	0.00	9.77	2.93
14	Apr 2-8	18.60	35.35	16.15	24.90	81.16	38.92	59.14	0.0	0.00	9.48	3.05
15	9-15	17.20	35.59	18.24	26.24	84.18	44.72	64.21	0.1	0.10	9.25	3.57
16	16-22	17.80	35.17	18.39	25.89	82.03	44.50	62.93	0.0	0.00	10.06	3.64
17	23-29	17.30	34.56	19.81	26.41	83.65	49.44	65.38	0.0	0.00	10.08	3.83
18	30-6	13.10	34.94	21.75	27.47	84.24	52.18	67.21	0.0	0.00	10.30	5.61
19	May 7-13	7.10	34.88	22.10	27.70	84.17	56.48	68.62	0.0	0.00	10.55	5.70
20	14-20	5.70	35.03	23.02	28.52	83.51	56.40	68.58	3.2	0.40	10.12	5.45
21	21-27	7.20	33.70	24.40	28.73	82.37	60.57	69.89	6.0	0.80	9.87	7.04
22	28-3	6.00	33.25	24.42	28.36	81.60	61.59	70.28	5.9	0.60	10.34	7.90
23	June 4-10	4.30	34.09	24.84	29.08	82.34	62.31	70.49	24.0	1.30	9.01	8.09
24	11-17	4.20	33.70	25.06	28.94	84.51	63.27	72.07	32.2	1.30	8.56	6.45
25	18-24	2.20	33.03	24.96	28.53	86.68	68.01	74.36	108.7	3.60	5.92	6.31
26	Jun 25- Jul 01	2.00	31.32	24.62	27.58	89.55	74.29	79.41	136.6	4.60	4.24	6.21
Average		12.16	32.04	18.67	24.67	87.84	57.89	71.15	43.90	1.66	7.67	4.07

Table 4. Correlation coefficients of abundance of mango thrips in relation to major abiotic factors during 2004-2014

Observation period	Correlation coefficient ('r') /Abiotic factors									
	Temperature			Relative humidity			Rainfall	Rainfall days	Sunshine	Wind velocity
	Maximum	Minimum	Average	Morning	Evening	Average				
2004-2005	-0.1690	-0.7974**	-0.7476**	-0.2033	-0.5582**	-0.4960**	-0.3253*	-0.4891**	0.3937**	0.3814**
2005-2006	0.0626	0.7656**	-0.6800**	-0.3546**	-0.6721**	-0.6228**	-0.3235*	-0.5199**	0.5229**	-0.4191**
2006-2007	0.2441	-0.2135	-0.1229	-0.4987**	-0.3616**	-0.4114**	-0.3948**	-0.4798**	0.5096**	-0.0809
2007-2008	-0.0581	-0.6635**	-0.6648**	-0.2819*	-0.6010**	-0.5704**	-0.2152	-0.4117**	0.3705**	-0.3087*
2008-2009	0.2503	-0.1336	-0.0208	-0.1187	-0.2677	-0.2508	--0.2171	-0.3066*	0.1821	-0.2678
2009-2010	0.3595**	-0.5514**	-0.3380*	-0.5079**	-0.6234**	-0.6273**	-0.2878*	-0.4462**	0.4034**	-0.1699
2010-2011	0.1210	-0.8080**	-0.7030**	-0.1600	-0.6453**	-0.5965**	-0.5275**	-0.5844**	0.5443**	-0.6462**
2011-2012	0.1262	-0.6726**	-0.5455**	-0.2127	-0.5553**	-0.5076**	-0.3999**	-0.5227**	0.4807**	-0.5932**
2012-2013	0.3847**	-0.2865*	-0.1239	-0.3709**	-0.4406**	-0.4558**	-0.3258*	-0.4230**	0.4414**	-0.2988*
2013-2014	0.4864**	-0.3892**	-0.0995	-0.4583*	-0.5161**	-0.5188**	-0.4611**	-0.5334**	0.5238**	-0.4560**
Mean (Av. of ten years)	0.2079	-0.6504**	-0.5677**	-0.3254*	-0.6129**	-0.4837**	-0.5508**	-0.5886**	0.5383**	-0.5146**
Overall (Pooled)	0.1182*	-0.5189**	-0.4279**	-0.2203**	-0.4809**	-0.3649**	-0.2944**	-0.4410**	0.4153**	-0.2143**

*Significant at 5 % level; **Significant at 1 % level

complex of flower thrips (*S. dorsalis* and *S. mangiferae*) between 2-17 SW (8 January – 29 April) which showed its peak (29.70/ panicle) on 9th SW (26 February – 4 March) coinciding with pea cum marble stages of crop.

Thrips population exhibited significant and positive correlation with sunshine and negative correlation with minimum temperature, relative humidity (morning and evening), rainfall, rainfall days and wind velocity (Anonymous, 2008). Kannan and Rao (2006) reported that thrips (*Thrips hawiiensis)* was responsible for mango syndrome (flower and fruit) and the activity was more during decreased level of temperature and rainfall.

The results obtained by the above workers indicate peak incidence of thrips when temperature and rainfall were in decreasing pattern which was also observed in the present findings indicating peak population of thrips (29.70/panicle during 9th SW of the entire experimental period of 2004-2014) (61 thrips/panicle during 6th SW in peak year of pest activity i.e., 2010-11) which is actually the period of decreasing temperature and rainfall, thus conform the present investigation.

So, it may be concluded that slight increase of temperature (maximum, minimum and average) (0.01, 0.08 and 0.73 °C), relative humidity (morning and average)(1.78 and 2.53 %), rainfall (11.78 mm), rainfall days (0.15), sun shine (0.12 hours) and wind velocity (0.06 kms/hours) which in turn increased dampness in the environment were conducive for sharp rise in thrips population. If wind velocity increased even by 0.06 kms per hour, migration of thrips on mango trees increased leading to higher population and its oriented damage. These results are also supplemented by results based on decrease in evening relative humidity (0.15 %).

(IV) Abundance of thrips in relation to various crop stages

Thrips population was noticed at various stages of crop growth *viz;* vegetative, emergence of new flush, new twigs, bud/bud burst stage, initiation of flowering, peak flowering, pea cum marble sized fruit, stone sized fruit, fruiting, initiation of ripening, ripening cum harvest and harvest stages of the crop. Average (10 years) thrips population varied from 0.33 to 27.95 per twig or panicle at various stages of crop growth wherein it peaked (27.95/panicle) at pea cum marble sized fruit stage of the crop. Highest thrips population (56/panicle) was observed at peak flowering stage of the crop during peak year of activity (2010-11) followed by 40.75 per panicle at pea cum marble sized fruit stage of the crop. Correlation of thrips in relation to various crop stages was significant and positive implying that population increased with the advancement of crop growth. As the crop growth advanced from new flush to new twig, the thrips oviposition and multiplication increased which might have led to increased population and subsequently higher damage. Similarly from new twig to bud or bud burst stage, the pest population increased further which ultimately reached to its peak either during peak flowering or marble sized fruit stage. As the annual crop cycle was near to its completion i.e. from flowering to fruiting or ripening, the pest population increased initially but later on decreased to its minimum at harvest stage. This clearly proves that succulent crop stages like new flush, twigs, bud, flowering and marble sized fruit stage were preferred most by the pest under

Table 5. Regression coefficients of abundance of mango thrips in relation to major abiotic factors during 2004-2014

Abiotic factors	Observation period										Mean	Overall Pooled
	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14		
Max.temp.(X_1)	--	--	--	--	--	2.4337	--	--	0.2957	2.5964	--	-100.3820
Min.temp. (X_2)	-0.6200	-5.1927	--	0.9347	--	1.2691	2.5991	-3.7486	0.1108	-1.4710	-2.3955	-101.2408
Av.temp. (X_3)	-2.4357	4.4009	--	125.0038	--	-3.4422	0.0193	3.0398	--	--	1.6549	200.5991
Mor.R.H. (X_4)	--	-172.2143	-364.9130	128.9441	--	240.8797	--	--	328.7852	-334.0289	-0.0208	0.0040
Eve.R.H. (X_5)	0.2250	-172.8679	-363.4886	-0.4312	--	240.9066	1.2214	0.2008	328.8395	-333.1583	0.1791	-0.0646
Av.R.H. (X_6)	-0.8053	346.0246	727.5893	-257.4465	--	-482.0923	-1.5413	0.5557	-657.8775	667.0550	0.1630	0.1936
Rainfall (X_7)	0.0091	-0.0101	-0.0165	--	--	0.0061	-0.0206	-0.0075	-0.0057	-0.0090	0.0051	-0.0041
Rainfall days (X_8)	0.6609	1.2196	-1.2312	-0.5396	-1.1652	-0.4677	-0.0274	-0.5656	0.4333	-0.2354	0.3817	-0.3549
Sun shine (X_9)	-0.1094	0.6865	0.9668	-0.0547	--	-0.9815	0.5983	1.2103	0.9758	-0.4392	1.4429	0.7500
Wind velocity (X_{10})	0.1419	1.0660	--	1.2602	--	--	-1.9620	-1.1529	-0.6888	-0.6827	-0.6307	-0.1717
R^2	0.6166	0.5558	0.2820	0.4887	0.0940	0.3527	0.6548	0.5112	0.1192	0.2756	0.3485	0.2973
Variation Explained (%)	61.66	55.58	28.20	48.87	9.40	35.27	65.48	51.12	11.92	27.56	34.85	29.73
R value	0.8226**	0.7964**	0.6054*	0.7542**	--	0.6833**	0.8420**	0.7667**	0.5240	0.6352*	0.6808*	0.5575**
Constant (A value)	128.38	9.8077	85.8159	88.6320	8.1004	23.8799	114.8857	-46.1585	20.7482	-11.6833	-14.5706	17.2716

Table 6. Impact of various crop stages on abundance of mango thrips during 2004-2014

Crop stages	Observation period/thrips population/twig or panicle										Pooled
	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	
Vegetative	0	0	0	1.25	0	0	0	0	5.66	0	0.33
Emergence of New flush	0	0	1.83	2.16	17.16	11.66	24.16	26.16	27.16	25.5	9.05
New twigs	9.5	9.25	22.25	2	2.5	9	22.25	24.5	16.25	13	13.05
Bud/bud burst	18.2	20	23.2	11.4	5	4.8	14.6	22.2	16	12.6	15
Initiation of Flowering	15	24.5	4.5	24	1.25	5.5	39	28.5	9.75	8.25	16.02
Peak flowering	35	20	10.5	34.5	4.5	11	56	24.5	16	15.5	22.75
Pea/marble	43.25	40.25	10	47	16.5	15	40.75	22.5	19.5	24.75	27.95
Stone size	8.75	18.5	21.87	6.87	11.75	11.87	26	26	34.37	34.87	20.08
Fruiting	0	0	11.5	4.5	0	0	5.5	9.5	21	12	6.4
Initiation of Ripening	0	0	16.5	12.5	3	0	9	3.5	13.5	8	6.6
Ripening/harvest	0	0	23	0	0	0	7	0	9	4	4.3
Harvest	0	0	21.66	0	0	0	1.3	1.3	6	0.66	2.8
Correlation coefficient ('r')	-0.1373**	-0.0996*	0.1111*	-0.0807	-0.2480**	-0.2925**	-0.3057**	-0.3908**	-0.1764**	-0.1486**	0.1747**
Constant (A)	6.8837	6.7829	6.1038	6.7340	7.1168	7.4002	7.7213	7.9560	7.0822	6.9143	4.4894
Regression coefficient	-0.0092	-0.0058	0.0077	-0.0053	-0.0233	-0.0328	-0.0149	-0.0204	-0.0083	-0.0066	0.0452

*Significant at 5 % level **Significant at 1 % level consideration whereas, hard crop stages like mature or ripened fruits were less preferred by the pest under consideration. Kannan and Rao (2006) reported that thrips (*Thrips hawiiensis)* was responsible for mango syndrome (flower and fruit) and the activity was more during decreased level of temperature and rainfall.

So, it may be concluded that thrips population peaked during 2010-11 wherein slight increase in temperature, relative humidity and rainfall, rainfall days, sun shine and wind velocity accounted for increased dampness in the environmental conditions which appeared to be conducive for sharp rise in thrips population. The pea cum marble sized fruit stage of the crop was preferred most by the pest under discussion.

Received 08 February, 2016; Accepted 08 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 645-649

Manuscript Number: 2351
NAAS Rating: 4.47

Effect of Nitrogen and Phosphorus Application on Growth, Flowering and Yield of African Marigold (*Tagetes erecta* L.) under Semi-arid Conditions of Haryana

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***Abstract*:** The present investigation was conducted to standardize the optimum dose of nitrogen and phosphorus in African marigold. Fertilizer requirement of African marigold was studied with twenty treatments comprising five levels of nitrogen (0, 15, 20, 25 and 30 g m^{-2}) and four levels of phosphorus (0, 15, 20 and 25 g m^{-2}). This field experiment was carried out as factorial randomized block design with three replications in all possible combinations. All growth and flowering parameters were significantly influenced with every increase in nitrogen and phosphorus dose. Maximum growth in terms of plant height, plant spread and number of branches per plant, fresh and dry weight of plant was observed at 30 g nitrogen with 25 g P_2O_5 m^{-2}. Various flowering parameters viz. number of buds per plant, number of flowers per plant, duration of flowering, flower diameter and stalk length and flower yield parameters viz. flowers yield per plant and yield per ha were obtained maximum at 30 g nitrogen with 25 g phosphorus m^{-2}.

***Key Words*:** Flowering, Growth, Nitrogen, Phosphorus, Yield

Floriculture is regarded as a viable alternative for diversification from the traditional field crops due to the increasing demand of flowers and higher returns per unit area. India's share in total floriculture products export of whole world is around 0.79%. In India, the total area under marigold cultivation is 255 thousand hectares with production of 1754 thousand MT loose flowers and 543 thousand MT cut flowers. In Haryana, the area under floriculture is 6.5 thousand hectares with a production of 65.5 thousand MT of loose flower and 11.3 thousand MT cut flowers, out of which 5.69 thousand hectares is covered under marigold cultivation with a loose flower production of 64.62 thousand MT (Saxena *et al*., 2014). African marigold (*Tagetes erecta* L.) belongs to the family Asteraceae and is a native of Mexico. Mainly two types of marigold are grown in India viz., African marigold (*Tagetes erecta* L., 2n = 24) and French marigold (*Tagetes patula* L., 2n = 48) for loose as well as cut flower production. Marigold is a very popular annual flower crop as a garden plant for beautification and used commercially for making garlands, wreaths, religious offering and as cut flowers. Marigold is a very hardy and vigorous plant having beautiful dark green foliage with large sized double globular flowers. Due to its hardiness, easy cultivation and high productivity marigold is extensively cultivated in India. It can be grown in sandy loam, well-drained soil in almost all seasons except in very hot summer. Its habit of free flowering, short duration, attractive colour, shape, size, good keeping quality and easy transportation attracts the attention of flower growers and traders. Marigold besides having ornamental, medicinal, industry use, it has additional use in controlling the soil nematodes. Nitrogen is an essential element required by the plants for growth and development.

It is equally important in crop plants being constituents of proteins, nucleic acids, chlorophyll etc. An adequate supply of N results in vigorous growth of the plant hence yield of flowers with better quality (Ahirwar *et al.*, 2012). Similarly, an adequate supply of phosphorus is associated with rapid and vigorous start to plant, helping to establish seedling quickly, stimulates flowering and decrease lodging tendency of plant. Number of flower heads per plant (31.83), fresh weight of the flower heads per plant (75.13 g) and yield (11.65 t ha^{-1}) were higher in treatment combination of 200 kg N ha^{-1} and 200 kg P ha^{-1} (Naik *et al.*, 2015). The successful commercial production of marigold depends upon many factors such as variety, time of planting, fertilizer application, spacing, cultural practices like gap filling, pinching, weeding, irrigation etc. However, some aspects of the production technology of marigold in agro-climatic conditions of Haryana have not been standardized so far. So in the light of above facts present investigation was conducted with the objective to standardize the optimum dose of nitrogen and phosphorus of African marigold under semi arid conditions of Haryana.

MATERIAL AND METHODS

The present investigation entitled was conducted at CCS Haryana Agricultural University, Hisar, India during winter season of 2013-14 to standardize the nitrogen and phosphorus requirement in African marigold. Twenty treatment combinations comprising five levels of nitrogen (0, 15, 20, 25 and 30 g m^{-2}) and four levels of phosphorus (0, 15, 20 and 25 g m^{-2}) were tried in factorial randomized block design with three replications. Thus 60 plots were used for 20 treatment combinations. The soil of the experimental field was sandy loam in texture and had pH (8.2), E.C. (0.48 dSm^{-1}), organic carbon (0.45 %) and 137.4 kg ha^{-1} available N, 25 kg ha^{-1} available P_2O_5, 449.5 kg ha^{-1} available K_2O. Experimental field was prepared by repeated ploughing and harrowing well in advance. Seeds were sown on 16th August, 2013 on raised nursery beds. One month old healthy and uniform seedlings were transplanted at the spacing of 40 x 40 cm on 19th September, 2013. Half dose of nitrogen and full dose of phosphorus was supplied through urea and single super phosphate, respectively at transplanting time as per treatments. Remaining half dose of nitrogen was applied at 30 days after transplanting while potash was applied as basal dose with a constant rate of 10 g m^{-2} through muriate of potash. Different intercultural practices like gap filling, irrigating, staking, weeding, etc. were performed as per crop requirement. Observations were recorded for various growth, flowering and yield parameters in African marigold cv. Local Selection (MGH-133-1-2). The data recorded for growth, flowering and yield characteristics during the course of investigation were subjected to statistical analysis.

RESULTS AND DISCUSSION

Growth parameters: Plant height, plant spread and number of primary branches per plant increased significantly with every increase in nitrogen and phosphorus levels over control (Table 1). Plant height, plant spread and number of primary branches per plant increased significantly with the increase in nitrogen level from 0 to 30g m^{-2}. Maximum plant height (74.23 cm), plant spread (62.03 cm) and number of primary branches (7.78) was found in 30g N m^{-2} and minimum (64.09 cm), (52.47 cm) and (5.34) was recorded in control in influencing plant height, plant spread and number of primary branches, respectively. However the nitrogen levels 30 & 25g m^{-2} were at par with each other in case of plant height and plant spread. It may be due to the fact that the vegetative growth increased with nitrogen application because nitrogen is an essential part of nucleic acid, which plays a vital role in promoting plant growth. Maharnor *et al.* (2011), Kaushik *et al.* (2013) and Polara *et al.* (2015) also reported similar results in African marigold.

The maximum plant height (72.14 cm), plant spread (61.64 cm) and number of primary branches per plant (7.18) was observed in 25g P_2O_5 m^{-2} and minimum (66.39 cm), (52.51 cm) and (5.97) was reported in control in influencing plant height, plant spread and number of primary branches per plant, respectively. However, the phosphorus levels 20 & 25g m^{-2} were at par with each other in influencing plant height, plant spread and number of primary branches per plant. The phosphorus application improved growth due to stimulation in root growth which helps in better root development and subsequently leading to more absorption of water and mineral nutrients from the soil. Polara *et al.* (2015) recorded similar results in African marigold.

The interaction effect of N & P_2O_5 showed significant increase in plant height, plant spread and number of primary branches per plant. Maximum plant height (77.10 cm) and plant spread (65.67 cm) was recorded in 30g N m^{-2} with 25g P_2O_5 m^{-2} whereas, number of primary branches per plant was found maximum (8.37) in 30g N m^{-2} with 20g P_2O_5 m^{-2}. Similar results were also recorded by Ahirwal *et al.* (2012) in the African marigold.

Fresh and dry weight of plant increased significantly with every increase in nitrogen and phosphorus levels over control as reveled by data shown in Table 1. Maximum fresh weight (434.65 g) and dry weight (43.96 g) of plant was found in 30g N m^{-2} and minimum (295.96 & 29.60 g, respectively) was recorded in control (0 g N m^{-2}). Maximum fresh weight (413.55 g) and dry weight (41.36 g) of plant was found in 25g P_2O_5 m^{-2} and minimum (343.28 & 34.32 g, respectively) in control (0 g P_2O_5 m^{-2}). The interaction effect of N and P_2O_5 showed significant increase in fresh and dry weight of plant. Maximum fresh weight (479.67 g) and dry weight (47.97 g) of plant was recorded in 30g N m^{-2} with 25g P_2O_5 m^{-2}.

Floral parameters: Significant increase in number of buds per plant, number of flowers per plant and flowering duration with successive increase in nitrogen levels from 0 to 30 g m^{-2} was reported (Table 1). Maximum number of buds per plant (65.34), number of flowers per plant (56.33) and duration of flowering (58.92 days) was recorded with 30 g N m^{-2} and minimum (52.17), (45.36) and (45.72 days) was observed in control in influencing number of buds per plant, number of flowers per plant and duration of flowering, respectively. Increase in flower production under nitrogen treatment was mainly due to the regular supply of available nitrogen to the plants which improved the vegetative parameters which in turn led to higher production whereas, this increase in duration of flowering was probably due to development of side branches and flowering continued for a longer period resulting in the extended duration of flowering. Sharma *et al.* (2010) and Polara *et al.* (2015) reported similar results in African marigold.

Number of buds per plant, number of flowers per plant and flowering duration increased significantly with

Table 1. Effect of nitrogen and phosphorus application on growth, flowering and yield parameters of African marigold (*Tagetes erecta* L.)

Treatment	Plant height (cm)	Plant spread (cm)	Primary branches plant^{-1}	Fresh weight of plant (g)	Dry weight of plant (g)	No. of buds per plant	Number of flowers per plant	Duration of flowering (days)	Flower diameter (cm)	Stalk length (cm)	Fresh weight of flower (g)	Dry weight of flower (g)	Flower yield plant^{-1} (g)	Flower yield hectare^{-1}(t)
N (g m^{-2})														
0	64.09	52.47	5.34	295.96	29.60	52.17	45.36	45.72	5.52	4.19	7.81	0.78	356.02	22.25
15	66.80	54.78	6.33	345.17	34.51	56.90	48.29	52.83	6.30	5.07	8.21	0.82	397.48	24.84
20	69.31	58.49	6.91	387.17	38.71	59.26	50.28	55.56	6.79	6.20	8.46	0.84	426.15	26.63
25	72.91	61.28	7.32	420.77	42.07	62.15	52.72	57.27	7.09	6.48	8.74	0.87	469.97	29.37
30	74.23	62.03	7.78	434.65	43.96	65.34	56.33	58.92	7.54	6.84	8.94	0.89	504.80	31.55
CD (p=0.05)	2.26	1.80	0.25	4.32	1.83	0.81	1.00	1.03	0.19	0.17	0.20	0.02	1.82	0.99
P (g m^{-2})														
0	66.39	52.51	5.97	343.28	34.32	54.52	47.29	50.08	5.95	4.60	7.71	0.77	372.92	23.31
15	68.44	56.46	6.69	364.31	36.43	57.39	48.97	52.88	6.40	5.78	8.39	0.83	412.88	25.81
20	70.90	60.27	7.10	385.74	38.58	60.39	51.34	55.48	6.96	6.14	8.74	0.87	449.38	28.09
25	72.14	61.64	7.18	413.55	41.36	64.35	54.78	57.81	7.27	6.49	8.90	0.89	488.36	30.52
CD (p=0.05)	2.02	1.61	0.23	4.18	1.74	0.73	0.89	0.92	0.17	0.15	0.18	0.02	1.63	0.88
N× P														
N_0P_0	62.67	46.42	4.60	267.71	26.77	47.14	40.81	43.51	4.90	3.62	6.94	0.69	282.99	17.69
N_0P_1	64.10	51.43	5.20	283.14	28.31	49.67	42.62	44.90	5.41	3.90	7.50	0.75	316.99	19.81
N_0P_2	64.60	53.14	5.67	312.12	31.21	54.75	47.75	46.44	5.73	4.30	8.25	0.82	393.63	24.60
N_0P_3	65.00	56.90	5.90	321.00	32.10	57.14	50.26	48.02	6.04	4.93	8.57	0.85	430.48	26.90
N_1P_0	63.00	49.13	4.87	322.57	32.25	53.75	45.64	48.44	5.51	4.08	7.67	0.76	349.78	21.86
N_1P_1	66.14	54.78	6.75	331.60	33.16	55.28	46.71	51.24	6.36	5.09	8.05	0.80	375.96	23.50
N_1P_2	69.71	57.16	6.80	350.00	35.00	56.57	48.81	54.43	6.64	5.31	8.55	0.85	416.94	26.06
N_1P_3	68.33	58.13	6.90	376.50	37.65	62.00	52.00	57.23	6.66	5.82	8.60	0.86	447.25	27.95
N_2P_0	65.43	53.50	6.14	360.28	36.02	53.86	47.31	50.80	6.10	4.84	7.87	0.78	372.46	23.28
N_2P_1	67.28	56.75	7.11	371.00	37.10	57.50	48.42	54.12	6.50	6.29	8.57	0.85	414.89	25.93
N_2P_2	70.10	61.60	7.12	390.00	39.00	60.55	50.53	56.72	7.13	6.73	8.60	0.86	434.05	27.13
N_2P_3	74.43	62.13	7.30	427.40	42.74	65.15	54.86	60.62	7.41	6.96	8.81	0.88	483.23	30.20
N_3P_0	69.43	56.40	6.86	380.50	38.05	57.87	49.72	52.93	6.44	5.12	7.98	0.79	429.99	26.87
N_3P_1	71.50	59.13	7.12	408.40	40.84	59.00	51.62	56.12	6.81	6.64	8.76	0.87	452.10	28.26
N_3P_2	74.86	64.30	7.57	430.50	43.05	63.55	52.33	59.13	7.21	6.98	9.08	0.90	475.04	29.69
N_3P_3	75.86	65.36	7.72	463.67	46.36	68.20	57.25	60.90	7.91	7.17	9.13	0.91	522.76	32.67
N_4P_0	71.44	57.10	7.37	385.33	39.38	60.00	53.00	54.71	6.79	5.37	8.10	0.81	429.37	26.83
N_4P_1	73.16	60.21	7.28	427.42	42.87	65.50	55.50	58.02	6.91	7.01	9.09	0.90	504.48	31.53
N_4P_2	75.24	65.15	8.37	446.20	45.62	66.55	57.30	60.70	8.16	7.41	9.20	0.92	527.26	32.95
N_4P_3	77.10	65.67	8.11	479.67	47.97	69.30	59.55	62.26	8.32	7.58	9.37	0.93	558.09	34.88
CD (p=0.05)	4.15	3.30	0.51	8.44	2.65	1.63	NS	1.8	0.38	0.33	0.36	0.04	3.64	1.92

gradual increase in phosphorus level from 0 to 25 g m^{-2} as shown in Table1. Maximum number of buds (64.35), number of flowers per plant (54.78) and duration of flowering (57.81 days) was recorded with 25 g P_2O_5 m^{-2} while minimum number of buds (54.52), number of flowers per plant (47.29) and duration of flowering (50.08 days) was found in control. Phosphorus is associated with the phosphorylation and is a constituent of energy rich compounds like ATP, ADP, NADH and NADPH. These energy rich metabolites ultimately increased the number of flowers per plant. Similar results were reported by Naik *et al.* (2015) and Polara *et al.* (2015) in African marigold. The interaction effect between nitrogen and phosphorus levels on number of buds per plant and duration of flowering was found significant while it was found non-significant for number of flowers per plant. Maximum number of buds per plant (69.30), number of flowers per plant (59.55) and duration of flowering (62.26 days) was found in 30 g N m^{-2} with 25 g P_2O_5 m^{-2}.

Flower diameter and stalk length increased significantly with every increase in nitrogen level from 0 to 30g m^{-2} (Table 1). Maximum flower diameter (7.54 cm) and stalk length (6.84 cm) was recorded with 30g N m^{-2} while minimum flower diameter (5.52 cm) and stalk length (4.19 cm) was recorded in control (0g N m^{-2}). This increase in flower diameter and stalk length might be due to the fact that at the onset of the reproductive phase, the vegetative growth seized and thereafter the manufactured food material was utilized exclusively by the sink resulting in increased flower diameter and stalk length. Similar results were recorded by Sharma *et al.* (2010) and Pushkar *et al.* (2011) in African marigold cv. Pusa Narangi Gainda.

The gradual increase in phosphorus level from 0 to 25 g m^{-2} resulted in significant increase in flower diameter and stalk length (Table 1). Maximum flower diameter (7.27 cm) and stalk length (6.49 cm) was observed with 25g P_2O_5 m^{-2} while minimum (5.95 cm) and (4.60 cm) was observed in control in influencing flower diameter and stalk length, respectively. Interaction effect between nitrogen and phosphorus levels on flower diameter and stalk length was found significant. Maximum flower diameter (8.32 cm) and stalk length (7.58 cm) was recorded in 30 g N m^{-2} with 25 g P_2O_5 m^{-2} (Table 1). The increase in stalk length due to nitrogen and phosphorus application might be due to the fact that nitrogen being the most important constituent of proteins, amino acids, enzymes and co-enzymes responsible for cell division and elongation. Ahirwal *et al.* (2012) and Joshi *et al.* (2013) reported similar results in African marigold.

Yield parameters: Fresh weight and dry weight of flower increased significantly with gradual increase in nitrogen and phosphorus levels over control as evident from data given in Table 1. Maximum fresh weight (8.94 g) and dry weight (0.89 g) of flower was recorded with 30g N m^{-2} which was found at par with 25 g N m^{-2} while minimum fresh weight (7.81 g) and dry weight (0.78 g) of flower was found in control. It may be due to the fact that the nitrogen, which was earlier been utilized by vegetative part, was translocated towards reproductive organs where it combined with the oxygen being evolved during photosynthesis and formed amino acids. On condensation, these amino acids formed proteins which ultimately increased the number of flowers per plant and fresh weight and dry weight of flower.

Maximum fresh weight (8.90 g) and dry weight (0.89) of flower was observed with 25g P_2O_5 m^{-2} and minimum (7.71 & 0.77 g) was observed in control in influencing fresh and dry weight of flower, respectively. The interactional effect between nitrogen and phosphorus levels on fresh and dry weight of flower was found significant. Maximum fresh weight (9.37 g) and dry weight (0.93 g) of flower was obtained with application of 30 g N m^{-2} with 25 g P_2O_5 m^{-2}. Similar results were recorded by Naik *et al.* (2015) in African marigold cv. Cracker Jack.

Significant increase in flower yield per plant and flower yield per hectare was observed with successive increase in nitrogen and phosphorus levels over control as revealed by data represented in Table 1. Maximum flower yield per plant (504.80 g) and flower yield per hectare (31.55 t) was recorded with 30 g N m^{-2} while minimum flower yield per plant (356.02 g) and flower yield per hectare (22.55 t) was observed in control. Increase in flower yield as a result of nitrogen application could be explained on the basis that with the onset of flowering phase there is subsistence anabolic activities and redistribution of organic and organic nutrient components. Results were found in confirmation with Pushkar *et al.* (2011) in African marigold cv. Pusa Narangi Gainda. Similar results were also recorded by Ahirwar *et al.* (2012) and Polara *et al.* (2015) in African marigold.

Maximum flower yield per plant (488.36 g) and flower yield per hectare (30.52 t) was recorded with 25g P_2O_5 m^{-2} and minimum (372.92 & 23.31 t) was found in control in influencing flower yield per plant and flower yield per hectare, respectively. The increase in flower yield as a result of phosphorus application seems to be due to the improvement in yield parameters due to the stimulation in root growth, which helped in better absorption of water and mineral nutrients from the soil. Naik *et al.* (2015) also reported similar results in African marigold cv. Cracker Jack. The interactional effect between nitrogen and phosphorus levels was found significant in influencing the flower yield per plant and flower yield per hectare. Maximum flower yield per plant (558.09g) and flower yield per hectare (34.88 t) was reported with combined application of 30 g N m^{-2} and 25 g P_2O_5 m^{-2}. Sharma *et al*. (2010) reported similar results in marigold.

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 650-654

Manuscript Number: 2352
NAAS Rating: 4.47

Application of Irrigation Management Model under Deficit Irrigation

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Abstract: Nonlinear optimization model was developed to obtain the optimal deficit levels for different crops to maximize the net economic returns and to work out the corresponding optimal cropping pattern for the optimal allocation of surface and ground water resources. The model was formulated for both the approaches, additive and multiplicative, to find out the optimal returns. The NLP model is optimized for the optimal value of deficit level, P_{SC}, for different crops to give the optimal cropping pattern which maximize the net economic return under deficit irrigation for Khairpur West Canal Command. It shows that net economic returns increased by 43.59% and 44.68% under additive and multiplicative approaches respectively by carrying more cropped area under irrigation and thereby increasing the overall crop production and water productivity under deficit irrigation as compared to the existing ones in the command area. Both the approaches, additive and multiplicative, are considered in the study area to find out the yield of the crops under deficit irrigation using corresponding modified crop yield response factors. The results corresponding to deficit irrigation are compared with the existing cropping pattern and show the advantage of deficit irrigation in maximizing the crop production with the available water.

Key Words: Deficit irrigation, Irrigation management, Optimization model

In the present scenario, agricultural segment is the largest end user of water in the world. About 80-90% of water is used in the agricultural sector. However scarcity of water and growing population, irrigation management pay great attention now days, in agricultural sector. The pressure for fresh water on farms, increasing competition of water will motivate to optimal utilization of water resources Optimum utilization of water may reduce expenditures for energy, chemicals, and labour inputs, at the same time as enhancing revenues through higher crop yields and improved crop quality. Therefore, irrigation water management (IWM) has become an important aspect for natural ecology point of view.

IWM decision can play an important role for deficit irrigation water availability. Deficit irrigation is practiced when water supply is less to the crop and irrigation water demand is not sufficient to fully satisfy the soil water efficiency in the entire root zone and subsequently full crop water requirement cannot be met for part of the growing season. Water deficiency in the crop can be quantified by the ratio of rate of actual evapotranspiration (ET_{ac}) to the rate of potential evapo-transpiration (ET_{max}). If water supply is not sufficient, the crop water use and yield relations which include the effect of both timing and amount of irrigation water are called crop water production functions.

Crop production functions are useful to evaluating deficit irrigation strategies. These functions commonly use in irrigation-optimization models. Many researchers have developed optimization models under deficit irrigation and crop water production functions can also play a key role in these models. An irrigation scheduling model (ISM) and a linear-optimization model (LPM) under hydrologic uncertainty were developed with the existing land and water resources of the canal command area (Raul *et al.,* 2012). These model have constant deficit levels throughout the season but Garg and Dadhich (2014) developed a non-linear optimization model for deficit irrigation. In the model deficit levels of irrigation kept as variables with a flexibility to keep the crops either at full irrigation or deficit irrigation.

In this study the results of non linear optimization model for deficit irrigation (Garg and Dadhich, 2014) applied to command area of Lower Indus Basin in context of cropping pattern, deficit levels and water availability. The results are obtained for maximum economic return for the culturable command area. Further, the results are also compared with the existing cropping pattern.

MATERIAL AND METHODS

The study area for the model application was taken Khairpur West Canal Command in lower Indus Basin and lies between latitude 27°32'N and longitude 68°46'E. There are two main cropping system in lower Indus Basin i.e. Kharif season (May to October) and Rabi Season (November to March). The non linear programming (NLP) model (Garg and Dadhich, 2014) applied to the study area. The climate data of the canal command were given by Ali (1995) are presented in Table 1.

The canal command area covers an approximately 110,000 ha and primarily consists of fine sandy loam soil. The

Table 1. Climatic data for the Khairpur West Canal Command

Temp °C (mean)	14.8	18.3	24.0	30.0	35.1	36.0	35.0	33.6	32.3	28.1	22.0	16.7
Wind Velocity (km/hr)	1.4	1.9	2.5	2.6	2.7	3.4	3.4	2.9	2.1	1.5	0.9	1.0
Relative Humidity (%)	50	47	42	34	34	43	55	60	56	45	46	52
Sunshine (%)	67	70	70	77	78	76	70	74	80	80	78	68
Rainfall (mm)	6.0	8.0	6.0	4.0	4.0	7.0	24.0	22.0	4.0	1.0	1.0	4.0
Reference evapo-transpiration (mm day^{-1})	2.39	3.36	5.26	7.00	9.27	9.52	7.42	6.45	6.07	4.42	3.10	2.26

major sources of water for the command area is included canal water and groundwater. Khairpur West canal is having the capacity of 54 m^3/s and is designed for perennial cropping system. The conveyance losses in the canal command area is varied between 31% to 57% of water supplied with an average loss of 45% (Garg and Dadhich, 2014). Further, 25 percent water losses occur within the field and the total losses in conveyance and in the field were 60% (SIDA, 2011). Furthermore, the groundwater recharges from these canals had been taken as 15 % of the total average canal supply (SIDA, 2011). All irrigation data of the Khairpur canal data are given in Table 2 and Table 3.

Table 2. Irrigation data of the Khairpur West canal command

Maximum Culturable area (CA, Mha)	0.11
Canal capacity (m^3 s^{-1})	54.00
Tube well capacity ($m^3 s^{-1}$)	12.00

Table 3. Water losses from the system in the Khairpur West canal command

	Surface runoff	Ground water recharge	Evaporation
Conveyance system	10%	15%	5%
Irrigated areas	10%	12%	10%

(Mukherjee, 2013)

The existing cropping intensities were 25.47% for Kharif (summer season) and 56.72% for Rabi (winter season). The existing cropping pattern, sowing dates of various crops, crop periods, maximum crop yields, net financial returns (base year 1990 prices), allowable deficit level (p_m) and some other data for different crops are shown in Table 4 (Ali, 1995, Garg and Dadhich, 2014).

The NLP model developed by Garg and Dadhich (2014) applied Khairpur West canal command area and obtained optimal value of deficit level, p_{sc}' for different crops to gave the optimal cropping pattern which maximized the net economic return under deficit irrigation. Both the approaches, additive and multiplicative, were considered to find out the yield of the crops under deficit irrigation using corresponding modified crop yield response factors. The results corresponding to deficit irrigation were compared with the existing cropping pattern of the canal command area with the available water.

The objective function of the NLP model was maximized the net financial return from the crops which was described by Garg and Dadhich (2014). The model was applied on decade basis and variables in the model was included decade water withdrawal from the canal and tube well for irrigation, different crop areas and deficit levels of different crops. Relative yield of the crop was determined by using multiplicative approach and additive approach (Doorenbos and Kassam, 1979; Rao *et al.*, 1988). The objective function bounded by different constraints like availability of water, crop water requirement, crop production, deficit levels etc. which described by Garg and Dadhich (2014). CROPWAT 8 and Microsoft Excel 2007 Solver were used to find to decade potential evapotranspiration and NLP optimization model respectively.

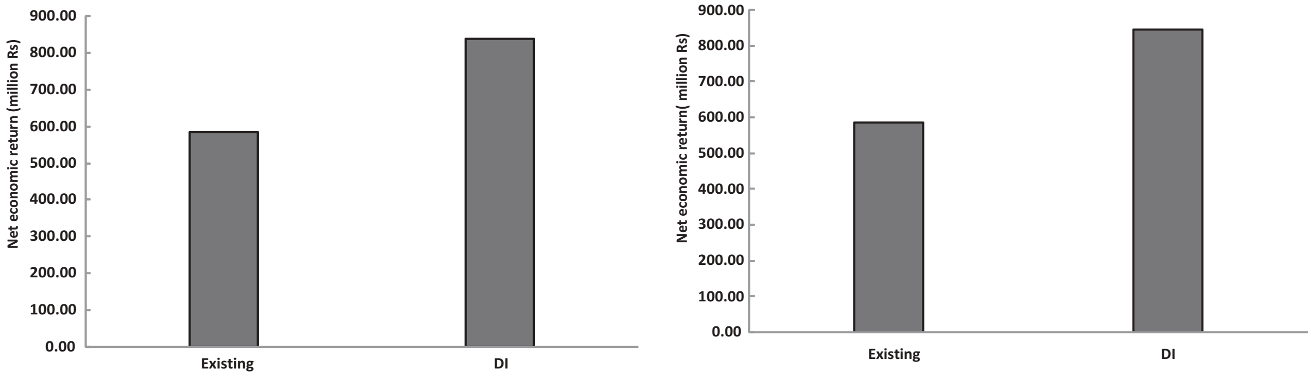
RESULTS AND DISCUSSION

Economic returns: The net optimal returns were increased to 839.45 and 845.75 million rupees respectively from the existing value of 584.62 million rupees for both the approaches (Additive and Multiplicative). The benefits were increased of 43.59% and 44.68% under additive and multiplicative approaches respectively by carrying more cropped area under irrigation and thereby increasing the overall crop production and water productivity under deficit irrigation as compared to the existing ones in the command area (Figure 1).

Optimum cropped area and decade water releases: There is an annual improvement of 54.21% and 49.67% under additive and multiplicative approaches respectively over the existing cropping intensity.

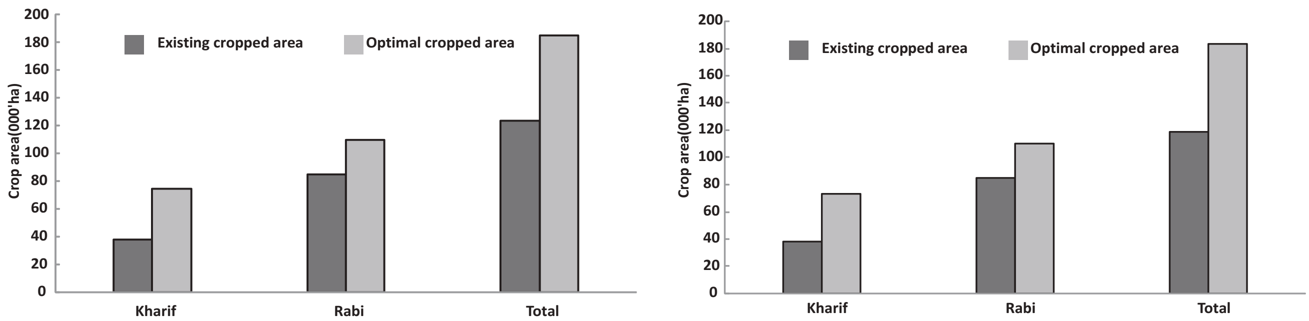
The surface water releases are considerably more than the ground water releases as the ground water is only used when the water requirements of the crops cannot be met by the available surface water as tube well water is around 9.0 times costlier than the surface water in the command area (Figure 3).

Optimal p_{sc} and water stress coefficients: The optimal values of p_{sc}' and k_s for eight major crops of the canal command indicate that the best possible cropping pattern kept cotton, sorghum and oilseed under maximum deficit irrigation in both the approaches (additive and multiplicative). While it



(a) Additive approach (b) Multiplicative approach

Fig 1. Comparison of net economic return between existing and deficit irrigation for Khairpur West canal command



(a) Additive approach (b) Multiplicative approach

Fig. 2. Comparison of existing cropped area and optimal cropped area under deficit irrigation for Khairpur West canal command

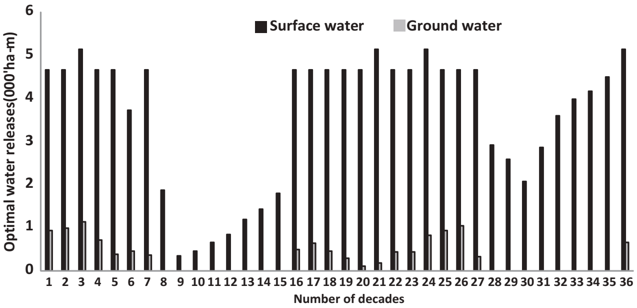
kept sugarcane, wheat, gram, mustard and rice crops under full irrigation. For both the approaches p_{SC}' and k_s values are same as modified K_{yi} values have been used to determine the optimal net economic returns. Furthermore, the water stress coefficients, k_s, are 1.0 for fully irrigated crops and less than 1.0 for the water stressed crops (Table 5). Therefore, the NLP model determined the optimal deficit levels with a flexibility to keep it at full level of irrigation, if required, as no prearranged deficit levels were set for the irrigated crops.

Effect of increasing tube well capacity: No slackness was found in tube well capacities constraints during peak demand periods and therefore it indicated the full utilization of the tube well capacities during the peak demand periods. However the slackness was in the annual ground water balance constraint, indicating that the annual ground water recharge was more than the annual ground water withdrawals in the study area. Therefore the existing tube well capacities were increased till annual ground water recharge became equal to

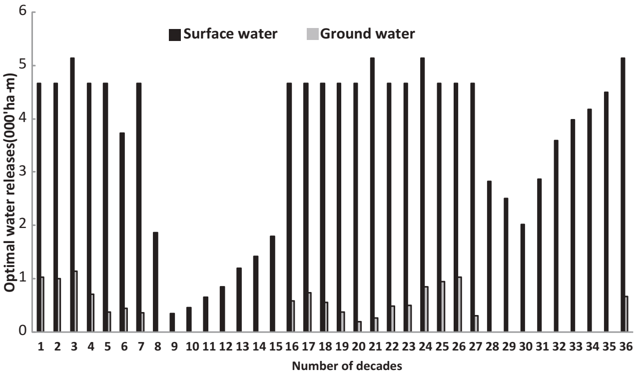
Table 4. Agricultural data for various crops

		Cotton	Oilseed	Rice	Sorghum	Gram	Mustard	Wheat	Sugarcane
Crop period (Days)		184	90	120	110	135	135	120	335
Sowing dates (day-month)		1 st-May	2nd-Aug	1st-June	1st –July	1st-Nov	1st-Nov	15th-Nov	1st-March
Maximum yield (y_m) (100 kg ha^{-1})		15	10	50	15	12	10	30	760
Existing cropping pattern (ha)		2530.00	18057.00	12100.00	1100.00	36663.00	2200.00	41800.00	4419.00
Economic returns (ECR_c, Rs/ 100 kg)		345	419	109	367	367	419	124	26
Maximum allowable deficit level (p_m)		.65	.60	.20	.50	.45	.45	.45	.65
Growth stages (days)	I	30	15	20	20	25	30	25	30
	II	50	30	30	30	35	35	30	60
	III	60	30	40	40	45	45	40	180
	IV	24	15	30	20	30	25	25	95

(Mukherjee , 2013; Garg and Dadhich, 2014)

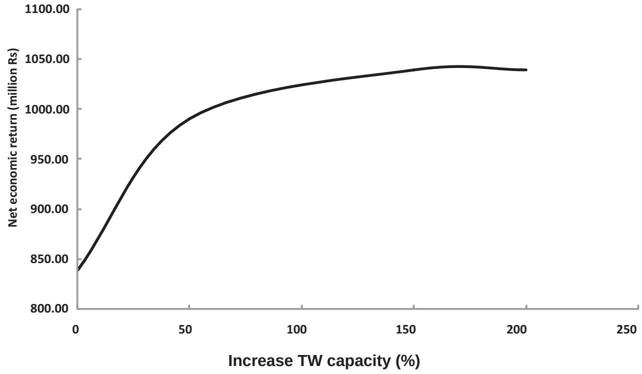


(a) Additive approach

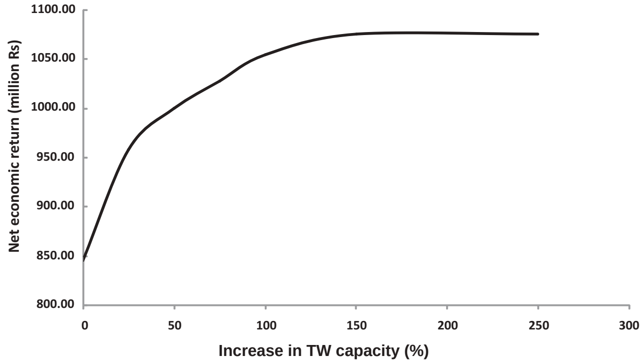


(b) Multiplicative approach

Fig. 3. Optimal water resources releases under deficit irrigation for Khairpur West canal command



(a) Additive approach



(b) Multiplicative approach

Fig. 4. The effect of increase in tube well capacities on optimal benefits under deficit irrigation for Khairpur West canal command

the annual ground water withdrawals and the corresponding optimal cropping patterns along with increase in the optimal economic returns were obtained. The effect of increasing the tube well capacities on the benefits is shown in Figs 4 (a-b).The result show a maximum increase of 23.8% and 27.1% in benefits under both the approaches (additive and multiplicative) respectively corresponding to a maximum increase in the tube well capacity by 150% under deficit irrigation.

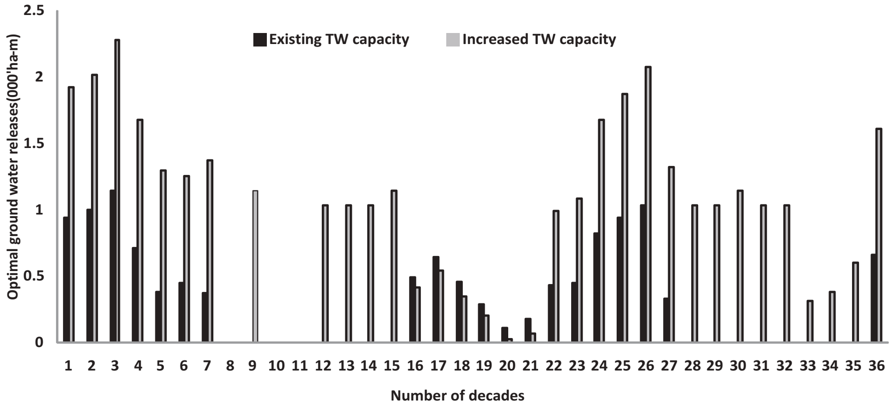
The new optimal deficit levels (p_{SC}) and soil water stress coefficients (k_s) for different crops under increased tube well capacity indicates that primarily most of the crops have shifted from deficit irrigation to full irrigation as the tube well capacity is increased in order to yield new optimal cropping pattern to maximize the return for both the approaches (additive and multiplicative).

There is a substantial increase in optimal ground water withdrawals in more or less all the decades under maximum increased tube well capacity for the new optimal cropping pattern as compared to the existing tube well capacity for additive and multiplicative approaches.

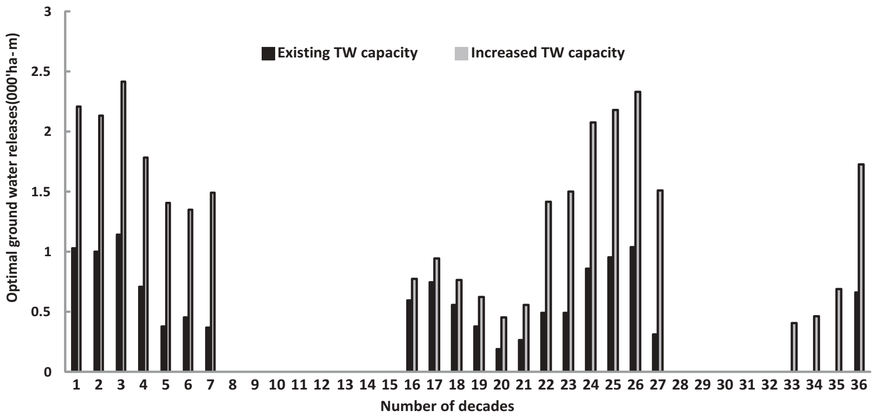
From the present study it is evident that net economic return and total cropped area are increased for both approaches (additive and multiplicative) as compared to existing ones. Further, cropped areas and economic return are more enhanced by increasing tube well capacities in the canal command area. Furthermore, Deficit irrigation showed a significant improvement in optimal cropping pattern, water recourses allocation and overall economic return for the command area. The proposed model under deficit irrigation is relatively general and can also be applied to other irrigation management systems.

Table 5. Optimal P_{SC} and water stress coefficients (K_s) for different crops for Khairpur West canal command

Approaches	Parameters	Cotton	Sugarcane	Wheat	Sorghum	Gram	Oilseed	Mustard	Rice
Additive	P_{sc}	0.83	0.65	0.45	0.75	0.45	0.80	0.45	0.20
	K_s	0.50	1.00	1.00	0.50	1.00	0.50	1.00	1.00
Multiplicative	P_{sc}	0.83	0.65	0.45	0.75	0.45	0.80	0.45	0.20
	K_s	0.50	1.00	1.00	0.50	1.00	0.50	1.00	1.00



a. Additive approach



b. Multiplicative approach

Fig. 5. Optimal water resources releases under deficit irrigation for Khairpur West canal command

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Received 26 March, 2016; Accepted 14 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 655-660

Manuscript Number: 2353
NAAS Rating: 4.47

Bio-efficacy of Different Herbicides for Weed Control in Direct-Seeded Rice

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Abstract: Field experiments were conducted during *Kharif* 2015 to determine the efficacy of different pre and post emergence herbicide treatment for weed management in direct seeded basmati crop. Among post emergence treatment bispyribac-sodium @ 0.03 kg ha^{-1} significantly reduced in weed biomass and weed density both at 60 days after sowing and at harvest in all weed species. Among pre emergence herbicides both at harvest and 60 days after sowing, pendimethalin 0.68 kg + Pyrazosulfuron ethyl 0.015 kg ha^{-1} produced higher reduction among weed density and biomass of all weed species, which was statistically equal with pendimethalin @0.75kg ha^{-1}, oxadiargyl 0.09 @kg ha^{-1}. The Sedges reported resistance to pendimethalin alone but when pendimethalin 38.7 CS was mixed with pyrazosulfuron and applied immediately after sowing before irrigation recorded very higher control of all the sedges presence in the experimental site. However, higher grain yield of basmati crop was obtained with the application of pendimethalin + Pyrazosulfuron ethyl herbicide (44.36 q ha^{-1}), which was statistically at par with oxadiargyl (43.76 q ha^{-1}) and pedimethalin (43.47 q ha^{-1}) but superior from butachlor (41 q ha^{-1}), pretilachlor (40.64 q ha^{-1}) and weedy check (37.73q ha^{-1}). The higher grain yield among these treatments was only due to the higher number of effective tiller and grains per panicle. Post emergence application of bispyribac also produce significantly higher grain yield and effective tillers over the non-post emergence herbicide application.

Key words: Basmati, Direct seeded rice, Weed density, Weed biomass, Yield

Rice (*Oryza sativa L.*) is the staple food for more than half of world population and most widely consumed high energy grain of human population especially in Asia and Latin America (Chauhan and Johnson, 2011). 90% of the world's total rice area and production are only in Asia. In India, rice is grown on approximately 45 million ha with the production of 104 million ton and use of groundwater also increased rice cultivation, which led to declineing the water table by 0.1 to 1.0 m yr^{-1}, resulting in the water scarcity and cost for pumping water also increased (Humpherys *et al.*, 2010; Mahajan *et al.*, 2013). Therefore, yield gains have to be achieved by using less water, labour, land, and energy. In India, rice is commonly grown by transplanting method into puddled soil and a large amount of water, labour, and energy is required. All these resources are becoming increasingly scarce and making rice production more expensive and less profitable (Bhushan *et al.*, 2007; Ehsanullah *et al.*, 2007). Therefore, interest has made in shifting from puddled transplanted method to direct seeded rice (DSR). DSR is more rapidly and easily planted, consumes less water, is less labour intensive, matures 7 to 10 days earlier, and has less methane emissions (Chauhan *et al.*, 2006, 2012; Mahajan *et al.*, 2009; Yadav *et al.*, 2010). With the introduction of DSR weeds are the serious constraint because dry tillage practices and aerobic soil conditions are conducive for the germination and growth of more weeds, which can cause higher grain yield losses from 50 to 90% (Chauhan *et al.*, 2011; Prasad, 2011; Chauhan, 2013, Kumar and Ladha, 2011; Singh *et al.*, 2006; Sanusan *et al.*, 2010). There is abundance of weed diversity in direct seeded rice fields (Tomita *et al.,* 2003; Singh *et al.,* 2008). Weeds grow very quickly in direct seeded fields compared with the transplanted flooded rice fields (Chauhan and Johnson, 2009; Kamoshita *et al.,* 2010). A weed free period of the first 25-45 DAS is required to avoid loss in yield in dry direct seeded rice (Singh *et al.,* 2012). Weeds are the major constraints to successful production of DSR and, therefore, the cultivation of DSR warrants intensive use of different herbicides for weed control (Mahajan and Chauhan, 2013).

Weeds in DSR can be controlled by various methods. Previously, hand-weeding was most common method for weed control in rice. However, due to shortage of labour, hand-weeding is not economical (Chakraborty *et al.,* 2008; Farooq *et al.,* 2011). Use of herbicides is an easy, effective and economically method for controlling different weed species in DSR (Chandra *et al.,* 1998). It has been estimated that yield loss in DSR was in the range of 17 to 24% when weeds were allowed to compete until 4 week after seeding (Chauhan and Johnson, 2011). Therefore, there is a scope to increase yield by adopting integrated weed management approaches including tillage systems, hand hoeing, and herbicides in DSR (Chauhan, 2012). In Punjab state, lot of pre-emergence herbicides namely pendimethalin, butachlor, pretilachlor, oxadiargyl and pyrazosulfuron ethyl have been recommended in the puddled transplanted rice. In direct seeded rice, identification of these herbicides for efficient weed management with wide-spectrum weed control ability is a major factor. Keeping this in view, experiment was conducted to study the bio-efficacy of different pre- and post-emergence herbicides in direct seeded rice.

MATERIAL AND METHODS

A field experiment was conducted during *Kharif* 2015 at Krishi Vigyan Kendra, Sri Muktsar Sahib (Punjab), to find out the best herbicide combination for controlling weeds in direct seeded rice. The geographical location of the experimental site has reference to 74°30'29" East longitude, 30°26'44" North latitude. The area is characterized by semi-arid type of climate with hot and dry early summers from April-June followed by hot and humid period during July-September and cold winters during December-January. The mean maximum and minimum temperatures show considerable fluctuations during different parts of the year. Summer temperature exceeds 38°C and may go up as high as 45°C with dry summer spells. The annual rainfall of the area was 430.7 mm, most of which is received during July to September. The soil was sandy loam, slightly alkaline in reaction (pH 7.75), high EC (0.930 dS m^{-1}), low in available organic carbon (0.24 %), medium in available phosphorus (17 kg ha^{-1}) and high in available potassium (720 kg ha^{-1}). The area is major rice growing pockets of Punjab and direct seeded rice is very popular in this region. In Punjab during *Kharif* 2014, the direct seeded rice/basmati was cultivated on 1,12,000 hectare. Out of this, 29,000 ha was only in Sri Muktsar sahib district, which consists the 25.9% of total area of Punjab. Due to the higher area under district the problems of aerobic weed increased in the district.

Wheat was grown as the previous *rabi* crop of 2014-15 in this experimental plot. Basmati variety Pusa 1121 was directly seeded with the help of seed-cum-fertilizer drill into the dry soil with 20 cm of row spacing on 16th of June, 2015. Irrigation was applied immediately after sowing. Crop was harvested on 29th October, 2015 and Basmati variety Pusa 1121 takes 133 days to maturity. Weed flora of the experimental plot comprised of grasses (*Echinochloa crusgalli*, *E. colona*), sedges (*Cyperus otundus*, *C. iria*) and broad leaved (*Digera arvensis*)) species.The experiment was replicated thrice time in a split plot design with two treatment as main plot and six treatments were sub plotted. Among two main plot first treatments was no post emergence herbicide application and second treatment was post emergence application of bispyribac-sodium applied at 0.03 kg ha^{-1} a.i after 25 days of sowing. However sub plot treatment comprised of pre-emergence application of pendimethalin 0.75 kg ha^{-1} a.i, Pendimethalin 0.68 kg ha^{-1} a.i. + Pyrazosulfuron ethyl 0.015 kg ha^{-1} a.i., Pretilachlor 0.47 kg ha^{-1} a.i., Oxadiargyl 0.09 kg ha^{-1} a.i., Butachlor 1.50 kg ha^{-1} a.i. and one treatment kept unweeded. Pendimethalin 0.75 kg ha^{-1} a a.i. is available as Stomp 30 EC as brand name. Pendimethalin 0.68 kg ha^{-1} a.i. + Pyrazosulfuron ethyl 0.015 kg ha^{-1} a.i. is available as Stomp extra 38.7 CS and Sathi 10 WP as brand name, respectively. However, Pretilachlor 0.47 kg ha^{-1} a.i. is available as Sofit 37.5 EC as brand name and this herbicide is recommended by Punjab Agricultural University in rice nursery raising for transplanting. Oxadiargyl 0.09 kg ha^{-1} a.i. is available as Topstar 80 WP as brand name and butachlor 1.50 kg ha^{-1} a.i. is available as Fast mix 50 EW as brand name. Pendimethalin was applied at 3 days after sowing in wet soil after irrigation and Pendimethalin + Pyrazosulfuron ethyl were applied immediately after sowing in dry soil before irrigation. However Pretilachlor, Oxadiargyl, butachlor were applied at first irrigation in standing water by mixing with stand.

The field experiment was arranged in split plot design with post emergence herbicides in main plots and pre-emergence herbicides in sub plots with three replications. The net plot size was 5 m × 2.5 m. All P, K and N were applied on soil test bases and irrigations were applied according to the requirement of the crop. Herbicides were sprayed with a knapsack sprayer with flat fan nozzles. The weed densities were counted at 60 days after sowing and before harvest. Before harvesting, the weeds within a randomly were cut, dried in an oven and total weed biomass was recorded. The data on number of effective tillers per square meter, plant height, number of grains per panicle, 1000 grain weight and grain yield were collected through field observations. Collected data were further analyzed by using appropriate statistical tools.

RESULTS AND DISCUSSION

Effect of post emergence herbicide on weeds: Weed flora of the experimental plot comprised of grasses (*Echinochloa crusgalli*, *E. colona*), sedges (*Cyperus rotundus*) and broad leaved (*Digera arvensis*) species. All the weed controlling treatments significantly reduced the weed population over the control treatment both at 60 days after sowing and at harvest (Table 1). Among post emergence treatment, 60 days after sowing, the bispyribac sodium produced significantly lower weed density (10.28 m^{-2}) as compared to no post emergence application (1.78 m^{-2}). Similar results were found among sedge, where significantly superior weed control with bispyribac herbicide (6.0 m^{-2}) application from non post emergence (2.39 m^{-2}) herbicide. However both of these post emergence treatments failed to produce any significant effect on the broad leaved weeds. The broad leaved weed shows resistance toward the application of bispyribac sodium herbicide. As we considered about combined all weed species bispyribac-sodium @ 0.03 kg ha^{-1} produce significantly reducing weed density (17.28 m^{-2}) over the non post emergence herbicide application (4.22 m^{-2}) at 60 days after sowing (Table 1).

At harvest the weed density results were similar as at 60 days after sowing (Table 1). Bispyribac-sodium @ 0.03 kg ha^{-1} produce significantly superior weed management (16.72 m^{-2}) over the non post emergence herbicide application (4.44 m^{-2}). However, the dry matter content also reduced significantly with bispyribac-sodium @ 0.03 kg ha^{-1} produce (20.13 g m^{-2}) over the non post emergence herbicide application (6.17g m^{-2}). Results indicated that sequential application of post emergence herbicides were equally more effective in controlling grasses and sedges coupled with lower dry weight of weeds. The efficiency of bispyribac sodium as a post emergence herbicide for direct seeded is also reported by (Mahajan *et al.*, 2009; Khaliq *et al*., 2011a; Mubeen *et al*., 2014).

Effect of pre-emergence herbicide on weeds: At 60 days after sowing, pendimethalin 0.68 kg + Pyrazosulfuron ethyl 0.015 kg/ha produced higher reduction (1.17 m^{-2}) among grasses, which was statistically at par with pendimethalin @0.75kg ha^{-1} (3.50 m^{-2}), oxadiargyl 0.09 @kg ha^{-1} (2.83 m^{-2}) and significant superior weed control over the Butachlor 1.50 @kg ha^{-1} (5.50 m^{-2}), Pretilachlor 0.47 @ kg ha^{-1} (5.83 m^{-2}) and unweeded treatment (17.33 m^{-2}). Similarly among sedge, lesser weed population was recorded with Pendimethalin + Pyrazosulfuron herbicide which was statistically at par with oxadiargyl but significant superior over the pendimethalin alone, Butachlor, Pretilachlor and unweeded treatment (Table 1). Sedges reported resistance to pendimethalin alone but when pendimethalin 38.7 CS was mix with pyrazosulfuron and applied immediately after sowing before irrigation recorded very high control of all the sedges presence in the experimental site. On broad leaved weeds, all the herbicides had superior reduction on weed population (Table 1). As we considered about all weed species combined at 60 days after sowing and at harvest lesser weed population was recorded with Pendimethalin + Pyrazosulfuron herbicide, which was statistically at par with oxadiargyl but superior over the pendimethalin alone, Butachlor, Pretilachlor and unweeded treatment. Higher weed reduction in Pendimethalin + Pyrazosulfuron over Pendimethalin alone was only due to its better control over sedges.

However, the reduction in dry matter content was recorded with Pendimethalin + Pyrazosulfuron herbicide (4.97 g m^{-2}), which was statistically at par with oxadiargyl (7.62 g m^{-2}) but significant superior over the pendimethalin (10.82 g m^{-2}), Butachlor (14.30 g m^{-2}), Pretilachlor (13.37 g m^{-2}) and unweeded treatment (29.42 g m^{-2}). The findings of present study corroborate the previous findings of Hussain *et al.* (2008), Jaya Suria *et al.* (2011), Khaliq *et al*. (2011a,b).

Interaction effect of Pre and post emergence herbicides: At 60 days after sowing, all the pre-emergence herbicide followed by bispyribac as post emergence recorded significantly reduction in weed population over the unweeded treatment (Table 2). Whereas, weed density at pendimethalin

Table 1. Effect of different pre and post emergence herbicides on weed density (numbers m^{-2})

	Weed density at 60 DAS (no. m^{-2})				Weed density at harvest	Weed dry matter at harvest
	Grasses	Sedge	Broad leaved	All weed density		
Post emergence herbicide						
No post emergence	10.28	6.00	1.22	17.28	16.72	20.13
bispyribac-sodium @ 0.03 kg ha^{-1}	1.78	2.39	0.17	4.22	4.44	6.77
CD (p=0.05)	3.39	1.87	NS	3.76	4.71	4.30
Pre-emergence herbicide						
Pendimethalin @0.75 kg ha^{-1}	3.50	6.17	0.50	10.00	9.00	10.82
Pendimethalin 0.68 kg + Pyrazosulfuron ethyl 0.015 kg ha^{-1}	1.17	1.00	0.17	2.17	3.50	4.97
Pretilachlor 0.47 @kg ha^{-1}	5.83	3.67	0.17	9.70	10.33	13.37
Oxadiargyl 0.09 @kg ha^{-1}	2.83	2.33	0.17	5.17	4.83	7.62
Butachlor 1.50 @kg ha^{-1}	5.50	3.83	0.17	9.83	10.50	14.30
Unweeded	17.33	8.17	2.67	27.67	25.33	29.42
CD (p=0.05)	4.28	2.40	1.22	4.75	4.37	4.94
Interaction CD (Pre x Post)	6.05	NS	NS	6.71	6.18	6.99

+ pyrazosulfuron herbicide treatment alone (no post emergence) was also recorded statistically at par reduction among weed population. Similar results of weed population were obtained at harvest (Table 3). However, as we consider about weed dry matter content, which was also obtained superior with Pendimethalin + pyrazosulfuron herbicide alone as pre-emergence and all pre-emergence herbicide followed by bispyribac as post emergence (Table 4).

Pendimethalin + pyrazosulfuron ethyl were applied immediately after sowing in dry soil before irrigation and recorded at par effectiveness over all species of weed with all the pre-emergence herbicide followed by bispyribac as post emergence.

Effect of pre and post emergence on yield and yield parameters: All the pre and post emergence herbicide treatments failed to produce any significant effect on the plant height and 100- grain weight of the basmati crop (Table 5). The number of effective tillers/ m^2 varied significantly among different weed control treatments (Table 5). Among post emergence treatments, bispyribac sodium produced significantly higher number of effective tiller (348.56 m^{-2}) from the non application of post emergence herbicide application (311.33 m^{-2}). Among different pre-emergence herbicide applications pendimethalin + Pyrazosulfuron ethyl (353.17 m^{-2}) produced significantly greater. Statistically equal number of tillers per unit area were recorded for oxadiargyl (345 m^{-2}) and pedimethalin (339.67 m^{-2} but significantly differ from butachlor (323.83), pretilachlor (319.83) and weedy check (298.17). Higher number of effective tiller in these treatments was due to lesser weed competition during growth period. Whereas, different post emergence treatments failed to produce any significant effect on the number of grains per panicle (Table 5). All the pre-emergence herbicides resulted in significantly higher number of grains per panicle from the unweeded check treatment.

However as we considered about the grain yield of the basmati crop, bispyribac sodium produced significantly higher grain yield (43.91 q ha^{-1}) from the non application of post emergence herbicide application (39.74 q ha^{-1}). Among different pre-emergence herbicides, higher grain yield was obtained with the application of pendimethalin + Pyrazosulfuron ethyl herbicide (44.36 q ha^{-1}) and which was statistically equal with oxadiargyl (43.76 q ha^{-1}) and pedimethalin (43.47 q ha^{-1}) but significantly superior from butachlor (41.0 q ha^{-1}), pretilachlor (40.64 q ha^{-1}) and weedy check (37.73q ha^{-1}) of basmati crop (Table 5). Higher rice yield

Table 2. Interaction effect of different pre and post emergence herbicide of weed density at 60 DAS

Post-emergence herbicide application	Pre-emergence herbicide application						
	Pendimethalin	Pendimethalin + Pyrazosulfuron	Pretilachlor	Oxadiargyl	Butachlor	Unweeded	Mean
No spray	14.33	3.67	16.00	7.33	16.00	46.33	17.28
Bispyribac	5.67	0.67	3.33	3.00	3.67	9.00	4.22
Mean	10.00	2.17	9.67	5.17	9.83	27.67	

CD (p=0.05). Post-emergence=3.76, Pre-emergence=4.75, Pre x Post = 6.71

Table 3. Interaction effect of different pre and post emergence herbicide of weed density at harvest

Post-emergence herbicide application	Pre-emergence herbicide application						
	Pendimethalin	Pendimethalin + Pyrazosulfuron	Pretilachlor	Oxadiargyl	Butachlor	Unweeded	Mean
No spray	14.33	5.33	16.00	7.00	16.00	41.67	16.72
Bispyribac	3.67	1.67	4.67	2.67	5.00	9.00	4.44
Mean	9.00	3.50	10.33	4.83	10.50	25.33	

CD (p=0.05). Post-emergence=4.71, Pre-emergence=4.37, Pre x Post = 6.18

Table 4. Interaction effect of different pre and post emergence herbicide of weed dry matter at harvest

Post-emergence herbicide application	Pre-emergence herbicide application						
	Pendimethalin	Pendimethalin + Pyrazosulfuron	Pretilachlor	Oxadiargyl	Butachlor	Unweeded	Mean
No spray	16.33	7.72	21.27	10.13	19.50	45.77	20.13
Bispyribac	5.27	2.23	5.87	5.10	9.10	13.07	6.77
Mean	10.82	4.98	13.57	7.62	14.30	29.42	

CD (p=0.05). Post-emergence=4.30, Pre-emergence=4.94, Pre x Post = 6.99

Table 5. Effect of different pre and post emergence herbicides on yield and yield contributing characters

	Plant height (cm)	Effective tiller (no. m^{-2})	Numbers of grains panicle^{-1}	1000 grain weight (g)	Grain yield (q ha^{-1})
Post emergence herbicide					
No post emergence	110.73	311.33	63.66	24.64	39.74
bispyribac-sodium @ 0.03 kg ha^{-1}	110.94	348.56	64.53	24.91	43.91
CD (p=0.05)	NS	12.24	NS	NS	0.95
Pre-emergence herbicide					
Pendimethalin @0.75 kg ha^{-1}	111.93	339.67	65.21	25.03	43.47
Pendimethalin 0.68 kg + Pyrazosulfuron ethyl 0.015 kg ha^{-1}	110.33	353.17	66.39	24.80	44.36
Pretilachlor 0.47 @kg ha^{-1}	111.60	319.83	64.65	24.83	40.64
Oxadiargyl 0.09 @kg ha^{-1}	111.43	345.00	66.33	24.87	43.76
Butachlor 1.50 @kg ha^{-1}	111.23	323.83	63.22	24.82	41.00
Unweeded	108.5	298.17	58.78	24.31	37.73
CD (p=0.05)	NS	29.40	3.98	NS	3.15
Interaction (Post x Pre emergence herbicide)	NS	NS	NS	NS	NS

in response to efficient weed control are reported elsewhere (Mahajan *et al*., 2009; Khaliq *et al*., 2011a,b, 2012; Jaya Suria *et al*., 2011). Whereas, interaction effect of all the pre and post emergence herbicide were found to be not significant among yield and all yield parameter of basmati crop.

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Received 04 February, 2016; Accepted 11 June, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 661-664

Manuscript Number: 2354
NAAS Rating: 4.47

Consequence of Land Degradation on Yield, Income at Farm Level in the Nilgiris of Tamil Nadu: An Empirical Estimation

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***Abstract*:** Hill areas have serious problems of landslides, torrents and slips. In Nilgiris district of Tamil Nadu 110,000 hectares of land are affected by soil degradation. Objectives were to examine the nature of conservation technologies adopted by the farmers and to study the impact of crop damage on productivity, income at farm level. Sample respondents were selected using multistage purposive sampling from the five categories of watersheds very high, high, medium, low and very low, priority watersheds at the rate of 50 in each priority watershed. The samples were post stratified into marginal, small, medium and large farmers based on land holding pattern. NPV, BCR and IRR were used to study the technical feasibility and economic viability of the different conservation technologies. In tea plantation, stone wall had the highest NPV of Rs.74335. The bench terrace had the highest IRR of 34 % for carrot. The BCR, NPV and IRR for both annual and perennial crops were found to be encouraging. Agricultural damage function was used to measure the yield loss due to soil erosion. On-farm income and maintenance of soil conservation structures influenced negatively and significantly in crop damage. Constraints to farmers were the high cost of conservation technologies.

Key Words: BCR, Damage function, Income NPV, IRR, Soil conservation technologies, Yield

In India, hill areas have serious problems of landslides, torrents, slips and encroachments. About 5334 Mt (16.5 t ha^{-1}) of soil is eroded annually and 5.37 - 8.40 Mt of soil nutrients are lost through water erosion (Sharma and Verma, 2010). In Tamil Nadu, land degraded by water erosion alone is estimated at 4.92 Mha and 41 per cent of the total geographical area of the state is affected by various forms of soil erosion. The resource allocation to soil conservation programmes has increased phenomenally over various plan periods in India.

Despite launching of several programmes heavy investments on technical and engineering structures, the data on costs and benefits of various conservation technologies are limited, incomplete and insufficient. The specific objectives of present study were to examine the nature of conservation technologies adopted by the farmers in the hilly terrains, the impact of crop damage on productivity, income and cost economics at farm level and suggest policy implications to protect soil resource through institutional intervention.

MATERIAL AND METHODS

For the present study, Lower Bhavani catchment lies between 11' 15" and 11' 45" N latitudes and 77' 00" and 77' 40" E longitudes located in the district of Nilgiris was purposively chosen. Then, five priority watersheds (very high, high, medium, low and very low priority watersheds) were identified based on the implementation of compliance programmes of Government of Tamil Nadu. Then 50 sample respondents were identified for survey in each of the five categories of watersheds, at making the total sample size of 250 farmers.

Investment analysis: The conventionally employed discounted methods of analysis *viz.*, Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR) were used to study the technical feasibility and economic viability of the different conservation technologies like staggered trench, stone wall, bench terrace and waterways. The crops were prioritized based on the total cultivated area in the sample farms and five major crops namely; tea, carrot, potato, cabbage and beans were considered for financial analysis.

Agricultural damage function: The damage function links soil erosion to yield. The agricultural damage function considered loss in productivity of crop land/ crop yield, increase in cost of cultivation, reduced farm income etc. The agricultural damage was the monetary value of loss in yield of the crops due to soil erosion and improper maintenance of conservation structures at the farm level. It was computed with the yield differential between the potential yield in the conservation compliance farmers and the actual yield realised in the non-compliance farms in the study area. The following model was constructed for estimations.

AGRDMG = SOCINV, FRMSIZ, INSTSUB, OFINC, ONINC, MANTCE, ANULCRP, EROPOTEL where:

AGRDMG	-	Aggregate damage (Rs ha^{-1})
SOCINV	-	SWC investment expenditure (Rs ha^{-1})
FRMSIZ	-	Farm size (ha)
INSTSUB	-	Share of subsidy total soil conservation investment (Rs ha^{-1})
OFINC	-	Annual off-farm income (Rs $household^{-1}$)
ONINC	-	Annual net farm income (Rs ha^{-1})
MANTCE	-	Maintenances of soil conservation structures
ANULCRP	-	Area under annual crops (ha)
PRCNTRET	-	Percentage of treated area to the total farm land area
EROPOTEL	-	Erosion potential of soil (1 if High; 0 otherwise)

Garrett ranking technique: The constraints in the adoption of soil conservation technologies were analyzed based on Garret's scoring technique. Garrett ranking was applied to rank a set of factors as perceived by the sample respondents based on certain criteria. The order of merit assigned by the respondents was transmuted into scores using the formula given by Garrett and Woodworth (1997).

$$\text{Per cent position} = \frac{100(R_{ij} - 0.5)}{N_j} * 100$$

Where,

R_{ij}= the rank of the i th item by j^{th} individual and

N_j=the number of items ranked by the j^{th}individual

RESULTS AND DISCUSSION

The sample farmers were post-stratified as (i) marginal (< 1 ha), (ii) small (1-2 ha), (iii) medium (2-4 ha) and (iv) large (> 4 ha) farmers based on their farm-size for further analysis. The personal characteristics of sample farmers like age, education, experience and average family size and general characteristics of the farms like size of holdings and cropping pattern were analysed through simple percentage analysis. The average farm size of marginal farmers was 0.5 ha and they constituted about 58 per cent of the sample size. Medium and large farmers were less in number and their average landholding size was 4.40 ha against the average landholding of 3.18 ha for the entire sample.

Adoption of soil conservation structures: The conservation structures in the sample farms, for perennial crops like tea, staggered trenches, stone wall and waterways were predominantly adopted, while for annual crops like vegetables, bench terrace was the commonly adopted technology by the farmers. The conservation structures adopted by the farmers showed that there had been different combinations of soil conservation technologies at the farm level. The 73 per cent farmers adopted staggered trench, about 15 per cent adopted both staggered trench and stone wall and 4.85 per cent adapted bench terrace (Table.1). Bench terrace was mostly followed by farmers growing annual crops like carrot, cabbage, beans, etc.

Cost on conservation and maintenance of soil and water conservation technologies: The staggered trench involved least cost, followed by water ways. The conservation structure commonly adopted in tea plantations was staggered, followed by stone wall. The stone wall was adopted by the farmers only to construct the water ways in their farms.

The BCR ranged from 1.03 for staggered trenches in tea plantation to 1.40 in bench terrace for carrot, indicating the economic viability of technologies. The BCR for bench terrace varied from 1.12 for beans to 1.40 for carrots. The BCR for tea plantation was more than unity for all the conservation structures, which indicates a positive impact of soil conservation technologies. The NPV of crops also reflected a significant impact of implementation of different conservation technologies (Table 4).

Among the soil conservation technologies adopted, stone wall had the highest NPV in tea plantation (Rs.74335),

Table 1. Farm level adoption of soil conservation structures in Nilgiris district

Conservation structure	Marginal farmers		Small farmers		Medium & large farmers		All farmers
	No.		No.	%	No.	%	No.
Staggered trench	136 (97.1)		77	69.37	27	34.18	240
Staggered trench + stone wall	4 (2.9)		23	20.72	23	29.11	50
Staggered trench + stone wall + water ways	-	-	4	3.60	8	10.13	12
Bench terrace	-	-	4	3.60	12	15.19	16
Staggered trench + Bench terrace	-	-	3	21.07	3	3.80	6
Staggered trench + Bench terrace + stone wall	-	-	0	0.00	5	6.33	5
Staggered trench + Bench terrace + stone wall + water ways	-	-	0	0.00	1	1.27	1
Total	140		111		79		330

Figures in parentheses indicates in per cent

Table 2. Cost on construction and maintenance of various conservation technologies (Rs.)

Conservation technology	Cost on establishment	Annual maintenance cost
Staggered trench	11,032	5,245
Stone wall	2,47,675	16,788
Waterway	1,27,891	13,654
Bench terrace	2,96,424	14,865

Table 3. Financial analysis of soil conservation technologies adopted in tea crop

Discounted measures	Conservation technology	
	Staggered trench	Stone wall
NPV	19237	74335
BCR	1.03	1.08
IRR (%)	14.99	15.58

Table 4. Financial analyses of soil conservation technology adopted in annual crops

Measure	Bench terrace		
Discounted measure	Carrot	Potato	Cabbage
NPV	57101	42008	34603
BCR	1.40	1.20	1.22
IRR (%)	34.81	32.29	28.47

followed by carrot (Rs.57101). The staggered trench had shown a lower NPV (19237) in tea plantation among all conservation structures. The bench terrace had the highest IRR (34%) for carrot, followed by potato (29%). The BCR, NPV and IRR values for both annual and perennial crops has been quite to be encouraging. The overall results on the feasibility analysis have shown that practices followed by most of the farmers had paid dividends and these technologies could be popularized to other areas for extending the benefits of the soil conservation compliance activities.

Agricultural damage function: Among problems, high cost of conservation technologies was the prime constraint hampering the adoption decisions of farmers, followed by non-availability of subsidy, high cost of credit and lack of long-lasting conservation technologies (Table 6). The poor technological support and lack of security of tenants were the less perceived problems of the hilly farmers.

Conclusions and policy implications

Among the conservation technologies staggered trench, stone wall and water way were the promising conservation methods for perennial crops like tea. Hence the government should formulate strategies and programmes to extent technical and financial interventions and promote these technologies on large, scale where ever perennial crops are grown. Tea is acting as erosion resistant crop and hence it may be advocated where ever the slope is high and the depth of the soil is very low to arrest soil erosion and protect the soil from rill and gully type of erosion. Strict regulations should be imposed in these areas to prevent farmers growing annual crops like carrot, potato etc., in slopylands which accelerate soil erosion in a big way.

Table 5. Results of the Agricultural Damage Function

Variables	Coefficients	t- Statistics
Intercept	12.83886***	16.82692
SOCINV	-0.55422**	-2.27817
FRMSIZ	-0.04403	-1.07618
INSTSUB	-0.07148*	-1.94074
OFINC	-0.03882	-1.26121
ONINC	-1.54318***	-12.1744
MANTCE	-0.19616***	-3.38582
ANULCRP	0.273196***	3.383281
PRCNTRET	-0.08067*	-1.95152
EROPOTEL	0.064047	0.984901
R Square	0.61	
Number of observation	250	

Note: P>0.01***, P>0.05**

Table 6. Constraints in adoption of soil conservation technologies in Nilgiris district

Constraints	Garret's score	Rank
High cost of conservation compliance technologies	81.62	1
Non-availability of subsidy in time	72.16	2
High cost of credit	63.65	3
Lack of long-lasting soil conservation technologies	55.12	4
Poor and unsustainable farm income	50.07	5
Low price for farm produce	45.85	6
Lack of technical support from institutions	37.04	7
Insecure land tenure	33.04	8

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Received 11 March, 2016; Accepted 24 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 665-674

Manuscript Number: 2355
NAAS Rating: 4.47

Endophytes of Finger Millet (*Eleusine coracana* Gaertn. L.)

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Abstract: Finger millet is a hardy crop capable of growing on degraded, acidic and moisture deficient soils. It is rich in methionine, calcium and iron all of which are lacking in other popular cereals. The possibility of these traits being due to the presence of endophytes was indicated by DNA sequence matches with certain bacterial oligotrophs during DNA based marker development. Investigations in the present study have revealed the presence of many putative endophytes which have similarities to those present in other crop species with properties as varied as drought or salinity tolerance, protection from pathogens, mineral uptake and growth induction. Some nitrate reducers which may be involved in nitrogen uptake has also been isolated, namely V4 and NRV (Accession no. KP 217809). A nitrogen fixing bacillus (V9) which is usually found 20 miles above sea level was isolated from the high altitude finger millet variety VL 149. This is the first known report of endophytes of finger millet. Identification of the role of these endophytes singly or in a consortium in the plant physiology is in progress. The possibility of transferring abiotic or biotic stress tolerance with the help of colonization with such endophytes is tantalizing and may bring in another revolution in the field of agriculture.

Key Words: Endophyte, Finger millet, JWM 1, Ribotyping, VL 149

Endophytic bacteria and fungi have been identified in a variety of plants. Various tools are used to identify these microbes for their phylogenetic classification. The most popular is the ribotyping of 16S or 18S sequences, as the case may be, because of their high information content, conservative nature, and universal distribution. Nine hypervariable regions have been identified in bacteria. These are flanked by conserved sequences. For phylogenetic studies primers are designed to bind to conserved regions and amplify variable regions. Among these the hyper variable regions V3 and V6 are the most prominent regions for bacterial diversity studies (Luna *et al*., 2007). The 18S rRNA is the eukaryotic counterpart of 16S rRNA. The small subunit 18S rRNA gene is one of the most frequently used genes in phylogenetic studies (Moran, 2008).

Endophytes have been shown to promote plant growth and yield, suppress pathogens, solubilise phosphate, contribute assimilable nitrogen to plants and also confer tolerance to abiotic stresses like drought (Sherameti *et al*., 2008). For instance, strain TR-5 of *Pantoea ananatis* isolated from maize kernels inhibits *in vitro* the growth of the pathogenic fungus *Lecanicillium aphanocladii* (Elvira-Recuenco and van Vuurde, 2000). The present study was under taken to identify putative endophytes in finger millet (*Eleusine coracana* Gaertn. L.). Once identified, these endophytes could be studied for their role in plant growth, defence, tolerance to stresses etc. and also used for changing the microbiome of other, more popular, crop species.

MATERIAL AND METHODS

Genotypes selected for study: Genotype JWM1 from Department of Plant Breeding & Genetics, Birsa Agricultural University, Ranchi, and VL149 from Vivekanand Parvatiya Krishi Anusandhan Sansthan, Almora, were selected on the basis of previous results obtained (Kumari Aradhana, 2012).

Primers used for amplification of microbial DNA: Two primer sets were used for amplification of bacterial sequences which either included the V 3 region or both V3 and V6 regions. The forward primer Fd1, 5'CAGAGTTTGATCCTGGCTCAG3' (Weisburg *et al.*, 1991) was combined with the reverse primer CD(R), 5'CTTGTGCGGGCCCCCGTCAATTC3' (Rudi *et al.*, (1997**)** and expected to yield a fragment 929 bp long inclusive of V3 region. The other primer set was 533F, 5'GTGCCAGCAGCCGCGGTAA3' and Rd (R), 5' AAGGAGGTGATCCAGCC3' (Weisburg *et al.*,1991). This was expected to yield an amplicon of 1026bp inclusive of V3 and V6 regions. Two sets of primers were used for amplification of fungal DNA (White *et al.*, 1990) (Table 1).

Surface sterilization of plant material and grinding: Surface sterilization was performed as given by Petrini and Carroll (1981). Three to four leaves were harvested from 10 day old seedlings. These were washed with absolute alcohol for 30 seconds. Thereafter, the leaves were submerged in a solution of 4% sodium hypochlorite and washed by intermittent shaking for 5 minutes. This was followed by another wash with absolute alcohol for 30 seconds. Four more washings was carried out with sterile distilled water,

Table 1. Eukaryotic 18S primers us

Primer	Sequence	Expected amplicon size
NS1 (F) NS8 (R)	5'-GTAGTCATATGCTTGTCTC-3' 5'-TCCGCAGGTTCACCTACGGA-3'	2000bp
NS3 (F) NS7 (R)	5'-GCAAGTCTGGTGCCAGCAGCC-3' 5'GAGGCAATAACAGGTCTGTGATGC3'	500bp

each for 30 seconds. The leaves were then transferred with the help of sterile forceps to an autoclaved mortar and ground with an autoclaved pestle. The water used for the last wash of the leaves was retained as control for further experiments.

Inoculation and incubation of culture media: The culture media was prepared as per the manufacturer's (HiMedia) instructions. Plates of different media viz. Luria Bertani, Nutrient Agar, McConkey Agar, Soy bean Casein digest agar and Potato dextrose were prepared. Slants of Nitrate Hi Veg Agar were also made. The plates and slants were divided into two sets for incubation at 28^{o}C and 37^{o}C, respectively. Each set was further subdivided into two sets one for VL149 and the other for JWM1. This subset had two plates/slants each. One of this was used to plate 100ìl of the last wash during the surface sterilization process. This served as the control plate. The other plate was used for the plant extract, 100ìl of which was spread on it using a sterile spreader. Similarly, the control and extract solution was stabbed in different Nitrate Hi Veg tubes and incubated at 28^{o}C and 37^{o}C.

Growth was observed after 24 and 36 hours. Some plates on which no growth was observed were incubated for longer periods. Those colonies were selected which showed growth only in extract plates. Single colony from each of the selected colonies was picked & suspended in 500ìl of distilled water. This suspension was used as inoculum for streaking in LB agar plate to obtain pure cultures and inoculation in LB broth for bacterial DNA isolation.

Bacterial DNA isolation and PCR amplification: HiPur bacterial and fungal DNA isolation kit was used as per the manufacturer's (HiMedia) instructions. The DNA quality was assessed on 1% agarose gel. A gradient PCR with annealing temperature of 45, 50 and 55^{o}C was first set with all bacterial primer combinations using DNA isolated from the microbes growing on Nitrate HiVeg Nutrient Agar. This microbe was designated as NRV (Nitrate Reductase VL149). The PCR was performed in Eppendorf S thermal cycler and the conditions were: Initial denaturation of 94^{o}C for 4 minutes, 35 cycles of Initiation: 94^{o}C for 30 sec, Annealing: 45/50/55^{o}C for 30 sec, Extension: 72^{o}C for 30 sec followed by a final extension of 2 minutes at 72^{o}C. After observing the amplification pattern another gradient PCR was set at 55^{o}C, 56^{o}C and 57^{o}C annealing temperature. Finally, 57^{o}C was used as the annealing temperature as it showed the amplification of a single band. Thereafter, all bacterial DNA was amplified in a 30ìl reaction system. The system was made up of 1x Taq Buffer A (Merck BioScience), 200 ìM of each dNTP, 0.25u Red Taq (Merck BioScience), 5pmoles each of the forward and reverse primers, 50 - 100ng of microbial DNA and sterile water to make up the volume to 30 ìl . Similarly, a gradient PCR at 50/55^{o}C was set for fungal primers. The amplification pattern was observed and annealing temperature 55^{o}C was selected on the basis of presence of amplification of correct molecular weight. The PCR product was purified with HiPurA MiniSpin DNA Clean-Up Kit as per the manufacturer's (Merck BioScience) instructions. The purified PCR product was sequenced commercially (Xceleris Genomics). The sequences obtained were subjected to BLAST with the known sequences in the NCBI database.

RESULTS AND DISCUSSION

Different culture media were used for growing the putative endophytes. It is known that endophytes are recalcitrant to growth (Thomas, 2004) and may need very specific environments. The different media used in the present study have different properties and they are briefly described. Luria Bertani (LB) agar is a non selective medium widely used for bacterial cultures mainly because it is a nutritionally rich medium. It is the medium of choice for growth of *Escherichia coli* and other related enteric species which have been shown to be endophytic by several workers (Charkowski *et al.*, 2002). Nutrient agar is a medium commonly used for the routine cultivation of non-fastidious bacteria. It consists of heat-stable digestive products of proteins (peptones) and beef extract which provide amino acids, minerals, and other nutrients used by a wide variety of bacteria for growth. Some species which grow well on this medium include *Bacillus subtilis, Candida albicans, Staphylococcus aureus.* Soybean casein digest is a general purpose medium used for the cultivation of a wide variety of microorganisms both non-fastidious and fastidious. It is not the medium of choice for anaerobes. Due to the inclusion of both tryptone and soy peptone, the medium supports growth of many fastidious organisms without the addition of serum such as *Neisseria, Listeria*, and *Brucella* etc. Potato Dextrose is a common medium made from potato infusion and dextrose used for cultivation and enumeration of yeasts and moulds, stimulating sporulation, for maintaining stock cultures of certain dermatophytes and for differentiation of typical varieties of fungus on the basis of pigment production. MacConkey agar is a selective and differential medium for cultivation of coliform organisms. Pancreatic digest of gelatin and peptones (meat and casein) provide the essential nutrients, vitamins and nitrogenous factors required for growth of microorganisms. Lactose monohydrate is the fermentable source of carbohydrate. The selective action of this medium is attributed to crystal violet and bile salts, which are inhibitory to most species of Gram-positive bacteria. Sodium chloride maintains the osmotic balance in the medium. Gram-negative bacteria usually grow well on the medium and are differentiated by their ability to ferment lactose. Lactose fermenting strains grow as red or pink and may be surrounded by a zone of acid precipitated bile. The red colour is due to production of acid from lactose, absorption of neutral red and a subsequent colour change of the dye when the pH of medium falls below 6.8. Lactose non-fermenting strains, such as *Shigella* and *Salmonella* are colourless and transparent and typically do not alter appearance of the medium. Nitrate HiVeg medium was used to identify microbes which can reduce nitrate. Potassium nitrate in the medium acts as a substrate for determining nitrate reduction by bacteria. The presence of nitrite is determined by addition of 0.5 ml colour reagent (equal proportion of sulphanilic acid alpha- napthylaminesolution). The development of red violet colour indicates nitrate reduction to nitrite. If no colour develops, it means that either nitrate is not reduced or further reduction to ammonia or nitrogen gas has taken place. This is known as Griess reaction. This medium was prepared as slants in boiling tube. This was done to provide an anaerobic environment for reduction of nitrate to nitrite as the enzyme responsible for this activity, nitrate reductase, is inhibited by oxygen. The inoculum was stabbed in the medium as described in Materials and Methods.

Many different bacteria and fungi were obtained on the different media used. These are presented in a tabular form in Table 2 and depicted in Plates 1 to 5. The putative endophytes obtained from the variety VL149 were given the prefix 'V' whereas those from the genotype JWM 1 were given the prefix 'J'. The microbe obtained on Nitrate HiVeg medium was named as NRV or NRJ for Nitrate Reductase VL149/**J**WM 1, respectively. NRV was earlier termed as V 23.

The development of red colour in two tubes inoculated with the extract from VL 149 and incubated at 28°C (Plate 6a) and 37°C (Plate 6b), and one tube inoculated with the extract from JWM 1 incubated at 28°C (Plate 6c) when subjected to Griess' reaction indicated presence of nitrate reducers. No colour development was found in the tubes where growth was absent, i.e. the tube inoculated with the extract from JWM 1 incubated at 37°C (Plate 6d) or control tubes. The culture appearance indicated that it was a pure culture. However, the fact that the isolate from JWM 1 could

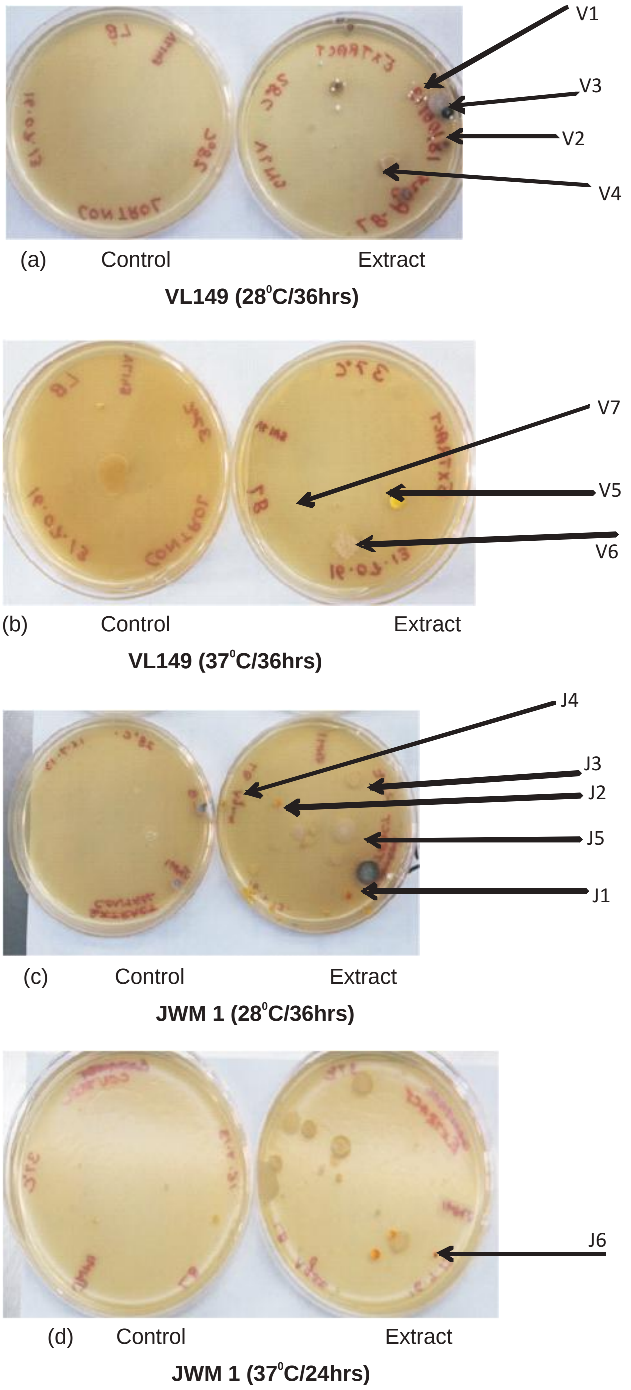


Plate 1. Microbial growth on LB medium

not grow at 37°C indicates that it may not be as robust as the isolate from VL 149 which showed better growth at this temperature.

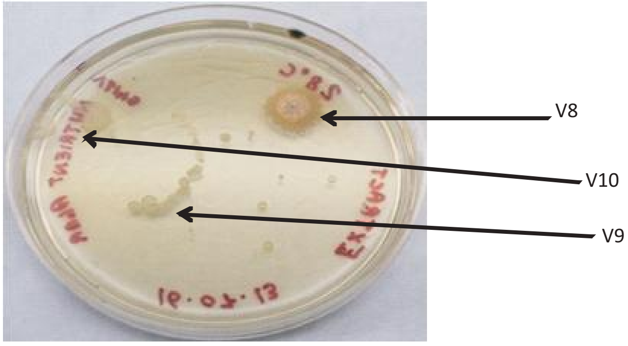
For isolation of DNA the microbes were grown in liquid culture. The microbes which appeared to be bacterial in nature were grown in LB broth with shaking at the appropriate temperature for 24 to 48 hours. The microbes which were fungal in appearance (V2, V8, V10, V18, V19 and J4) were

Table 2. List of finger millet endophytes and their characteristics

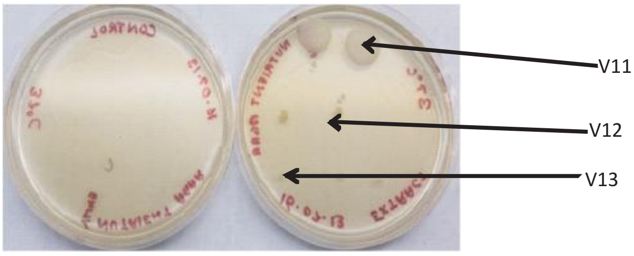
Plate	Colony	Growth condition	Colony characterization
1a	V1	LB, 28^{o}C	White deposit like colony
1a	V2	LB, 28^{o}C	Brown fungus with dark centre
1a	V3	LB, 28^{o}C	White Fungus
1a	V4	LB, 28^{o}C	Shiny large colony
1b	V5	LB, 37^{o}C	Yellow pigmented colony
1b	V6	LB, 37^{o}C	Papery fungus like growth
1b	V7	LB, 37^{o}C	Pale cream border, white inner circlewith dark centre
2a	V8	Nutrient Agar, 28^{o}C	Large fungal colony, Pale orange outer circle white inner circle, black centre
2a	V9	Nutrient Agar, 28^{o}C	Motile organism/ several colonies in rows.
2a	V10	Nutrient Agar, 28^{o}C	Ring shaped colony with hollow centre
2b	V11	Nutrient Agar, 37^{o}C	White / cream large concentric colony
2b	V12	Nutrient Agar, 37^{o}C	Pale yellow small colony
2b	V13	Nutrient Agar, 37^{o}C	Irregular colony
3a	V14	Soyabean Casein digest, 28^{o}C	Transparent shiny colony
3a	V15	Soyabean Casein digest, 28^{o}C	Pale Yellow colony
3a	V16	Soyabean Casein digest, 28^{o}C	White colony
3a	V17	Soyabean Casein digest, 28^{o}C	Black spores
3b	V18	Soyabean Casein digest, 37^{o}C	Transparent edge with transluscent centre
3b	V19	Soyabean Casein digest, 37^{o}C	White centre with radiating edges
---	V20	Potato Dextrose, 28^{o}C	White circular shiny raised colony
4a	V21	Potato Dextrose, 37^{o}C	Brown centred colony
---	V22	Mc Conkey agar, 37^{o}C	One red colony
5b	NRV	Nitrate stab culture	Cream coloured streak
1c	J1	LB, 28^{o}C	Orange raised colony
1c	J2	LB, 28^{o}C	Yellow smooth colony
1c	J3	LB, 28^{o}C	Papery irregular colony
1c	J4	LB, 28^{o}C	White fungus like
1c	J5	LB, 28^{o}C	White raised
1d	J6	LB, 37^{o}C	Dark orange/ red
4b	J7	Potato Dextrose, 28^{o}C	Smooth, shiny, sticky colony
4c	J8	Potato Dextrose, 37^{o}C	Concentric matt
3c	J9	Soyabean Casein Digest, 28^{o}C	Transparent, irregular edges
3d	J10	Soyabean Casein Digest, 37^{o}C	è shaped yellow transparent culture, irregular edges
---	J11	Nutrient Agar,28^{o}C	Pale pink colony
2**c**	J12	Nutrient Agar, 37^{o}C	Yellow colony
5c	NRJ	Nitrate stab culture, 28^{o}C	Yellow streak

inoculated in potato dextrose broth and grown similarly. Some microbes were slow growing and had to be incubated for several days. Notable amongst those were V10, V18 and V20. No growth was observed in some cases even after incubation for several days. These were V21, J8 and J9. NRV (Earlier named as V23) which was grown in LB broth showed the exudation of some particulate matter (Plate 7) which is under investigation.

The DNA amplified with the help of primers described in Materials and Methods was sent for commercial sequencing. The sequences obtained were first subjected to base pair alignment to detect mismatches. The regions which showed complete match with both the forward and reverse primers were used for performing BLAST analysis. BLAST was done for identification of the microbes by matching with the sequences in the 16S ribosomal database available on

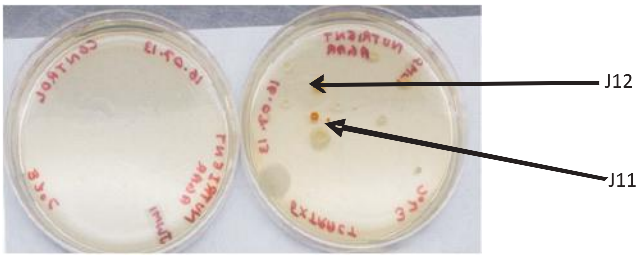


(a) Extract VL149 (28°C/48hrs)



(b) Control Extract

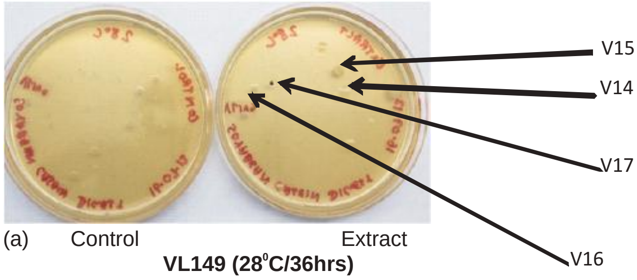
VL149 (37°C/36hrs)



(c) Control Extract

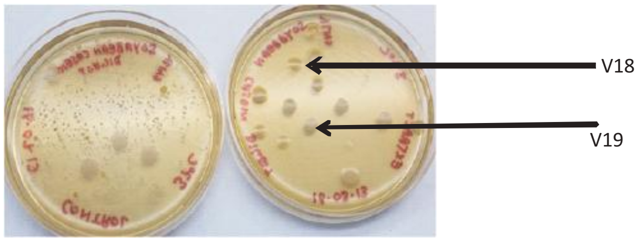
JWM1 (37°C/36hrs)

Plate 2. Microbial growth on nutrient agar



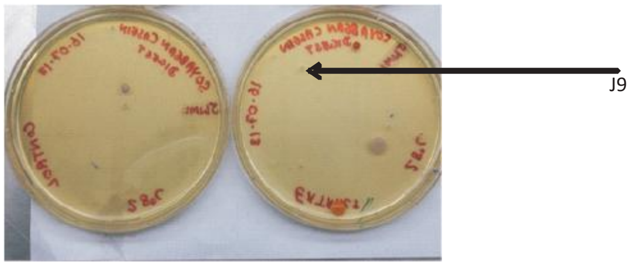
(a) Control Extract

VL149 (28°C/36hrs)



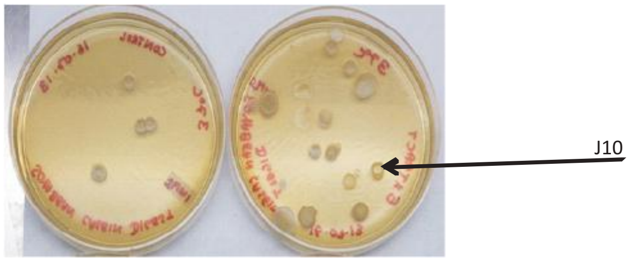
(b) Control Extract

VL149 (37°C/36hrs)



(c) Control Extract

JWM1 (24°C/24hrs)



(d) Control Extract

JWM1 (37°C/24hrs)

Plate 3. Microbial growth on soybean casein digest

NCBI. The fungal sequences were matched with the nucleotide database. The result of the BLAST analysis is presented in Table 3.

Majority of the endophytes thus identified belonged to the bacterial phyla firmicutes. These were *Bacillus kribbensis* (NRV), *Bacillus firmus* (V4), *Bacillus stratosphericus* (V9, V15, V16, J3 & J5), *Bacillus thuringiensis, Paenibacillus polymyxa* (V13), *Bacillus licheniformis* (V14), *Bacillus anthracis* (J4) and *Paenibacillus barcinonensis* (J10). Firmicutes are Gram-positive bacteria with a low G+C content (less than 50%) and they constitute one of the main phyla of bacteria. This lineage is highly diverse in their morphology (rod, coccoid, spiral), physiology (anaerobic, aerobic), lifestyle (endospore-forming, nonspore-forming) etc. (www.bacterialphylogeny.com). Currently, firmicutes encompass 3 classes, Bacilli, Clostridia, and Mollicutes, including 164 genera.

Other microbes characterised were *Escherichia fergusonii* (V1), *Achromobacter spanius* (V22), *Enterobacter cowanii* (J7) and *Salmonella bongori* (J12). They belong to the phylum proteobacteria. This is the largest and phenotypically most diverse phylogenetic lineage amongst bacteria. It consists of more than 460 genera and more than 1600 species scattered over 5 major classes (Kersters *et al.*, 2006).

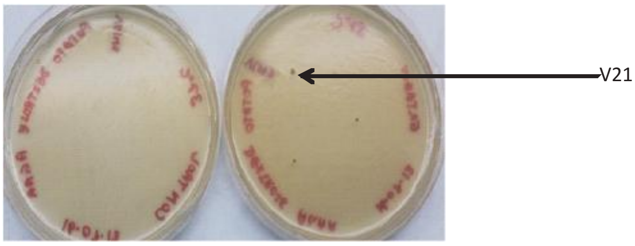
The highest 16S rRNA gene sequence similarity for NRV sequence was found with *Bacillus kribbensis* which is a Gram-positive, endospore-forming bacterium and was first isolated from a soil sample of Korea (Lim *et al.*, 2007). It was

Table 3. Details of BLAST analysis

Microbe	V3 partial region included	V6 region included	Best match	Organism to which matched
NRV	YES	YES	882/895(99%)	*Bacillus kribbensis*
V1	YES	YES	925/929(99%)	*Escherichia fergusonii*
V4	YES	YES	975/981(99%)	*Bacillus firmus*
V9	YES	YES	864/867(99%)	*Bacillus stratosphericus*
V11	YES	YES	773/777(99%)	*Bacillus thuringiensis*
V13	YES	YES	748/749(99%)	*Paenibacillus polymyxa*
V14	YES	YES (Partial)	587/594(99%)	*Bacillus licheniformis*
V15	YES	YES	734/736(99%)	*Bacillus stratosphericus*
V16	YES	YES	670/672(99%)	*Bacillus stratosphericus*
V22	YES	YES	728/730(99%)	*Achromobacter spanius*
J1	YES	YES	648/657(99%)	*Escherichia fergusonii*
J3	YES	YES	872/873(99%)	*Bacillus stratosphericus*
J4	YES	YES	594/596(99%)	*Bacillus anthracis*
J5	YES	YES	790/793(99%)	*Bacillus stratosphericus*
J7	YES	YES	940/953(99%)	*Enterobacter cowanii*
J10	YES	YES	1003/1015(99%)	*Paenibacillus barcinonensis*
J12	NO	YES (Partial)	309/316(98%)	*Salmonella bongori*
V2	-	-	808/808(100%)	*Cladophialophora bantiana*

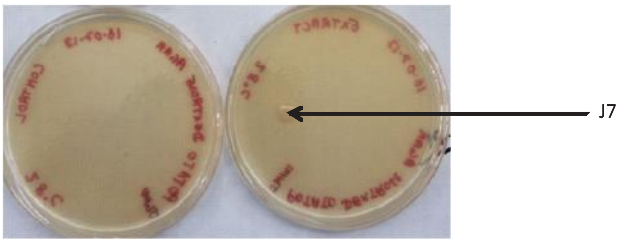
shown to be strictly aerobic, rod shaped and motile and grew well at 30-33°C and pH 5.5-6.5. Optimal growth of NRV was observed at 37°C (Plate 6b) but growth was also seen at 28°C (Plate 6a) in Nutrient HiVeg medium (pH of 6.8), which is meant especially for growth of nitrate reducers. The colour reaction for detection of nitrites (Plate 6a and b) showed it to be a nitrate reducer so it is probably involved in fixing environmentally available nitrates. It showed good growth as a stab culture which indicates that it is not a strict aerobe. Nitrate reductase activity has not been reported in *B. kribbensis*. The cloning of the 16S amplicons followed by sequencing (Eurofins) generated an almost complete sequence of NRV (Accession no. KP 217809). This showed the greatest match with an uncultured *Bacillus* sp.

V1 was a white deposit like colony (Plate 1a) while J1 (Plate 1c) showed orange pigmentation. Despite their different morphological characteristics, V1 and J1 isolates had strong sequence similarity with one common strain i.e. *Escherichia fergusonii.* The endophytic strain of *Escherichia fergusonii* in coffee tissues has been shown to promote plant growth. This strain produces phosphatase and indolacetic acid under *in vitro* conditions (Silva *et al*., 2012). The role of V1 and J1 in finger millet can only be elucidated when they are identified using the complete 16S sequence. Since they differed significantly in their morphology they cannot be the same organism or even different strains of the same organism. Complete sequence analysis of the 16S rRNA is therefore necessary before any conclusions can be drawn.



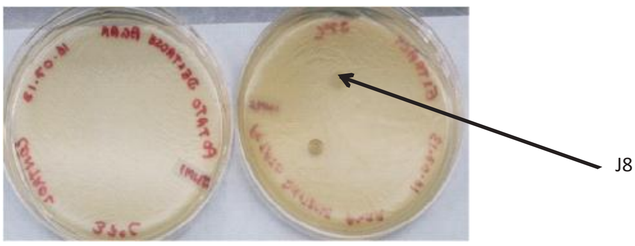
(a) Control Extract

VL149 (37°C/48hrs)



(b) Control Extract

JWM1 (28°C/36hrs)

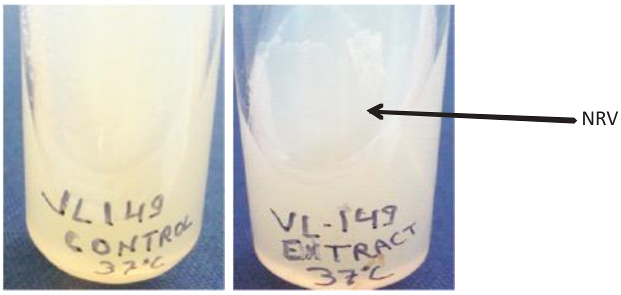


(c) Control Extract

JWM1 (37°C/48hrs)

Plate 4. Microbial growth on potato dextrose

(a) Control Extract **VL149 (28°C/24hrs)**



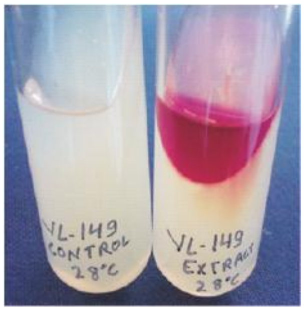
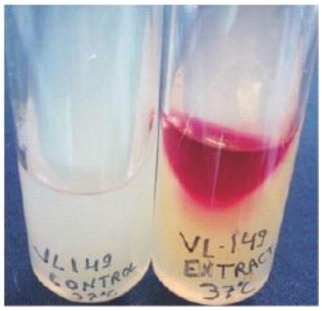
(b) Control Extract **VL149 (37°C/24hrs)**

(c) Control Extract **JWM1149 (28°C/24hrs)**

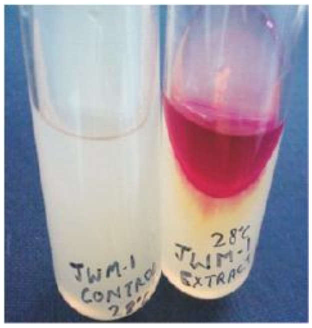
Plate 5. Microbial growth on nitrate HiVeg medium

Bacillus firmus 16S rRNA sequence was the best match for V4. This bacterium is mainly found in soil isolates. It is a facultative anaerobe and can tolerate a maximum temperature of 40-50°C. It shows positive results for reduction of nitrate to nitrite (Gordon *et al*., 1977). Nitrite production by V4 was established in the present study also by the Griess' reaction in a microfuge tube containing a suspension of V4. *Bacillus firmus* is an eco-friendly biological nematocide. Combined application of *Fusarium oxysporum* and *Bacillus firmus* was shown to be the most effective treatment in controlling the nematode, *Radopholus similis,* on banana than *B. firmus* alone (Mendoza and Sikora, 2009).

Five different isolates, namely V9, V15, V16, J3 and J5, had 99% sequence similarity with a strain of *Bacillus stratosphericus.* However, all of them differ significantly in their morphology. V9 was a cream coloured, motile organism (Plate 2a). The other four did not appear to be motile. V15 showed yellow pigmentation (Plate 3a) while V16 (Plate 3a)

(a) Control Extract **Vl149 (28°C/24hrs)** (b) Control Extract **Vl149 (37°C/24hrs)**




(a) Control Extract **JWM1 (28°C/24hrs)** (b) Control Extract **JWM1 (28°C/24hrs)**

Plate 6. Colour reaction indicating presence of nitrate reducing organisms

was a non- pigmented white colony. J3 was a papery irregular microbe (Plate 1a) and J5 was a white raised organism (Plate 1a). *B. stratosphericus* is usually found 20 miles above the earth (stratosphere). It is a motile rod-shaped, Gram positive facultative anaerobe (http://eol.org/pages/975756/overview). Amongst the 5 isolates showing sequence similarity with *Bacillus stratosphericus,* only V9 was found to exhibit motility which increases the probability it being the same organism. *B. stratosphericus* has double the electricity generating potential of other bacteria and is a particularly potent form of bacteria which can be used in a microbial fuel cell (MFC) to convert river waste into power and clean water (Zhang *et al*., 2012). It grows at temperature ranging from 8-

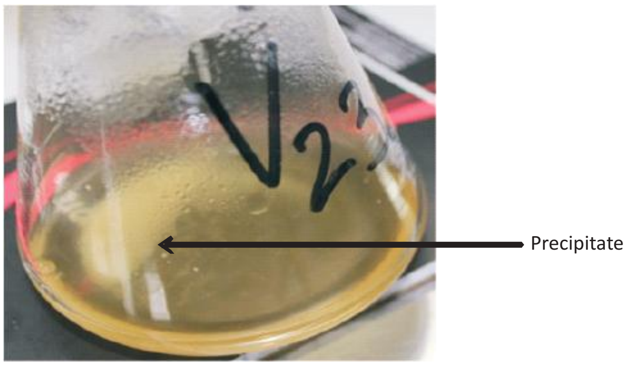


Plate 7. Particulate matter in NRV(V 23) broth culture

37°C. Different strains of *B. stratosphericus* have been shown to be halo-tolerant and positive for nitrogen fixation, IAA production and sulphur oxidation in canola plant (Siddikee *et al*., 2010).

V11 had high sequence similarity with sequences of *Bacillus thuringiensis* which is a naturally occurring bacterium common in soils. Its insecticidal property due to the production of ä-endotoxin in insect larvae gut is well known (Masson *et al*. 1992) and it has widely been used for genetic engineering of crops. If presence of such kind of organism is confirmed inside finger millet, it will be a step towards understanding the inherent hardiness of this crop.

Paenibacillus polymyxa 16S rRNA sequence was the best match for V13. *P. polymyxa* is found in soil, plant roots and marine sediments. It is used as a soil inoculant in agriculture and horticulture. Biofilms of *P. polymyxa* growing on plant roots have been shown to produce exopolysaccharides which protect the plants from pathogens in *Arabidopsis thaliana* (Timmusk *et al*., 2005). It has also been reported that a natural isolate of *P. polymyxa* induces drought tolerance in *A. thaliana* (Timmusk *et al*., 2003). Finger millet is an inherently drought tolerant crop and this trait may be because of such endophytes being harboured by the plant. However, further studies are required before anything can be concluded. It is imperative to have the complete 16S rRNA sequence of V13 for its proper identification. If V13 is indeed *P. polymyxa* then its drought tolerance attributes would have to be confirmed by introducing it into varieties of finger millet or other crop species which are drought sensitive and then analysing them for tolerance to drought.

V14 shows sequence similarity with *Bacillus licheniformis.* It is a common soil bacterium known to be able to degrade a variety of substrates by secreting different hydrolytic enzymes (Reilly, 1991). *B. licheniformis* has been used as the main source of industrial protease in detergents (Eveleigh, 1981). *It* has been shown to produce a peptide antibiotic at 50 °C which was found to be highly resistant to several proteolytic enzymes and also resistant to heat (Mendo *et al*., 2004). Unlike most bacilli, it can grow under anaerobic as well as aerobic conditions at temperatures as high as 55°C (Claus and Berkeley, 1986). V14 was isolated from soyabean casein digest incubated at 28°C (Plate 3a) while similar colonies were also present at 37°C (Plate 3c). It would be interesting to study if it can tolerate higher temperatures like *B. licheniformis*.

V22 showed 100% sequence similarity with *Achromobacter spanius* which is isolated from clinical samples whereas no such report of isolation from plants is available. It is a gram-negative, oxidase and catalase-positive, rod-shaped bacterium. V22 was isolated from MacConkey agar at 28°C where it appeared as a red colony. Growth on this medium indicates it is a Gram negative bacteria. The red colour of the colony indicates that it is a lactose fermenting strain. Further studies to first confirm if V22 is indeed an endophyte and then to elucidate the role it plays within finger millet is warranted.

J7 showed 99% sequence homology with *Enterobacter cowani* which has been earlier isolated from eucalyptus trees showing symptoms of bacterial blight. Though its presence was observed whenever bacterial blight infection took place it was found not to be the causal agent of the disease (Brady *et al*., 2009). This microbial strain has also been reported as a pathogen-causing disease in *Mabea fistulifera* (Fertudo *et al*., 2012). Thus, it appears that its presence inside a plant is either an indication of some disease or it is the causal agent of the disease itself.

J10 showed 99% sequence similarity with *Paenibacillus barcinonensis* which is a Gram positive, endospore-forming xylanase producing bacterium isolated from rice fields (Sanchez *et al*., 2005). It is a facultative anaerobe which was analysed for nitrate reduction activity (Mormeneo *et al*., 2011) and shown to be negative for the same. J12 showed 98% sequence similarity with a pathogenic bacterium *Salmonella bongori* which is a Gram negative rod shaped bacteria. *S. bongori* has earlier been isolated as an endophyte from root and stems of sweet pototo and cotton (McInroy and Kloepper,1994). Defense response was observed in *Arabidopsis* upon inoculation with *Salmonella* (Schikora *et al*., 2012).

Plate 5 c shows the growth of the nitrate reducer at 28°C (NRJ). No growth was seen at 37°C. This organism was also a nitrate reducer (Plate 6 c). The 16S ribotyping of NRJ is being done.

V2, which was a fungal isolate, was matched with nucleotide database of NCBI and it showed 100% match with *Cladophialophora bantiana*. Species of *Cladophialophora* has been recovered from different mosses like *Polytrichum juniperinum, Aulacomnium palustre*, and *Sphagnum fuscum*. On potato dextrose agar (PDA) the *Cladophialophora* species showed slow growth, attaining a diameter of 25 mm after 30 days. The growth was dark grey, velvety and cracked at the centre. V2 was isolated from the LB (Plate 1a) incubated at 28°C for 36hrs. It had a brown appearance with dark centre. The similarity in morphology indicates that V2 may be a species of *Cladophialophora.*

Thus, it appears that there is a wide plethora of endophytes present in finger millet. As far as our knowledge goes this is the first known report of presence of endophytes in this crop. Investigations regarding confirmation of identity of the microbes, detection of uncultured microbes and evaluation of the specific role of the endophytes are being carried out. Finger millet is a crop adapted to arid environments and shows ability to grow on poor soils. If it is shown that these attributes are actually because of the endophytes present it would have a great impact on future manipulations of other crop species. For example, rice which is more popular and widely accepted compared to finger millet, could be manipulated for a change in its microbiome by introduction of species of endophytes from finger millet. Before this can be achieved the role of each endophyte should be established. If change in microbiomes by introduction of specific endophytes could change the attributes of a plant species, for eg. by making a plant resistant to pathogens or by making it drought tolerant, then the concerns over genetic engineered plants could be overcome. This would be an important way of tackling food security without compromising on actual or perceived health security and potential for another revolution in the agricultural sector.

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Received 16 April, 2016; Accepted 24 August, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 675-680

Manuscript Number: 2356
NAAS Rating: 4.47

Development of *In-vitro* Propagation Protocol of *Alstroemeria Hybrida* Cv. Pluto

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Abstract: To standardize the protocol for sterilization, aseptic establishment, proliferation, and rooting from rhizome tips and rhizome section was evaluated in this study. Highest culture asepsis of (68.08 % and 61.63 %) at 4 weeks of culture was recorded in rhizome tips and rhizome sections respectively, following sterilization treatment with carbendazim 200 ppm for 30 minutes + $HgCl_2$ (0.1 %) dip for 10 minutes and final treatment with ethyl alcohol (70 %) for 1 minute. Rhizome tip explant survived sterilant treatment better than rhizome sections. MS-liquid medium supplemented with BAP + IBA: 1.5 + 0.2 mg l^{-l} proved best for culture establishment 89.42 % and 56.13 % establishment in case of rhizome tips and rhizome sections respectively. MS-solid medium fortified with activated charcoal and BAP + IBA: 1.0 + 0.2 mg l^{-1} resulted in 78.25 % establishment in rhizome tips and 40.24 % in rhizome sections. Rhizome tips cultured on MS-medium BAP + IBA + GA_3 + Activated charcoal: 2.0 + 0.4 + 0.5 + 1000 mg l^{-l} resulted in highest proliferation (88.85 %), highest number of erect shoots (5.75), number of new rhizome buds (3.75), rhizome fresh weight per shoot complex (6.05), and multiplication index (× 2.76). Highest Rooting (54.81 %) and lowest days to appearance of root (10.87), highest number of roots (3.12) and highest root length (16.42 mm) was recorded on MS-liquid medium fortified with NAA 1.5 mg l^{-1}.

Key Words: Alstroemeria, Growth regulator, Micropropagation, Rhizome tips, Rhizome sections, Tissue culture

Alstroemeria is a rhizomatous monocot belonging to family *Alstroemeriaceae*. *Alstroemeria* hybrids are among top ten cut flowers globally owing to diversity of colours, low energy cultivation and long vase life and is relatively recent introduction into the world's floriculture scene and has become a major cut flower. In India crop was introduced in 2001 by Ministry of Agriculture, GOI, under Food and Agriculture Organization programme at three Model Floriculture Centers Ooty (Tamil Nadu), Chial (Himachal Pradesh) and Srinagar (Jammu and Kashmir). The crop was introduced in SKUAST-Kashmir, Shalimar in 2005-06 under ICAR sponsored Horticulture Mini Mission-I. Legal planting material imported from foreign breeder companies is still very costly ranging from Rs. 500-600 plant^{-1}. Cultivars introduced in late nineties in India are currently out of the patent regime. However, planting material is not easily available due to constraints imposed on multiplication rate under conventional propagation method of rhizome division. This has been the single major stumbling block that has prevented *Alstroemeria* from becoming widely adopted by cut flower growers in Kashmir and Himachal Pradesh. Alstroemeria is generally propagated by rhizome division of three year old plants. However, multiplication rate is low. Propagation through seed is not commonly practiced due to variability in hybrids and long and difficult germination. Attempts have been made by few workers to multiply *Alstroemeria in vitro* through rhizome tips (Hussey *et al.*, 1979; Gabryszewska and Hempel, 1985; Lin and Monette, 1987; Chiari and Bridgen, 2000) but contamination was the major bottleneck to start cultures. *In vitro* multiplication of elite genotypes of *Alstroemeria* is widely used in commercial multiplication and offers immense opportunities to multiply more number of disease free plants in shortest possible time (Lin *et al*., 2000). *Alstroemeria* can be started with apical shoot tips but there is also a strong dominance effect suppressing the growth of axillary buds (Bond and Alderson, 1993). To promote cultivation of *Alstroemeria,* there is need to establish *in vitro* propagation protocols for the cultivars already available with research institutes and Government departments. This shall not only ensure availability of quality planting material for growers but also open up avenues for cultivar improvement through *in vitro* mutagenesis. Therefore current study involved standardization protocol for aseptic establishment of rhizome tips and subsequent multiplication and rooting.

MATERIAL AND METHODS

Standardisation of disinfection protocol for various explants in *Alstroemeria:* Explant surface sterilization is the first vital step for the initiation of cultures *in vitro.* Final steps in surface sterilization were performed under the aseptic conditions of laminar flow hood. While making incisions, flame sterilized knives and forceps were used to avoid spread of contamination between different parts of the explant.

Rhizome tips and rhizome sections: Explants were washed with running tap water to remove any adhering dust and debris and cut into manageable size pieces. Afterwards the explants were put in a Tween-20 surfactant solution (few drops) along with required quantity of fungicides and shaken for 30 minutes to ensure thorough cleaning. There after the surfactant along with the fungicides was washed off under running tap water followed by a final washing with single distilled water. The specimens were treated with mercuric chloride 0.1%, ethyl alcohol 70% and aseptic inoculation under laminar flow hood. The details of composition of different sterilant formulations and duration of application are given in Table 1. The **o**bservations recorded were on per cent asepsis and survival after 4 weeks of culture

Standardization of media and growth regulator combinations for culture establishment: In *Alstroemeria,* ***e***xplant surface sterilized with optimal concentration of sterilant were established on MS medium (solid, solid with activated charcoal and liquid) containing different concentrations of plant growth regulators (Table 2). Explants were given final 3-4 washings with sterile water before placing on the establishment medium fortified with different concentrations of BAP, IBA, NAA, Kinetin and activated charcoal. 250 ml flasks were used for conducting this experiment. The observations were recorded on per cent established cultures based on number of cultures showing elongation of shoots or sprouting of buds from rhizome section, days to rhizome sprouting, days to start of shoot elongation and rhizome initiation and number of sprouted buds.

After the establishment phase, single axillary bud rhizome tips were placed on basal MS media (solid, solid with activated charcoal) fortified with various concentrations of BAP, IBA, GA_3 and activated charcoal (Table 3)**.** Percent proliferation, number of erect shoots, number of new rhizome buds, rhizome fresh weight per shoot complex (g) and multiplication index per cycle was recorded after 6 weeks of culture. Observations recorded were per cent proliferation (based on the number of proliferating cultures), number of erect shoots/ rhizome, number of new rhizome buds formed with apical buds from cultured rhizome tips, fresh weight of rhizome/shoot complex (g) based on the weight of cluster formed along-with shoots and rhizome per explant cultured. The multiplication index was calculated on the basis of number of individual propagules realized from one explant after 6 weeks of culture.

Standardisation of rooting in *Alstroemeria:* *In vitro* raised shoots of 1 cm length and each consisted a rhizome segment with 2-3 buds per shoot were transferred on MS media (solid and liquid) containing different concentration and combination of auxins. IBA, NAA and activated charcoal (Table 3) was used to standardize rooting. The observations recorded were days to appearance of root, per cent rooting, number of roots and root length

RESULTS AND DISCUSSION

Surface sterilization of rhizome tips and rhizome sections with carbendazim 200 ppm for 30 minutes followed by mercuric chloride (0.1 %) dip for 10 minutes and ethyl alcohol 70% for 1 minute resulted in highest per cent uncontaminated cultures (68.08 per cent in case of rhizome tips and 61.63 per cent in case of rhizome sections at 4 weeks of culture respectively), which is statistically at par with asepsis attained by 5 minute mercuric chloride 0.1 % treatment followed by a 30 second 70% ethyl alcohol dip (Table 1). Rhizome tips proved to be better for starting *in vitro* cultures. Higher asepsis in rhizome tips may be attributed to

Table 1. Influence of sterilant treatments on culture asepsis (%) and survival of rhizome tip and rhizome section explants of *Alstroemeria cv*. Pluto

Sterilants		Rhizome tips		Rhizome sections	
		Asepsis*	Survival *	Asepsis*	Survival*
S_1	Mercuric chloride dip (0.1%) for 5 minutes	14.59 (16.81)	20.84 (24.06)	12.51 (15.49)	6.27 (8.24)
S_2	Mercuric chloride dip (0.1%) for 10 minutes	22.91 (28.36)	33.33 (35.18)	22.92 (25.37)	16.68 (18.12)
S_3	Ethyl alcohol (70%) dip for 30 seconds	10.43 (14.01)	4.18 (6.76)	4.18 (6.76)	4.18 (6.76)
S_4	Ethyl alcohol (70%) dip for 1 minute	31.24 (33.86)	29.16 (32.38)	27.08 (31.15)	24.99 (29.83)
S_5	Carbendazim 200 ppm for 30 minutes followed by S_1 and S_3	62.49 (52.38)	54.16 (47.43)	54.16 (47.43)	49.99 (44.99)
S_6	Carbendazim 200 ppm for 30 minutes followed by S_2 and S_4	85.41 (68.08)	85.41 (68.08)	77.08 (61.63)	74.99 (60.15)
S_7	Carbendazim 400 ppm for 30 minutes followed by S_1 and S_3	58.33 (49.83)	70.83 (57.60)	52.08 (46.19)	49.99 (44.99)
S_8	Carbendazim 400 ppm for 30 minutes followed by S_2 and S_4	70.83 (57.60)	83.33 (66.25)	72.91 (58.84)	68.74 (56.13)
CD (p=0.05)		12.62	14.31	14.86	14.87

Values in parentheses are arcsine transformed; *Data recorded at 4 weeks of culture its lesser surface area exposed as a result of single cut at the distal end of the rhizome and hence less area for entry of potential infections. At the end of four weeks of culture, 68.08 per cent rhizome tips survived under carbendazim 200 ppm for 30 minutes followed by mercuric chloride (0.1 %) dip for 10 minutes and ethyl alcohol 70 % for 1 minute (Table 1).

Rhizome tips survived better than the rhizome sections which may be due to less injured area in the former and hence lesser quantity of exudates. In this study elusion of exudates from explants was a major cause of physiological mortality *in vitro*. Data reveal the importance of ethyl alcohol in the eventual survival of the aseptic explants recorded at the end of 4 weeks of culture. Use of carbendazim followed by ethyl alcohol dip significantly improved culture survival both in rhizome sections and rhizome tips. Carbendazim decreased mortality due to fungal infections whereas ethyl alcohol may have contributed in survival by not only through sterilization but also due to mitigation of harmful effects of mercuric chloride. Ethyl alcohol being a dehydrant may have played a role in drawing out excess Hg^{2+} ions out of the explant tissues along with the exudates which may have significantly contributed to higher survival in explants under S_6 and S_8 sterilant treatment. Mohanty *et al*. (2005) advocated use of final wash in 1% hypertonic KCl solution to draw out any traces of Hg^{2+} from the explant tissue. In *Alstroemeria*, Pierik *et al*. (1988) reported use of 70 % ethyl alcohol for 2-3 seconds followed by 20 minute dip in 1.5 % NaOCl (with few drops of Tween 20). Jyothi *et al*. (2008) reported use of 1.0 % mercuric chloride for 8 minutes in ginger which is a plant with an underground rhizome similar in architecture to *Alstroemeria.* Sathyagowri and Seran (2011) also reported reasonable level of culture asepsis and survival with Carbendazim (0.3%) + Doxycycline (0.2%) for 10 minutes followed by 70% ethanol for 1 minute in ginger rhizome

Table 2. Influence of growth regulator combinations on culture establishment in *Alstroemeria hybrida cv.* Pluto

Treatment	MS + PGRs mg l^{-1}					Rhizome tips				Rhizome sections	
	BAP	IBA	NAA	Kinetin	Activated charcoal	Establishment per cent*	Days to sprouting	No. of sprouted buds*	Establishment per cent*	Days to sprouting	No. of sprouted buds*
T_1	0.4	0.02	-	-	-	35.83 (36.74)	5.32	0.87	29.91 (33.11)	5.87	0.62
T_2	0.6	0.02	-	-	-	41.66 (40.16)	8.07	1.00	35.49 (36.46)	8.12	0.75
T_3	0.8	0.02	-	-	-	86.66 (69.02)	11.52	1.00	37.49 (37.61)	11.71	0.98
T_4	1	0.02	-	-	-	86.88 (68.83)	14.56	1.21	38.91 (38.54)	14.63	1.00
T_5	1	0.2	-	-	-	88.92 (70.84)	15.06	1.97	39.74 (39.06)	14.13	1.91
T_6	1.5	0.4	-	-	-	41.35 (39.95)	15.45	0.92	29.16 (32.63)	15.76	0.75
T_7	1.5	0.6	-	-	-	38.12 (38.04)	16.23	0.82	22.91 (28.52)	16.47	0.62
T_8	2	0.2	-	-	-	41.35 (39.95)	10.23	1.00	22.16 (28.01)	11.67	0.80
T_9	2	0.4	-	-	-	33.08 (35.11)	12.13	0.93	20.33 (26.71)	12.27	0.75
T_{10}	2	0.6	-	-	-	31.00 (33.79)	12.38	0.71	18.74 (25.56)	13.23	0.62
T_{11}	2.5	0.2	-	-	-	39.58 (38.93)	14.06	0.77	20.33 (26.71)	14.25	0.72
T_{12}	2.5	0.6	-	-	-	31.00 (33.79)	14.07	0.70	16.66 (24.09)	14.31	0.62
T_{13}	-	0.2	-	0.5	-	30.00 (33.17)	12.10	0.92	16.66 (24.09)	12.87	0.87
T_{14}	-	-	0.2	1	-	30.11 (33.24)	11.03	0.87	18.74 (25.56)	11.71	0.56
T_{15}	0.5	-	0.2	-	1000	31.00 (33.79)	10.72	1.20	18.75 (22.48)	11.67	1.00
T_{16}	1	-	0.4	-	1000	29.00 (32.53)	11.03	0.91	16.66 (24.09)	11.98	0.87
T_{17}	2	-	0.4	-	1000	27.93 (31.87)	11.61	0.75	16.66 (24.09)	12.16	0.62
T_{18}	1	0.2	-	-	1000	94.55 (78.25)	11.08	2.25	41.74 (40.24)	11.91	2.05
T_{19}	1.5	0.2	-	-	1000	93.74 (77.43)	12.50	2.10	39.58 (38.93)	12.92	1.96
T_{20}	-	0.2	-	1.5	1000	39.58 (38.93)	13.13	0.93	39.58 (38.93)	13.81	0.87
T_{21}	-	0.2	-	2	1000	29.00 (32.53)	13.52	0.80	37.49 (37.73)	14.00	0.62
T_{22}	1.5	0.2	-	-	-	99.99 (89.42)	9.18	4.05	68.74 (56.13)	9.98	3.00
C.D$_{(p\leq 0.05)}$						(6.37)	(0.63)	(2.03)	(6.32)	(0.54)	(0.56)

Values in parentheses are arcsine transformed
T_1-T_{21}= Solid media
T_{22}= Liquid media only
*Data recorded at the end of 6 weeks of culture

explants with buds.

Rhizome tips proved better explants for culture establishment. This may be due to presence of an intact growing tip that is a source of auxin and hence a strong sink/growing area with better chances of continued growth and sprouting. MS- liquid media (T_{22}) proved better for culture establishment in terms of per cent establishment, days to sprouting and number of sprouted buds. MS-liquid media supplemented with BAP + IBA: 1.5 + 0.2 mg l^{-1} (T_{22}) resulted in maximum per cent establishment (89.42) along with lowest days to sprouting (9.18) and highest number of sprouted buds (4.05) while as MS-solid media supplemented with BAP + IBA + Activated charcoal: 1.0 + 0.2 +1000 mg l^{-1} (T18) resulted in maximum per cent establishment (78.25) (Table 2). In the current study dark coloured media fortified with 1000 mg l^{-1} activated charcoal was used to simulate photophobic conditions suitable for *Alstroemeria* rhizome growth in soil. Use of activated charcoal (1000 mg l^{-1}) gave comparable results with that of the liquid medium. Effect of plant growth regulator combination on culture establishment in *Alstroemeria* have been reported by several workers. Klerk and Brugge (2010) reported good establishment and subsequent growth in liquid medium where explants are placed on Filter Paper Bridge. In this study, establishment of explants on liquid medium using filter paper bridge and sterile hospital gauze gave highest success in terms of per cent establishment, sprouting and number of sprouted buds (Table 2, Fig. 1 and 2).

MS-solid medium supplemented with BAP + IBA + GA_3 + activated charcoal : 2.0 + 0.4 + 0.5 + 1000 mg l^{-1} resulted in highest proliferation in terms of per cent proliferation (88.85), number of erect shoots (5.75), number of new rhizome buds (3.75), rhizome fresh weight per shoot complex (6.05g) and multiplication index per cycle of (× 2.76) (Table 3, Fig. 3 and 4). Gabryszewska (1995) recommended use of BA for tissue multiplication in *Alstroemeria.* Podwyszynska *et al*. (1997) recorded highest number of shoots with BA 6 mg l^{-1}.

In comparison to MS-solid medium, MS-liquid medium proved better in terms of rooting. Explants placed on MS-liquid medium supplemented with NAA 1.5 mg l^{-1} resulted

BAP + IBA: 1.5 + 0.2 mg l^{-1}

Fig. 1. Establishment of rhizome tips in liquid media

BAP + IBA: 1.5 + 0.2 mg l^{-1}

Fig. 2. Sprouted buds of rhizome tips in liquid media

BAP + IBA + GA_3 + AC: 2.0 + 0.4 + 0.5 + 1000 mg l^{-1}

Fig. 3. Rhizome tip proliferation in media with activated charcoal

Table 3. Influence of growth regulator combinations on proliferation in rhizome tip explants of *Alstroemeria cv.* Pluto

Treatment	MS + PGRs mg l^{-1}				Percent proliferation	No. of erect shoots*	No. of new rhizome buds**	Rhizome fresh weight/ shoot complex (g)	Multiplication index/ cycle
	BAP	IBA	GA_3	Activated charcoal					
T_1	1	0.2	0.5	1000	99.96 (88.85)	5.00	3.50	5.77	× 2.52
T_2	1	0.2	0.5	-	85.83 (68.31)	3.25	2.00	4.75	× 1.67
T_3	1.5	0.2	0.5	1000	99.96 (88.85)	4.25	2.25	5.05	× 1.95
T_4	1.5	0.2	0.5	-	66.66 (54.81)	2.75	1.12	4.06	× 0.95
T_5	2	0.4	0.5	1000	99.96 (88.85)	5.75	3.75	6.05	× 2.76
T_6	2	0.4	0.5	-	81.66 (65.01)	3.00	1.75	4.45	× 1.50
T_7	4	0.4	1	1000	31.26 (26.66)	1.50	0.62	3.55	× 0.30
$CD_{(P \leq 0.05)}$					17.23	1.55	1.30	0.37	0.43

Values in parentheses are arcsine transformed data in per cent
*Data was recorded after 6 weeks of culture
**Data was recorded after 6 weeks of culture

Table 4. Influence of growth regulator combinations on rooting in rhizome tip explants in *Alstroemeria cv.* Pluto

Treatment	MS + PGRs mg l^{-1}						
	IBA	NAA	Activated charcoal	Rooting (%)	Days to appearance of roots	Number of roots	Root length (mm)
T_1	2	-	1000	25.00 (30.00)	15.37	1.12	12.12
T_2	0.5	-	-	25.00 (30.00)	12.87	1.25	12.31
T_3	1	-	-	27.08 (31.15)	12.75	2.00	14.65
T_4	2	-	-	25.00 (26.55)	13.12	1.87	12.75
T_5	-	1	-	37.49 (37.73)	12.62	1.37	14.90
T_6	-	1.5	-	45.83 (42.56)	12.45	2.50	15.50
T_7	-	2	-	39.58 (38.93)	13.75	2.12	14.11
T_8 (Liquid)	1	-	-	49.99 (44.99)	11.04	2.11	15.12
T_9 (Liquid)	-	1.5	-	66.66 (54.81)	10.87	3.12	16.42
T_{10} (Liquid)	-	2	-	56.24 (48.63)	12.50	2.81	15.01
CD $_{(P \leq 0.05)}$				10.49	NS	1.33	NS

Values in parentheses are arcsine transformed data in per cent

BAP + IBA + GA_3 + AC: 2.0 + 0.4 + 0.5 + 1000 mg l^{-1}

Fig. 4. Erect shoots in media with activated charcoal

NAA 1.5 mg l^{-1}

Fig. 5. Rooting in liquid media

in significantly higher per cent rooting of 54.81 % (Table 4, Fig. 5). In *Alstroemeria,* Hakkart and Versluijs (1988) recorded root formation was better on filter paper bridges in a liquid medium than on a solid medium. Pierik *et al*. (1988) reported best rooting of *Alstroemeria cv*. Toledo with NAA 0.5 mg l^{-1}. Pedraza *et al*. (2006) reported rooting of shoots was induced on MS liquid medium, either with or without plant hormones. Gabryszewska (1995) reported rooting was strongly influenced by NAA and growth retardants applied with NAA strongly stimulated root formation but suppressed their elongation. Kristiansen *et al*. (1999) reported thick root formation in the presence of NAA and not affected by sucrose treatment. Gabryszewska (1995) reported rooting success with NAA concentration ranging from 1.0 to 16.0 mg l^{-1}.

CONCLUSION

Rhizome tips taken during the vegetative growth are suitable explant for starting the culture in *Alstroemeria cv. Pluto* resulting in maximum uncontaminated growing cultures, establishment, proliferation and rooting of rhizome tip explants. Thus the present study resulted in standardizing a suitable protocol for in vitro propagation of *Alstroemeria*

ACKNOWLEDGMENTS

Authors wish to thanks 'ASPEE' foundation Mumbai for providing the financial support during the course of programme.

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Received 30 April, 2016; Accepted 12 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 681-685

Manuscript Number: 2357
NAAS Rating: 4.47

Effect of Alternating Constant Temperatures on Development of *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae) on Transgenic Bt Cotton

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Abstract: The effect of different alternating (minimum and maximum) temperatures on development of *Amrasca biguttula biguttula* was observed on Bt cotton cultivar, NCS 855 (BG II) during 2013-14 under laboratory conditions at PAU, Ludhiana. Nymphal survival, growth index and fecundity-cum-viability was significantly higher i.e. 86.67%, 8.89 and 14.67, respectively at alternating temperature (12hr: 12hr) of 26/32°C. However, nymphal survival and fecundity-cum-viability was significantly lower (55% and 9.67, respectively) at alternating temperature of 26/35°C. The nymphal period, incubation period, male longevity, female longevity and total development period was significantly higher being 12.70, 5.73, 14.67, 14.93, 33.23 days, respectively at alternating temperature of 22/32°C and was lower at 26/35°C. Sex ratio (male: female) was lower (1: 0.94) at 22/32°C and higher (1: 1.33) at 26/35°C in comparison to field collected populations (1: 1.37). Among various developmental parameters, nymphal period and female longevity had a significant negative correlation with alternating temperatures.

Key Words: *Amrasca biguttula biguttula*, Alternating constant temperatures, Adult longevity, Cotton, Growth index, Nymphal survival, Nymphal period, Sex ratio

Among the key pests of cotton, the cotton leafhopper, *Amrasca biguttula biguttula* (Ishida) (Homoptera: Cicadellidae) is an alarming pest throughout the crop growth. It remained as a serious pest of cotton during 1975 in cotton growing belts of Punjab, Haryana and Rajasthan. In north zone, with the shift in varietal pattern from insect pests susceptible medium and long duration varieties to insect pest resistant/tolerant early maturing varieties, the population of jassid declined. However, the excessive and indiscriminate use of contact insecticides viz. quinalphos and chlorpyriphos recommended for management of bollworms, caused resurgence of cotton jassid. This pest had already attained the status of a regular cotton insect pest in the Punjab probably due to over use of pesticides (Dhawan *et al.,* 2011). This pest is active during July to September with the peak activity period during mid July to end August. plants and has become one of the limiting factors in economic productivity of the crop. Climatic factors exert great influence on the development, survival and reproductive capacity of insect pests. Sudden or periodic changes in temperature adversely affect the insect development. Different levels of humidity and rainfall also reduce the population of certain insect species (Prasad and Logiswaran, 1997). The temperature is the most important factor determining distribution, survival, development, multiplication, over wintering, number of generations/year, abundance, crop-pest synchronization, dispersal, migration and behaviour of insects (Bale *et al*., 2002; Sharma, 2010; Arora and Dhawan, 2011). Insect development occurs within a specific temperature range. High temperatures can affect photosynthesis, respiration, aqueous relations and membrane stability as well as levels of plant hormones, primary and secondary metabolites. Anonymous (2011) estimates indicated that warming of about 1.25°C is expected to occur in India over the next three decades. A significant increase in the annual minimum temperature of 0.06°C per year was recorded in Punjab (Sandhu *et al.,* 2013). The population of *A. biguttula biguttula*, like other insects is goverened by their innate ability to increase, under the influence of different environmental factors. It was estimated that with every 2°C rise in temperature, multivoltine insects may have 1-5 additional generations and can cause more economic damage to the crops (Yamamura and Kiritani, 1998). Therefore, under changed climatic conditions and changing cropping pattern, there is need to study the development of *A. biguttula biguttula o*n Bt cotton. There is not much research done on effect of different constant alternating (mean minimum and maximum) temperatures on development and reproduction of cotton jassid on Bt cotton from India and Punjab. The generated information will be helpful in better understanding of the effect of particularly constant alternating lower temperature on the development of cotton jassid.

MATERIAL AND METHODS

The studies on the effect of different alternating constant temperatures on development of cotton jassid, *A. biguttula biguttula* on transgenic Bt cotton was carried out during *kharif* 2013-14 in the plant growth chamber installed at Entomological Research Farm, Punjab Agricultural University Ludhiana. Test plants were raised by sowing two or three seeds of BG II cotton cultivar, NCS 855 in earthen pots, filled with soil and farmyard manure in 1:1 ratio, at 10 days interval to get a continuous supply of required stages of plants. Various stages of *A. biguttula biguttula* i.e. nymphs and adults, collected from unsprayed cotton fields, were reared on the potted cotton plants kept in screen cages. The adults thus obtained, were used for raising culture of *A. biguttula biguttula.* The effect of different alternating constant temperatures on development of *A. biguttula biguttula* was observed in the plant growth chamber. The different set of minimum and maximum temperature conditions were maintained for 12hr: 12hr with six replications each. The relative humidity was maintained 70 ± 5 per cent throughout the experiment. Ten newly hatched nymphs of cotton jassid per treatment were transferred to glass jars (15 x 21 cm). Single layer of filter paper was placed at the base of the glass jars. The leaves of cotton plants were kept in glass jars and the mouth of jar was covered with double layer of muslin cloth and tied using rubber band. After two days, these nymphs were transferred to leaf cages fixed on leaves of 40 days old potted cotton plants at the rate of ten nymphs per leaf cage. The nymphs were transferred by cutting the portion of leaf with nymph and moving it to leaf cage with forceps. Observations were recorded in the morning (7.00 a.m.) and evening (7.00 p.m.). Growth was assessed by counting the number of nymphs that survived and become adults and by recording the time taken to reach adult stage. Growth index was calculated by using the formula given by Soo Hoo and Fraenkle (1966) as:-

Growth index = Mean nymphal survival (%) / Mean nymphal period (days)

The newly emerged adults from nymphal duration experiment were transferred to new leaf cage made on 40 days old potted cotton plants to study adult longevity of *A. biguttula biguttula.* Ten adults were released per leaf cage and adults were observed daily in morning and evening till death to calculate time period upto which the adults survived.

Forty days old potted cotton plants were selected and covered with split cage. These plants were kept free from any previous infestation by jassid by confining the culture plants to separate screen cages. Two pairs of mated adults were released per split cage. Split cages were observed every day twice (morning and evening) for presence of live adults. Once all the adults died, the split cages were removed. Daily observations were continued to calculate incubation period. Once hatching started, newly emerged nymphs were counted daily in the morning (7.00 a.m.) and evening (7.00 p.m.). After counting, these nymphs were removed with camel hair brush. The counts were continued till the termination of hatching. These counts were an indirect measure of fecundity-cum-viability of the cotton jassid.

RESULTS AND DISCUSSION

Nymphal survival, nymphal period and growth index: There was significant difference in nymphal survival at different alternating temperatures. The nymphal survival was significantly higher with a mean value of 86.67 per cent at alternating temperature of 26/32°C being at par with 70 to 90 per cent with a mean value of 78.33 per cent at temperature of 24/32°C followed by 71.67 per cent at alternating temperature of 22/32°C. However, nymphal survival was significantly lower (55.00%) at alternating temperature of 26/35°C (12 hr: 12 hr) being at par with 24/35°C and 22/35°C, respectively. It is evident from the studies that there is increase in the nymphal survival from 78.33 to 86.67 per cent with increase in the minimum temperature from 24 to 26°C. Nymphal period of *A. biguttula biguttula* was significantly higher with a mean value of 12.70 and 12.32 days at alternating temperature of 22/32°C and 22/35°C (12 hr: 12 hr), respectively being at par with each other However, nymphal period of cotton jassid was significantly lower with a mean value of 8.15 days at alternating temperature of 26/35°C (12 hr: 12 hr). It is evident from the studies that there is decrease in the nymphal period from 12.70 to 8.15 days with increase in the mean minimum and maximum temperature from 22/32°C to 26/35°C (Table 1).

Growth index of *A. biguttula biguttula* was significantly higher i.e. 8.89 at alternating temperature of 26/32°C (12 hr: 12 hr) than by 7.01 , 6.85 and 6.26 days at alternating temperature of 24/32, 26/35 and 24/35°C, respectively the latter three being at par with each other. Growth index of cotton leafhopper was found to be significantly lower i.e. 4.60 ± 0.17 and 5.64 ± 0.21 at alternating temperature of 22/35°C and 22/32°C, respectively and were at par with each other. This was followed by growth index value of 6.26 at 24/35°C. It clearly indicated that growth index increased from 5.64 to 8.89 with increase in minimum temperature from 22 to 26°C (Table 1). The combination of alternating temperature of 26/32 and 22/35°C were best and least optimum, respectively for growth of cotton jassid. Jayasimha *et al* (2012) reported that nymphal period varied from 4.50 to 9.50 days with an average of 7.28 days on okra at 25 ± 1°C. The difference in nymphal survival, nymphal period and growth index may be ascribed to variation in temperature and host species involved.

Incubation period: The incubation period differed significantly at different alternating temperatures (Table 2). It decreased with increasing temperatures andwas significantly lower i.e. 3.97 and at par with 4.30 and 4.43 days at alternating temperature of 26/35 and 26/32°C & 24/35°C than 5.73 days at 22/32 °C. The incubation period was significantly higher at alternating temperature of 22/32 and 22/35°C (12 hr: 12 hr), respectively being at par with each other .

Fecundity-cum-viability: Fecundity-cum-viability differs significantly at different alternating temperatures and was significantly higher (14.67) at 26/32°C (12 hr: 12 hr) being at par with 24/32°C followed by alternating temperature of 22/32°C and 22/35°C.Fecundity-cum-viability was significantly lower at alternating temperature of 26/35°C being at par with 24/35°C. With increase in the minimum temperature from 22 to 26°C and maximum temperature of 32°C, fecundity-cum-viability of cotton jassid also increased. The temperature 26/32°C, being at par with 24/32°C was the best optimum and 26/35°C the least optimum for fecundity -cum- viability of the pest.

Adult longevity: There was significant difference in male and female longevity at different alternating temperatures (mean minimum and maximum). Male longevity was significantly higher (14.67 days) at alternating temperature of 22/32°C (12 hr: 12 hr) and 22/35°C. It was significantly lower at 26/35°C being at par with alternating temperature of 26/32°C. There was decrease in the male longevity from 14.67 to 9.37 days with increase in the minimum temperature from 22 to 26°C (Table 2). Female longevity was significantly higher , at alternating temperature of 22/32°C (12 hr: 12 hr) 22/35°C and 24/32°C. It was significantly lower mean value of 9.63 days at alternating temperature of 26/35°C followed 26/32°C. The males are short lived as compared to females. There was decrease in the female longevity from 14.93 to 9.63 days with increase in the minimum temperature from 22 to 26°C. Our findings are in close proximity with Singh *et al* (2014). They reported that longevity of male and female of *A. biguttula biguttula* was 13.35 and 14.50 days, respectively on Bt cotton at 25-30°C and 70-80 per cent RH. Shivanna *et al.* (2009) also reported that male longevity of jassid was 15.90 days, while for female it was 16.38 days on cotton. Sutaria *et al.* (2010) recorded male and female longevity of 9.52 and 11.40 days. , The difference in the male and female

Table 1. Effect of alternating temperature combinations on nymphal development of *Amrasca biguttula bigutttula* on American cotton cultivar, NCS 855 (BG II) during 2014

Treatment	Mean temperature (°C)		Number of nymphs released	Number of adults developed	Nymphal survival (%)	Nymphal period (days)	Growth Index
	Minimum (Night)	Maximum (Day)					
T1	22	32	60	43	71.67 (60.00-80.00)	12.70 (11.67-13.50)	5.64
T2	24	32	60	47	78.33 (70.00-90.00)	11.25 (10.17-11.50)	7.01
T3	26	32	60	52	86.67 (80.00-	9.79 (9.28-10.83)	8.89
T4	22	35	60	34	56.67 (50.00-60.00)	12.32 (11.67-12.83)	4.60
T5	24	35	60	38	63.33 (50.00-80.00)	10.14 (9.80-11.25)	6.26
T6	26	35	60	33	55.00 (50.00-60.00)	8.15 (7.12-9.25)	6.85
CD (p=0.05)			-	-	8.92	0.89	1.12

Figures in the parenthesis denote the range; Minimum and maximum temperatures were maintained for 12hr: 12 hr (Day/night)

Table 2. Effect of alternating temperature combinations on different developmental parameters of *Amrasca biguttula*

Treatment	Incubation period (days)	Fecundity-cum- viability/ pair (number)	Adult longevity (days)		Total development period (days)
			Male	Female	
T1	5.73	11.67	14.67	14.93	33.23
T2	4.80	13.83	13.22	13.48	29.40
T3	4.30	14.67	10.15	10.37	24.34
T4	5.27	11.50	13.50	13.90	31.28
T5	4.43	10.50	12.18	12.70	27.01
T6	3.97	9.67	9.37	9.63	21.62
CD (p=0.05)	0.63	1.61	1.10	0.68	-

See table 1 for treatment details

longevity may be ascribed to differences in temperature involved and host nutrition.

Total development period: Total development period i.e. incubation period, nymphal period and adult longevity varied from 21.62 to 33.23 days at different alternating temperatures. This period was shortest (21.62 days) at alternating temperature of 26/35°C (12 hr: 12 hr) followed by 24.34 ± 0.37 days at 26/32°C. Total development period higher (33.23 days) at alternating temperature of 22/32°C (Table 2). The life cycle of *A. biguttula biguttula* under laboratory conditions ranged from 24 to 41 days on Bt cotton at 25-30°C and 70-80 per cent of relative humidity (Singh *et al* 2014). Our results also get support of the findings of Jayasimha *et al* (2012) who reported that total life cycle of *A. biguttula biguttula* was completed in 28.30 to 34.00 days, with an average of 30.31 ± 2.07 days on okra at 25..

Sex ratio: The sex ratio (male: female) of field collected population of cotton jassid was higher (1:1.37) as compared to laboratory population reared at different alternating temperatures (Table 3). Sex ratio of laboratory reared population was1: 0.94 in favour of males at alternating temperature of 22/32°C (12 hr: 12 hr) which increased to 1: 1.22 in favour of females at 24/32°C and 26/32°C. The present findings corroborate the earlier findings of Shivanna *et al* (2009) who reported the male: female sex ratio of *A. biguttula biguttula* as 1: 1.22 under laboratory condition and 1:1.08 under field conditions. Similarly, Sutaria *et al* (2010) recorded sex ratio of 1: 1.18 in soyabean jassid. Jayasimha *et al* (2012) recorded sex ratio of *A. biguttula biguttula* as 1: 1.16 at 25 ± 1°C on okra.

The correlation of various developmental parameters like incubation period, nymphal period, adult longevity and fecundity-cum-viability of *A. biguttula biguttula* and different alternating temperatures was worked out. The data presented in Table 4 revealed that all developmental parameters, showed negative correlation but nymphal period and female longevity had a significant negative correlation with alternating temperatures.

Table 3. Sex ratio of *Amrasca biguttula biguttula* at different alternating temperatures

Treatment	Sex ratio Male : Female	
	Population from nymphal developmental studies in laboratory experiment	Field collected population
T1	1: 0.94	1: 1.37
T2	1:1.22	
T3	1: 1.22	
T4	1:1.08	
T5	1: 1.29	
T6	1:1.33	

A total of 60 adults were observed to work out sex ratio Minimum and maximum temperatures were maintained for 12 hr: 12 hr (Day: Night); See table 1 for treatment details

Our results are in close proximity with the earlier findings of Ratanpara *et al* (1994) who reported that minimum temperature was negatively associated with population build-up of *A. bigutulla bigutulla*. Similarly, Selvraj *et al* (2011) recorded maximum population of *A. devastans* at temperature of 21-31°C and showed a significant and negative association with minimum temperature. The incidence of okra leafhopper, *A. biguttula biguttula* was highly correlated with minimum temperature (Srinivasan e*t al* 1988). In contrast, Sharma and Sharma (1997b) recorded negative correlation of population of nymphs of *A. biguttula biguttula* with maximum temperature and positive correlation with minimum temperature. Similarly, Dhaka and Pareek (2008) found that maximum temperature had negative significant effect on jassid population in Rajasthan. Aheer *et*

Table 4. Correlation coefficient between different developmental parameters of *Amrasca biguttula biguttula* and alternating temperatures

Treatment	Incubation period (days)	Fecundity-cum-viability/ pair (No.)	Nymphal period (days)	Adult longevity (days)	
				Male	Female
T1	5.73	11.67	12.70	14.67	14.93
T2	4.80	13.83	11.25	13.22	13.48
T3	4.30	14.67	9.79	10.15	10.37
T4	5.27	11.50	12.32	13.50	13.90
T5	4.43	10.50	10.14	12.18	12.70
T6	3.97	9.67	8.15	9.37	9.63
Correlation coefficient (r)	- 0.70	- 0.36	-0.83*	-0.80	-0.82*

* 5 per cent level of significance;Minimum and maximum temperatures were maintained for 12hr: 12 hr; Correlation was worked out for mean temperature; See table 1 for treatment details

al (2006) studied that minimum and average temperatures and relative humidity showed positive and significant correlation with jassid adult of *A. devastans.*

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Received 14 March, 2016; Accepted 23 August, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 686-691

Manuscript Number: 2358
NAAS Rating: 4.47

Physiological Influences of Pyriproxyfen on Economically Important Insect Pests

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Abstract: Pyriproxyfen is a pyridine based juvenile hormone analogue that acts on the endocrine system by inhibiting molting as insects treated with pyriproxyfen are unable to molt successfully to adult stage and inhibit reproduction of adults. This molecules shows abortive molting, larval-pupal intermediates with precocious evagination of wing disks, deformed pupae and larval adult intermediates that are unable to give rise to normal adults. It has high level of toxicity against agriculturally important pests belonging to different orders including Lepidoptera like diamondback moth, tobacco caterpillar, cotton whitefly, onion thrips, citrus psyllid, cotton leaf worm etc. and induced morphogenetic abnormalities, untanned pupae, larval-pupal intermediates and reduction in the adult longevity. Pyriproxyfen also caused failure of larvae to completely shed their old cuticles and larvae with distorted setae, females with reduced reproduction capacity, fecundity/fertility and laying unviable eggs. Given to its efficacy and safety to mammals and other non-target organisms, pyriproxyfen stands good chances of becoming effective component of IPM following its success in field trials.

Key Words: Juvenile hormone, Pyriproxyfen, Sublethal effects

Pyriproxyfen is a pyridine based juvenile hormone analogue i.e. 4-phenoxyphenyl (*RS*)-2-(2-pyridyloxy) propyl ether that was first registered in Japan in 1991 for controlling public health pests (Miyamoto *et al.,* 1993). It is a broad-spectrum insect growth regulator with insecticidal activity against agricultural, horticultural and public health insect pests and much less toxic to our ecosystem (Ishaaya and Horowitz, 1992; Ishaaya and Horowitz, 1992; Sullivan and Goh, 2008; Korrat *et al.,* 2012) and is a relatively stable compound with very low mammalian toxicity which acts on the endocrine system by inhibiting molting as insects treated with this IGR are unable to molt successfully to adult stage and inhibit reproduction of adults (Yokoyama and Miller, 1991). Pyriproxyfen inhibits juvenile hormone synthesis in corpora allata, thus simulating the activity of endogenous juvenile hormone (Baker *et al.,* 1986). It competes for juvenile hormone binding receptors in insects, mimicking the action of juvenile hormone and is a potent inhibitor of embryogenesis, metamorphosis and adult formation. It functions as an insecticide by overloading the endocrine system of the target insect ultimately affecting egg production and inhibiting growth (Zhang *et al.,* 1998). The sublethal effects of pyriproxyfen influence the physiological or behavioural responses of insects that survived prior exposure to this IGR (Desneux *et al.,* 2004). Hatakoshi *et al.* (1988) reported that pyriproxyfen has a strong translaminar activity which affects developmental stages hiding at the lower surface of the leaves.

Physiological Influences of Pyriproxyfen

Pyriproxyfen is a pyridine based juvenile hormone analogue that competes for juvenile hormone binding site receptors in insects, mimicking the action of juvenile hormone and is a potent inhibitor of embryogenesis, metamorphosis and adult formation. As a result, insects either fail to reach adulthood because they die as immature, or they mature into sterile adult females (Medina *et al.,* 2003). Thus, embryogenesis was disrupted when young eggs treated with JHAs. Application to early last instar larvae would result in the development of supernumerary instars, whereas treatment at the later stage would result in abnormal pupation, development of larval- pupal mosaics or intermediates and are unable to molt successfully to adult stage (Tunaz and Uygun, 2004).

When first instar larvae of beet armyworm, *Spodoptera exigua (Hubner)* were treated with pyriproxyfen the larval duration was extended upto 20 days as compared to 16 days in control (Moadeli *et al*., 2014). The duration of nymphal instars of corn bug, *Eurygaster integriceps* (Puton) was 30 and 28.5 days when first instar nymphs were treated with two different concentrations of pyriproxyfen i.e. 100 and 1000 ppm, while that in control was 26.5 days (Mojaver and Bandani, 2010). The time taken for pupation in males and females of obliquebanded leafroller, *Choristoneura rosaceana* (Harris) increased from 5 -6 days in control to 16 days in treated adults at 30 ppm concentration of pyriproxyfen (Sial and Brunner, 2010). When first instars of onion thrips, *Thrips tabaci* (Lindeman) were released on pyriproxyfen treated leaves, There were no significant differences in development of first instar and pupal stage, but the second instars and pre-pupal stage developed significantly slower than those in control (Liu, 2003). By increasing concentrations of pyriproxyfen, the duration of larval period till the emergence of adults of Indian meal moth, *Plodia interpunctella* (Hubner) was significantly increased, ranging from 16.23-25.68 days compared to the 13.97 days in control (Ghasemi *et al., 2010)*. The duration of the larval stage of elm leaf beetle, *Xanthogaleruca luteola (*Muller) significantly increased in the treated larvae compared with control (Valizadeh and Jalali, 2014). When first instar larvae of *S. exigua* were treated with pyriproxyfen the pupal duration was decreased to 7.2 days as compared to 7.7 days in control (Moadeli *et al*., 2014). The percentage of normal pupation of *C. rosaceana* treated at fifth instar larvae with pyriproxyfen was 13.7 per cent at 30 ppm concentration as compared to 96.9 % in untreated control and time to adult emergence significantly increased from 20 days in the control to 35 days in the pyriproxyfen treated larvae (Sial and Brunner, 2010). When pupae of *T. tabaci* and onion leaves were treated with pyriproxyfen, the pupal stage developed significantly slower than those in the control (Liu, 2003).

Application to early last instar larvae would result in the development of supernumerary instars, whereas treatment at the later stage would result in abnormal pupation and development of larval-pupal mosaics or intermediates (Tunaz and Uygun, 2004). Pyriproxyfen showed abortive molting, larval-pupal intermediates with precocious evagination of wing disks, deformed pupae and larval adult intermediates that were unable to give rise to normal adults due to its exposure to *S. litura* (Khafangi and Hegazi, 1999). Application of pyriproxyfen to the tobacco caterpillar induced molting of larvae into supernumerary larvae (Hatakoshi *et al*., 1988). Female adults of *S. litura* when treated with 0.3 ng of pyriproxyfen at one day old pupal stage showed wing abnormalities like wing twisting and deformation like thicker antennae and darker body colouration (Nomura *et al.,* 2000). The sublethal effect of pyriproxyfen on diamondback moth, *Plutella xylostella* (Linnaeus) was observed and found that pyriproxyfen induced morphogenetic abnormalities, untanned pupae, larval-pupal intermediates and reduction in the adult longevity (Alizadeh *et al*., 2012). They also observed that pyriproxyfen caused failure of diamondback moth larvae to completely shed their old cuticles and larvae with distorted setae, females with reduced reproduction capacity, fecundity/fertility and laying unviable eggs.

The juvenile hormone mimic pyriproxyfen disrupted embryogenesis when applied topically to eggs of the desert locust *Schistocerca gregaria*. Eggs treated on days 3-6 were inhibited at various stages of development, depending on dose and age. In particular, 0.001-0.01 µg blocked development of 3 and 4 days old eggs at blastokinesis. Treatment of 7 to 11 day old eggs was ineffective up to 10 µg. Insects that hatched successfully failed to display any postembryonic defects. Topical application of the mimic to females had a small ovicidal effect. The metamorphic molt was disrupted when the mimic was applied topically to 5th-instar of *S. gregaria.* Insects retained characteristics of the 5th instar and in extreme cases supernumerary 5th instars were formed. Additional defects included essentially normal adults that were malformed and could not fly. Application to 4th instar nymphs did not produce supernumerary characteristics in postecdysial insects, though a large proportion of insects showed abnormalities when they reached adult, which in some cases prevented flight. Topical application of the mimic to 5th instar affected the length of the instar (Vennard *et al*., 1998).

The major morphogenetic effects of pyriproxyfen treatment observed in *C. rosaceana* larvae include abortive molting, larval-pupal intermediates, deformed pupae, and larval-adult intermediates that were unable to give rise to normal adults (Sial and Brunner, 2010). Pyriproxyfen treated Asian citrus psyllid, *Diaphorina citri* (Kuwayama) showed abnormalities such as a wider abdomen, thicker antennae (nymphal characters), twisted wings and darker body colouration (Boina *et al.,* 2009). The adults with legs and abdomen attached to exuviae and unable to emerge completely upto 3 days and eventually died. When Pyriproxyfen was applied to last instar larvae of *G. mellonella* topically on the dorsal thorax significant decrease was observed in total hemocyte count exposed to 1, 5 and 10 ì g/ml of pyriproxyfen. Pyriproxyfen treatment caused different levels of deformations on almost all hemocyte types. Vacuolization in granulocytes, loss of pseudopod in plasmatocytes becoming round shaped, rarefaction in cytoplasm, forcing nucleus through the cell membrane were identified. Mitotic division and some cells lost their smooth cell boundary to become irregular were also determined as a result of toxic effects of pyriproxyfen (Sezer and Ozalp, 2015).

The pupal weight of Egyptian cotton leafworm, *Spodoptera littoralis* (Boisduval) treated as fourth larval instar were 0.3444, 0.3401, 0.3112 and 0.3085 g, respectively observed by Reda *et al* (2013), at the pyriproxyfen concentrations of 50, 100, 200 and 400 ppm, respectively as compared with 0.3656 g in control. The average pupal weight of the treated males and females of *C. rosaceana* with pyriproxyfen was 69.8 and 103.2 mg as compared with 56.7 and 85.0 mg in control (Sial and Brunner, 2010).

The adult emergence of *S. littoralis* moth pretreated as fourth instar with pyriproxyfen was 2 per cent (Aziza and

Abdel, 2012). The adult emergence of *S. littoralis when* fourth larval instar treated with different pyriproxyfen concentrations significantly decreased with decrease in concentrationfrom 17 to 5 per cent, respectively as compared with 90 per cent in control (Reda *et al*., 2013). Only 0-36 per cent of first, second and third instars and 25-74 percent of fourth and fifth instars of *D. citri* survived to adults following exposure to 16- 64 ì g/ml of pyriproxyfen (Boina *et al.,* 2009). At 0.3 ppm concentration of pyriproxyfen, adult emergence of *P. interpunctella* was 20 per cent as compared to 96.25 per cent in control (Ghasemi *et al.,* 2010).

When second and third instars of cotton whitefly, *Bemisia tabaci* (Gennadius) were treated with 0.04-1.00 mg/l of pyriproxyfen pupate at a level similar to that of control, but more than 90 per cent adult emergence suppressed (Ishaaya and Horowitz, 1995). Mojaver and Bandani (2010), observed the lowest adult emergence when first and fifth instar nymphs of *E. integriceps* were treated with a 1000 ppm concentration of pyriproxyfen, it was about 46 and 53 per cent as compared to 92 per cent in control. When first and fifth instar nymphs were treated with 0.01 and 1000 ppm, percentage of deformed adults were 46.78 and 83.97 per cent, respectively. When fifth instar larvae of *C. rosaceana* treated with 30 ppm concentration of pyriproxyfen the adult emergence was 6 and 5 per cent in males and females as compared with 86 per cent in control (Sial and Burner, 2010). The longevity of *S. littoralis* males and females were 8.5 and 8 days when treated with 100 ppm concentration of pyriproxyfen as compared with 7.5 and 7 days in untreated lot (Reda *et al*., 2013). The adult longevity of *S littoralis* was recorded as 14.5 days when treated with pyriproxyfen as compared to 12.3 days in control (Aziza and Abdel, 2012).

Steigenga *et al.* (2006), observed that the females of squinting bush brown, *Bicyclus anynana* (Butler) when treated with pyriproxyfen exhibited an increase in egg laying rates and fecundity started early in adult life, but it caused a reduction in longevity as compared with control. The adults of *T. tabaci* that continued feeding on treated leaves of pyriproxyfen had significantly shorter lives than those that were subsequently transferred to water treated leaves (Liu, 2003). Increasing the concentration of pyriproxyfen upto 0.3 ppm, resulted in decreased adult longevity of *P. interpunctella* upto 3.57 days as compared with 8.81 days in control (Ghasemi *et al.,* 2010). The prolongation of larval or pupal duration may be due to the persistence of JH in the hemolymph where it is only in the absence of JH that ecdyson could be activated and lead to the formation of the next stage (Kuwano *et al*., 2008). The prolongation or shortening of stage duration with IGRs, except chitin synthesis inhibitors, is due to the interference of these compounds on an endocrine source or inhibition of the release site of the prothoracico-tropic hormone (PTTH) (Schmutter 1989, Subramanyam *et al*., 1989). *In vitro* and *in vivo* studies clearly showed that pyriproxyfen remarkably caused an inhibition of the ec-dysone production thus interfering with normal development in *Tenebrio molitor* (Aribi *et al*., 2006).

Physiological Influences of Pyriproxyfen on Various Reproductive Parameters

The pre-oviposition, oviposition and post-oviposition period of *S. littoralis* moth pretreated as fourth instar with pyriproxyfen was 3.2, 5.3 and 6 days as compared to 2.3, 5.6 and 4.6 days in control (Aziza and Abdel, 2012). The pre-oviposition and post-oviposition period was increased upto 3.50 and 3 days when first instar larvae of *S. exigua* treated with pyriproxyfen as compared to 2.39 and 1.42 days in control (Moadeli *et al.,* 2014). A significant effect of pyriproxyfen on the oviposition period of 5 day old females of stable fly, *Stomoxys calcitrans* (Linneaus) was reduced at the highest pyriproxyfen dose (8 µg/fly) (Liu *et al.,* 2012). The affect of pyriproxyfen on the reproduction of *S. litura* when one day old pupae were treated with the topical application of 0.1 ng of pyriproxyfen, the total number of oviposited eggs reduced than untreated ones (Nomura *et al.,* 2000). When *S. littoralis* females treated with 50, 100, 200 and 400 ppm *concentration of* pyriproxyfen the fecundity was recorded as 678, 402, 319 and 0, respectively as compared with 850 in control (Reda *et al.,* 2013).

The fecundity of *S. littoralis* moths treated as fourth instar larvae with LC_{50} of pyriproxyfen (756.19 ppm) was 305, 307 and 390.7 eggs in three mating combinations of 'treated female x treated male', 'treated female x untreated male' and 'treated male x untreated female' as compared to 408 eggs in control (Aziza and Abdel, 2012). The average number of eggs laid per female was 210, 330 and 345 where both males and females were treated, treated male x untreated female and untreated male x treated female of *C. rosaceana* against pyriproxyfen as compared to 601 in untreated (Sial and Burner, 2010). Significantly lower number of eggs was observed at 32 and 64 ì g/ml concentration of pyriproxyfen, it was 61 and 58 per cent, respectively as compared with 95 per cent in control (Boina *et al.,* 2009). The fecundity of *P. interpunctella* was 47.8 at 0.3 ppm concentration of pyriproxyfen as compared with 294.7 eggs in control (Ghasemi *et al.,* 2010). Reproductive potential of *S. littoralis* when fourth instar larvae were treated with LC_{50} of pyriproxyfen (756.19 ppm) was significantly reduced as compared to control lot (Aziza and Abdel, 2012). Pyriproxyfen treatment caused a significant reduction in the reproductive effort in each of the two consecutive generations i.e. parent and F_1 generation of *P. xylostella* (Alizadeh *et al.,* 2012).

Topical application of 0.1 ng of pyriproxyfen to one day old pupae reduced the hatchability of oviposited eggs of *S. litura* than untreated ones (Nomura *et al.,* 2000). When fourth instar larvae *S. littoralis* were treated with LC_{50} of pyriproxyfen (756.19 ppm) the egg hatchability was 71, 73 and 94 per cent, respectively in three mating combinations of treated female x treated male, treated female x untreated male and treated male x untreated female, respectively as compared to 91.8 per cent in control (Aziza and Abdel, 2012). Similarly, when one day old egg of *E. integriceps* was treated with 0.0, 0.1, 10, and 100 ppm concentration of pyriproxyfen *the egg* hatchability was 96.90, 92.38, 98.4 and 93.21 per cent, respectively (Mojaver and Bandani, 2010). The egg hatchability of *C. rosaceana females* decreased from 78.0 per cent in control to 16.4, 22.5 and 31.7 per cent, respectively when treated with pyriproxyfen in three mating combinations i.e. treated male and treated female, treated male x untreated female and untreated male x treated female (Sial and Burner, 2010). The hatching of *T. tabaci* larvae reduced by 72.2 and 39 per cent on the leaves treated with 0.128 and 0.064 g l^{-1} of pyriproxyfen as compared to 92 per cent in control (Liu, 2003). Pyriproxyfen concentration of 64 µg/ml significantly inhibited the hatching of younger eggs of *D. citri* nearly 70 per cent as compared with control (Boina *et al.,* 2009). Treatment with relatively low concentrations 1-25mg l^{-1} of pyriproxyfen on the upper surface of cotton leaves totally suppressed egg hatchability rates of cotton whitefly females present on the lower surface (Ishaaya and Horowitz, 1995). When third instar larvae of DBM were treated with pyriproxyfen, larvae failed to pupate and caused a 90 per cent reduction in egg hatching rate (Oouchi, 2005). Pyriproxyfen successfully terminated reproductive diapause of 45 and 90 days old adult Sunn pest, *Eurygaster integriceps*. Treatment of females with pyriproxyfen (10,000 ppm) induced termination of diapause and made egg-laying activity appear. However, egg number and percent of hatchability were significantly lower than the treatment of both males as well as females with pyriproxyfen (Amiri *et al.,* 2012).

Physiological Influences of Pyriproxyfen on Ultra Structural Studies of Ovary/ovariole

Ovarian development of insects can be affected adversely by application of juvenile hormone to larva or pupa. Reproduction in insects requires juvenile hormone for ovarian development and maturation of adults. Pyriproxyfen significantly induced the vitellogenesis of the decapitated females of *S. exigua* at 1 and 10 µg/ml concentrations (Dongki *et al.,* 2004). The mechanism of inhibition of oviposition in *S. litura* due to pyriproxyfen was evaluated, in which untreated females had tiny ovaries one day before eclosion, but it increased in size by day one, whereas pyriproxyfen-treated females showed the same pattern of ovarian development upto day three (Hatakoshi, 1992). Ovarian development was also inhibited and about 40 per cent of female adults showed morphological ovarian abnormalities (Nomura *et al.,* 2000). The lethal effects of pyriproxyfen on Red imported fire ant, *Solenopsis invicta* (Buren) that the development of immature and degeneration of the reproductive organs of the queen (Banks and Lofgren, 1991). The ovarioles of the queens of red imported fire ant treated with pyriproxyfen become vacuolated, the tunica propria thickened and eggs are resorbed (Glancey *et al*., 1990). Other studies showed that sublethal doses of fenitrothion and ethion continuously increased the content of trehalose and glucose, whereas pyriproxyfen at sublethal doses reduced glucose levels in haemolymph of *Bombyx mori* (Nath, 2003; Etebari *et al*., 2007). Adult females of the ovoviviparous Argentinian cockroach, *Blaptica dubia*, were repeatedly treated with 100 ìg pyripr oxyfen in 5 ìL acetone either during the first vitellogenic cycle or during the period of gestation. Treatment during the first vitellogenic cycle (days 2–20 of adult life) did not inhibit vitellogenesis and oocyte growth, but prevented the formation of an ootheca. Treatment of adult females during the period of gestation (days 30–70) resulted in a complete degradation and resorption of the ootheca and induced another vitellogenic cycle (Alamer and Hoffmann, 2014). The effects of pyriproxyfen on ovaries development, oviposition and eggs hatching of the malaria vector, *Anopheles gambiae* were assessed. Both blood unfed and fed mosquitoes exposed to pyriproxyfen exhibited nearly complete inhibition of fecundity (70-100%) and fertility (90-100%). Observation of the ovaries of exposed females to pyriproxyfen under microscope revealed that the ovaries failed to develop even after several blood meals (Koama *et al*., 2015). Pyriproxyfen significantly reduced egg production in queens of Pharaoh ant, *Monomorium pharaonis* (L.) from week 3 onwards. Queens that were exposed to 1% pyriproxyfen stopped producing eggs at week 8. The ovaries of queens in treated colonies were smaller than those in untreated queens, and the number of ovarioles in the ovaries was significantly lower in all pyriproxyfen-treated queens. Queens treated with the highest concentrations of pyriproxyfen tended to have significantly shorter oocytes than untreated queens. Histological studies of the ovaries revealed that pyriproxyfen caused vacuolation in the ovarioles, thickening of the tunica propria, development of small eggs, and underdevelopment of nurse cells and the follicular epithelium (Tay and Lee, 2014).

CONCLUSION

Given to its efficacy, pyriproxyfen stands good chances of becoming effective component of IPM following its success in field trials. Pyriproxyfen exerted highly pronounced sublethal influences on larval, pupal duration and on adults. It also adversely influenced the morphogenesis of larvae, pupae and adults of number of insects like disruption in metamorphosis, deformed pupae, reduced in size and died, before adult emergence and also adults show reduced body size, twisted antennae and wings which prevent their normal flight and mating. Pyriproxyfen resulted in significant influence on various reproductive parameters also. Due to low mammalian toxicity and safety to non-target organisms coupled with its physiological influences against number of economically important insect-pests, pyriproxyfen can prove to be an effective tool for their management.

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Received 08 March, 2016; Accepted 03 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 692-696

Manuscript Number: 2359
NAAS Rating: 4.47

Effect of Duckweed (*Lemna minor*) Incorporated Diets on Growth Performance and Flesh Quality of Carps in Semi-Intensive Culture System

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Abstract: The study was conducted to assess the efficacy of sun dried duckweed (*Lemna minor*) in the diet of carps viz. rohu, *Labeo rohita* and common carp, *Cyprinus carpio* under semi-intensive culture system for 180 days. Five duckweed based experimental diets were prepared by incorporating *Lemna* powder @ 10, 20, 30, 40 and 50 % (D_2 to D_6) respectively by replacing basal (control) diet (D_1). Carp fingerlings were stocked in 20 m^2 outdoor cemented tanks @ 1/m^2 and were fed with different diets @ 5 % and 2% of their body weight daily for 60 and 120 days respectively. During the experimental period, the water quality parameters did not vary significantly in different treatments and remained in optimum range required for fish growth. Fish growth in terms of average final body weight, percent net weight gain, specific growth rate and protein efficiency ratio was maximum in D_2 (*Lemna* @ 10 %) for both the fish species, however it didn't differ significantly ($p<0.05$) from control. The minimum FCR in D_2 revealed efficient utilization of *Lemna* incorporated diet @ 10 % by the fish. However, flesh composition of both the species did not vary much in control and experimental diets. The overall results revealed that *Lemna* can be incorporated in carp diet @ 10 % by replacing the basal diet without compromising fish growth.

Key Words: Carps, Duckweed, Fish growth, *Lemna,* Non-conventional feed resources

Supplementary feed is one of the key inputs in fish culture for elevating production, constituting more than 60% of the input cost. Considering the ever increasing cost of these conventional feed ingredients (rice bran, oiled seed cakes, fish meal etc.) and competition with other livestock for the same, it is vital to substitute the costly conventional fish feed ingredients with some cost effective locally available equally or more nutritive non-conventional feed resources (NCFR). Among various NCFR, aquatic plants are one of the most important category due to their high nutritive value and digestibility (Dhawan *et al.,* 2004, Ansal *et al.,* 2008, Ansal and Dhawan, 2009, Dhawan and Sharma, 2008). Among aquatic plants, duckweeds has been proved to be the most promising, due to their superior nutritive value and exceptionally fast growth rate (Iqbal, 1999, Kaur *et al.,* 2012, Singh *et al.,* 2012, 2013). Duckweeds are small (1-15 cm) free floating aquatic plants with worldwide distribution. They belong to family Lamnacae and are widely available under four genera i.e. *Lemna, Spirodela, Wolffia* and *Wolfiella* having 37 species (FAO, 2009). Among these four genera, *Lemna* is the largest group and *L. minor* is found to be the most promising one (Mandal *et al.* 2010).

Growth rate of duckweeds is faster than any other higher plant and more closely resemble the exponential growth of unicellular algae. Biomass of duckweeds get doubled in 16 hrs to 2 days under ideal conditions of nutrient availability (NH_3-N = 7-12 mg/l, PO_4-P = 4-8 mg/l), temperature (15 - 30^oC), pH (6.5 to 8.0) and sunlight (Iqbal, 1999). Nutrient content in duckweeds vary according to the conditions in which these are grown (FAO, 2009). However, these have been found to have 15 - 45 % crude protein on dry matter basis depending on the culture system (Effiong *et al.,* 2009). In addition to this, duckweed has better array of essential amino acids than major plant proteins and more closely resembles animal protein. Further, its amino acid spectrum with regard to lysine (7.5 % of total protein) and methionine (2.6 % of total protein) is much higher as compared to other commonly used plant feed resources (Mishra, 2007) except soybean. Because of excellent nutritional profile of duckweeds and easy production procedure, a number of studies have been carried out to produce and exploit duckweed biomass (fresh/dried) as livestock feed including fish. Although duckweeds have been reported to induce positive growth response in various fishes like carps, snakeheads, catfishes etc. (Leng *et al.,* 1995, Saha *et al.,* 1999, Bairagi *et al.,* 2002 and Effiong *et al.,* 2009) in laboratory or field conditions, it is essential to evaluate growth response and its best utilization as fish feed ingredient in region specific conditions.

Based on the above discussion, the study was taken up for developing *Lemna* based nutritionally balanced diet for rearing carps (rohu, *Labeo rohita* and common carp, *Cyprinus carpio*) in a semi-intensive culture system.

MATERIAL AND METHODS

The experiment was carried out at College of Fisheries, Guru Angad Dev Veterinary and Animal Sciences University), Ludhiana, Punjab in 20 m^3 outdoor cemented tanks in triplicate. A 5 cm thick soil layer was spread at the bottom of each tank to hasten the decomposition process. The tube well water was used for filling and maintaining water level in the tanks during the culture period. All the tanks were manured with cow dung @ 20,000 kg ha^{-1} yr^{-1} (40 kg $tank^{-1}$ yr^{-1}). One fourth of the manure (10 kg $tank^{-1}$) was applied 15 days prior to stocking of fish and rest in equal fortnight installments (2.5 kg $tank^{-1}$).

Culture of Duckweed (*Lemna minor*) : *L. minor* stock was maintained in poly sheet (silpaulin) lined earthen pits (4 m^2) in net house. Soil layer (2 – 3 cm) was spread at the bottom of pits and manuring was done with slurry of 1 kg cow dung (CD) and 1 kg poultry droppings (PD), which was spread was over the soil layer and water was filled up to 1 m level. One kg fresh inoculum of *L. minor* was added after 1 week of manuring. Half of *Lemna* was harvested every time it covered the whole surface. Re-manuring was done with 1 kg of CD and 1 kg of PD slurry every fortnight. Harvested *Lemna* was sun dried and powdered for incorporation in different experimental diets.

Preparation of experimental diets: Five experimental diets (D_2 to D_6) were prepared with traditionally used basal diet (deoiled rice bran – 49%, deoiled mustard meal - 49 %, vitamin – mineral mixture – 1.5 % and salt – 0.5 %) and sundried *Lemna* in different combinations (Table 1). Proximate analysis (% on dry matter basis) of different feed ingredients and prepared diets was done as per AOAC (2000) methods (Table 2).

Stocking and feeding of fish: Rohu, *L. rohita* (Ham.) and common carp, *C. carpio* (Linn.) fry were stocked in outdoor tanks @ 10,000 ha^{-1} (20 fish $tank^{-1}$ viz. rohu – 10, common carp – 10). Fish were fed with different diets @ 5 % fish body weight (FBW) for the first two months followed by 2 % for the following four months. Water quality parameters (temperature, pH, dissolved oxygen, total alkalinity, total hardness, ortho-phosphate, total ammonical nitrogen, nitrite nitrogen and nitrate nitrogen) were analyzed at fortnightly intervals as per APHA (2005). Fish sampling was carried out at fortnightly intervals to record total body length and weight. Per cent net weight gain (%NWG), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) for all the treatments were calculated as per standard formulae. Flesh samples of both the fish species were collected from each treatment at the end of the experiment and flesh quality in terms of total protein (Lowery *et al.,* 1951), lipids (Folch *et al*., 1957), carbohydrates (Dubois *et al.,* 1965), moisture and ash contents were estimated.

Table 1. Per cent composition of control and experimental diets

Feed/ feed ingredients	Control	*L. minor* incorporated diets			
	D_1	D_2	D_3	D_4	D_5	D_6
Basal Diet*	100	90	80	70	60	50
Sun dried *L. minor*	-	10	20	30	40	50

***** Basal diet - de-oiled rice bran (49%), de-oiled mustard meal (49%), Vitamin mineral mixture - 1.5% and common salt - 0.5%

RESULTS AND DISCUSSION

Water quality: The water temperature (29.07-29.39^{0}C), pH (8.60-8.73), dissolved oxygen (6.97-7.49 mgl^{-1}), total alkalinity (167.08-184.62 mgl^{-1}), total hardness (174.46-200.92 mgl^{-1}), orthophosphate (0.185-0.216 mgl^{-1}), ammonical nitrogen (0.099-0.128 mgl^{-1}), nitrite nitrogen (0.101-0.115 mgl^{-1}) and nitrate nitrogen (0.134-0.159 mgl^{-1}) were well within the range in all the treatments recommended (Boyd and Tucker, 1998) for carp culture and support optimum growth of carps throughout the culture period. Further, the differences for all the water quality parameters were insignificant among treatments.

Fish survival and growth: At the termination of the experiment, 100 % survival of *L. rohita* and *C. carpio* was recorded in all the treatments and control, showing equal acceptability of *Lemna* incorporated diets. Singh *et al.* (2013) too reported 100 % survival of *Catla catla, L. rohita* and *Cirrhinus mrigala* fed with *Spirodela* incorporated diets (10-40 %). However, previous study by Kaur *et al.* (2012) revealed 80 % survival of rohu fed with *Lemna* incorporated diets formulated by replacing rice bran and mustard meal in control diet. Effiong *et al.* (2009) also reported 80 % and 73 % survival of cat fish *Heterobranchus longifilis* fingerlings at 10 % and 30 % inclusion level of *L. pauciscostata* respectively without affecting the growth of fish.

In *L. rohita***,** diet D_2 and D_1 (control) supported highest growth in rohu as compared to other diets (Table 2). At the end of the experiment, maximum per cent net weight gain (3248.67) was recorded in rohu fed with diet D_2, while it was minimum in D_4 (2266.76) and the differences among different treatments were significant. Likewise SGR and PER were maximum in D_2 (1.95, 1.96) and minimum in D_6 and D_3 (1.74, 1.72), respectively. Incorporation of *L. minor* at 10 % (D_2) also resulted in efficient utilization of feed observed in the form of minimum FCR (1.87).

In common carp, similar results were observed as diet D_2 and D_1 (control) supported the maximum growth. At the end of experiment, maximum per cent net weight gain was recorded in D_2 (3605.88) and minimum in D_3 (2528.37) and the differences were significant. Likewise SGR and PER were maximum in D_2 (2.01, 2.09) and minimum in D_3. Incorporation of *L. minor* at 10 % (D_2) resulted in efficient utilization of feed observed in the form of minimum FCR (1.75).

Highest growth performance of fish in *Lemna* based diet (D_2) can be attributed to higher nutritive value of *Lemna* in terms of crude protein, ether extract etc. particularly in comparison to rice bran. Moreover, superior essential amino acid profile of duckweed proteins (Mishra 2007) might have played a role in fish growth improvement, but at lower incorporation level. Likewise, Noor *et al* (2000) also revealed that *L. minor* can replace fish meal at the minimum incorporation level @ 10 % in the diet of silver barb, *Barbodes gonionotus* Bleeker. Further, incorporation of *Lemna* at higher rate (> 10 %) resulted in reduced fish growth, which may be due to decreased apparent protein digestibility (Hassan *et al*., 1990) of plant protein sources at higher levels. Decline in fish growth after certain inclusion level of any ingredient may also be attributed to the presence of anti-nutritional factors, which could directly or indirectly (through their metabolic products) interfere with food utilization, and hence affects health and production of animals (Fasakin *et al.,* 2001). Further, in the present study, as the ash content of diets increased with *Lemna* inclusion level from 10-50 %, the higher concentration of micro and macro nutrients may also have a depressing effect on fish growth after 10 % inclusion level.

Kaur *et al.* (2012) also revealed that sun dried *L. minor* can be incorporated in rohu diet @ 20 % as a protein supplement for mustard meal replacement without affecting fish growth besides lowering the feed cost by 36 %. Similar results were obtained in the study conducted by Yilmaz *et al.* (2004), in which *L. minor* up to 20 % level resulted in similar growth of common carp fry as obtained with control diet with respect to growth, feed utilization and body composition. The study conducted by Tavares *et al.* (2008) reported that dried *L. minor* can replace 50% of commercial diet having 40% protein for tilapia without reducing its growth. Guru and Patra (2007) recorded highest SGR in *L. rohita* fingerlings fed diets with 13.2% dried *Lemna*, whereas, Das *et al.* (2007) revealed 205% higher weight gain, about 105% higher feed conversion in *L. rohita* fed diets with 20% dried *Lemna* and also saved about 20% on feed cost. Ansal *et al.* (2008) recorded 70 % higher weight gain in common carp, *C. carpio* fed with diets having 20% sundried duckweed (*Spirodela polyrrhiza*) and saved 50% on feed cost. Further, Ansal and Dhawan (2009) also reported 20.6 % and 12.68 % higher growth in rohu, *L. rohita* and mrigal, *Cirrhinus mrigala* by 20 % inclusion of sun dried *S. polyrrhiza* in their diet. Singh *et al.* (2013) also revealed that *Spirodela* can be incorporated up to 30 % level in diet of Indian major carps for formulating low cost eco-friendly diets for producing high quality fish with higher economic returns.

Flesh Quality: Total protein (TP) and total lipid (TL) content increased, whereas total carbohydrate (TC) content decreased in both rohu and common carp fed with *Lemna* based diets. Ash content also exhibited an increase with increasing incorporation level of *Lemna* from 20 – 50 % (D_3-D_6). Maximum TP, TL, TC and Ash contents were recorded in D_2, D_3, D_4,D_5 and D_3 respectively in rohu, whereas, these were maximum in D_2, D_3, D_2, D_1 and D_4 respectively in common carp and the differences among the diets were significant for TL, TC and ash content for both the species. Flesh moisture content decreased with increasing *Lemna* content, but the differences were insignificant. Maximum flesh moisture content was recorded in D_1 and minimum in D_5 for both rohu and common carp (Table 3). Overall effect of feeding *Lemna*

Table 2. Proximate Composition (% DM basis) of feed ingredients and diets

Feed ingredients / Diets	Crude protein	Ether extract	Crude fibre	Nitrogen free extract	Ash
Rice bran*	17.00	1.45	17.75	51.90	11.90
Mustard meal*	39.49	1.25	11.85	40.24	7.17
L. minor	24.90	1.94	10.36	32.05	30.75
D_1 (Control)	27.68	1.32	14.50	47.16	9.34
D_2	27.34	1.38	14.05	45.77	11.46
D_3	27.01	1.42	13.61	44.38	13.58
D_4	26.67	1.49	13.16	42.96	15.72
D_5	26.34	1.55	12.72	41.56	17.83
D_6	26.00	1.61	12.28	40.17	19.94

* De-oiled

Table 3. Changes in growth parameters and flesh composition (g/100g on wet weight basis) of *L. rohita* and *C. carpio* fed on different diets

Parameters	*L. rohita*						*C. carpio*					
	D_1	D_2	D_3	D_4	D_5	D_6	D_1	D_2	D_3	D_4	D_5	D_6
Av. IBL (cm)	4.3^{a}	4.25^{a}	4.21^{a}	4.29^{a}	4.25^{a}	4.28^{a}	4.71^{a}	4.67^{a}	4.61^{a}	4.61^{a}	4.62^{a}	4.67^{a}
Av. FBL (cm)	14.00^{a}	14.22^{a}	13.43^{b}	13.47^{b}	14.17^{a}	13.94^{a}	15.00^{b}	15.8^{a}	13.22^{d}	13.97^{cd}	14.17^{c}	14.25^{bc}
Av. IBW (g)	1.12^{a}	1.087^{a}	1.127^{a}	1.107^{a}	1.113^{a}	1.133^{a}	1.54^{a}	1.53^{a}	1.48^{a}	1.41^{a}	1.51^{a}	1.51^{a}
Av. FBW (g)	35.70^{a}	36.40^{a}	30.70^{ab}	29.00^{c}	26.75^{cd}	26.20^{d}	55.00^{a}	56.70^{a}	38.90^{b}	38.80^{b}	40.60^{b}	41.30^{b}
% NWG	3087.5	3248.67	2273.56	2266.76	2658.31	2459.57	3471.43	3605.88	2528.37	2651.77	2588.74	2635.10
SGR	1.92	1.95	1.84	1.81	1.77	1.74	1.98	2.01	1.81	1.84	1.82	1.83
PER	1.87	1.96	1.72	1.80	1.80	1.81	1.91	2.09	1.72	1.78	1.82	1.77
FCR	1.93	1.87	2.15	2.08	2.11	2.12	1.89	1.75	2.15	2.11	2.09	2.17
Flesh Composition												
Total Protein	14.07^{a}	15.53^{a}	15.37^{a}	15.43^{a}	14.93^{a}	14.47^{a}	13.87^{a}	14.45^{a}	14.45^{a}	14.12^{a}	14.11^{a}	13.89^{a}
Total lipid	2.10^{ab}	2.41^{a}	2.69^{a}	2.69^{a}	2.32^{ab}	2.25^{ab}	2.78^{ab}	3.43^{a}	3.10^{a}	3.12^{a}	3.23^{a}	3.15^{a}
Total carbohydrates	2.97^{ab}	2.10^{b}	2.19^{b}	2.14^{b}	3.80^{a}	3.37^{a}	2.57^{a}	2.43^{a}	2.12^{b}	2.17^{b}	2.56^{a}	2.18^{b}
Ash	1.35^{ab}	1.06^{b}	1.78^{a}	1.57^{a}	1.57^{a}	1.09^{b}	1.29^{b}	1.06^{b}	2.01^{ab}	2.61^{a}	2.60^{a}	2.52^{a}
Moisture	79.51^{a}	78.90^{a}	77.97^{a}	78.17^{a}	77.38^{a}	78.82^{a}	79.25^{a}	78.63^{a}	78.32^{a}	77.98^{a}	77.50^{a}	77.98^{a}

Values with same superscript in a row do not differ significantly ($P \leq 0.05$); IBL = initial body length, FBL = Final body length, IBW=Initial body weight, FBW = Final body weight, NWG = Net weight gain, SGR= Specific growth rate, PER = Protein efficiency ratio, FCR = Feed conversion ratio

based diets on flesh quality of rohu and common carp revealed an increase in TP, TL and ash content and decline in carbohydrates and moisture content in both the species. This can be attributed not only due to higher protein, ether extract and ash content of *Lemna* incorporated diets as compared to basal diet ingredients especially rice bran (Table 2), but also superior amino acid profile of *Lemna*, which fulfils the essential amino acid requirement of carps more than any other plant ingredient especially rice bran.

All duckweed species contain higher lysine (6.43 – 8.62 %) and methionine (0.95-1.14 %) content as compared to most of the commonly used plant based ingredients except soybean (6.28 and 1.14 %, respectively) (Hertarampf and Pieda-Pascual, 2000). Lysine and methionine are most important essential amino acids, which help in building muscle protein and boosting the immune system of an organism, when added at an appropriate level. It is also supported by higher PER values recorded for diet D_2 in both the fish species in the present study (Table 3). Yilmaz *et al.* (2004) also reported similar results in terms of increase in carcass protein and lipid with increase in incorporation of *Lemna minor* in the diet of common carp. They concluded that a diet containing up to 20 % duckweed could be used as a complete replacement of fish meal for commercial feed in the diet formulation for common carp fry. Bairagi *et al.* (2002) also reported similar findings in terms of significantly higher carcass protein and lipid content in rohu fingerlings fed with diets containing raw duckweed (*L. polyrrhiza*) at 30 % and 40 % inclusion levels as compared to fish fed with control diet. However, Fasakin *et al.* (2001) and Schneider *et al.* (2004) found no significant differences in the protein content of nile tilapia (*Oreochromis niloticus*) fed with *Lemna* and *Spirodela* diets, respectively.

Collectively, results of the present study revealed that dried *Lemna* powder can be incorporated in carp diet @ 10 % by replacing conventional feed ingredients without compromising fish growth and with improved flesh quality. Hence, incorporation of *Lemna minor* in carp diet is the best way to utilize readily available resources in the form of duckweeds to generate higher fish biomass.

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Received 12 April, 2016; Accepted 22 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 697-705

Manuscript Number: 2360
NAAS Rating: 4.47

Phosphorus Adsorption and Desorption in Agro-climatically Disparate Soils Representing Foothills of Northwest Himalayas

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Abstract: A study was conducted to understand the phosphorus (P) behaviour in soils representing different agro climatic zones in foothills of northwest Himalayas. Langumir and Freundlich isotherms were tested for adsorption/desorption studies and from these, adsorption maxima (b), bonding energy constant (K) and maximum buffering capacity (MBC) was calculated. Adsorption/desorption studies showed that P adsorption was more in temperate soils followed by intermediate and sub-tropical soils. Results indicated that P adsorption increased with added P but incubation with farm yard manure (FYM) decreased the P adsorption (decreased bonding energy as well as adsorption maxima), thus making the adsorbed P available for crops. It was further observed that sorption got influenced by different moisture regimes too. The values of bonding energy and adsorption maxima were lower under saturation in comparison to field capacity. The study revealed that P addition, FYM application, incubation period, soil properties and agro-climatic situations influenced P behaviour in soils under investigation.

Kew Words: Adsorption, Adsorption maxima, Bonding energy, Desorption, Maximum buffering capacity

Phosphorus (P), a key element and vital component of the substances that are building blocks of genes and chromosomes, is taken up by crops from the soil. This P must be replenished or resupplied adequately for normal crop growth. The ability of the soil to re-supply this phosphorus is dependent on the adsorption/desorption behaviour of soil system, as this will govern the movement of applied as well as native phosphorus. Factually the Phosphorus movement in soil is very petite even with hefty amounts of rainfall or irrigation.

Adsorption and desorption reactions are considered as key aspects of the chemical behaviour of P in soil (Ahmed *et al.,* 2008). These chemical processes gets influenced by moisture regimes, as these effects soil properties and subsequently the P behaviour. Solution P increases on flooding and this P varies widely in different soils. Soil reduction of flooding results in the release of organic acids, which help in displacement of soluble phosphorus. The magnitude and rate of phosphate adsorption depends on the properties of soils and phosphate sources. Soils differ widely in their chemical and physical make up according to geological and geographical location. Consequently it is almost impossible to draw a generalized fixation model from the result of specific soils. It is however, known that clay, organic matter, hydrous oxides of Fe and Al in acid soils, and calcite and Ca^{++} in calcareous soil plays major role in phosphate sorption. Application of organics in the form of farmyard manure, compost or green manure should invariably increase the soluble P in the flooded soil by enhancing the reduction conditions through the release of electron.

Continuous and intensive cropping coupled with limited P fertilization, as is followed in foothills of northwest Himalayas, has resulted in negative phosphorus balance, as no or low P may expose more sites for P sorption as a result of desorption. Application of phosphorus (P) fertilizers in agriculture soils has introduced some problems mainly due to P fixation, low recovery and accumulation in soil. Small as well as jagged recovery of applied P in agro-climatically diverse soils in foothills of northwest Himalayas has enthused the present investigation with intend to present an overall depiction of phosphorus behaviour as influenced by organic and in-organic P under different moisture regimes, in northwest Himalayas. The study helped in planning/ designing the stratagem for optimizing the P supply to agricultural crops.

MATERIAL AND METHODS

Present investigation was carried out in soils belonging to Shivalik ranges of north-west India sandwiched between two physiographic regions *i.e.* Himalayan ecosystem and great Indo-Gangetic plains. Unstable landscape, erratic rains and unscientific/traditional management practices are the main characteristics of the area. Agro-climatically the region is divided into three zones viz, subtropical, intermediate and temperate zone. Sub-tropical zone includes foot hill plains at an altitude of 215 to 360 m amsl, with an annual average rainfall of 1000 mm and annual mean temperature of 24°C. The altitude of sub-mountainous intermediate zone varies between 360 to 1500 m amsl and this zone receives an annual average rainfall ranging between 1110 to 1476 mm and has mean annual temperature of 13°C. The temperate zone includes areas at an altitude of more than 1500 m and up to 2500 m above mean sea level. The annual average rainfall of this zone is around 650 mm.

On the basis of variable texture, organic carbon, altitude and cropping pattern, surface soil samples (0-15 cm) were collected from three agro-climatic zones in foothills of northwest Himalayas. Soil samples were mainly collected from cultivated areas being cropped mostly with maize, wheat, rice, pulses, mustard and beseem clover (*Trifolium alexandrinum* L).The soil samples collected were dried under shade, processed, sieved through 2 mm sieve (for organic carbon through 0.5 mm sieve) and finally stored in polythene bags for analysis so that they could be used for determining various physico-chemical properties, phosphorous adsorption vis-à-vis for determination of phosphate desorption and effect of organic matter and moisture regimes on phosphate adsorption. The collected soil samples were analysed for their general physical and chemical properties following standard procedures. Soil texture was determined by bouyoucous hydrometer method (Piper, 1966), pH was measured by suspension of soil & water (1:2.5) using glass-calomel electrode (Jackson, 1967), Electrical conductivity was determined by Salt bridge measurements from the suspension used for pH determination (Jackson, 1967). Organic carbon was estimated by dichromate oxidation of organic matter (Walkley and Black, 1934), calcium carbonate by titration of soil suspension with 0.5N H_2SO_4 (Piper, 1966) and cation exchange capacity by NH_4OA_C K method with alcohol washings (Rhoades, 1982). Exchangeable aluminium was determined by extracting soil with 1N KCl and then its estimation by aluminon method (Hisu, 1963). Free Iron oxide was determined by extracting soil with Dithionate-citrate-bicarbonate method (Mehra and Jackson, 1960). The total soil phosphorus was determined by predigesting the soil with concentrated HNO_3 and evaporated to dryness and again re digested with $HClO_4$ until a white residual was left. The residue was filtered and made to a known volume. Total phosphorus was then estimated by vando-molybdo-phosphoric yellow colour method at 470nm as described by Olsen and Sommers (1982).

For adsorption-desorption, Langumir and Freundlich isotherms were tested for adsorption/desorption data and from these adsorption maxima(e), bonding energy constant(K) and maximum buffering capacity were calculated.

Adsorption studies: For this study 5 grams of soil was taken in a series of plastic bottle and 50 ml of 0.01M$CaCl_2$ was added containing 0, 20, 40, 80, 120, 200, 250, 300 and 350 ppm of phosphorus and were incubated for six days. After equilibrium suspension were centrifuged and P were remaining in the solution was determined by Ascorbic Acid method. The amount of P adsorbed was calculated by the difference between P initially added and equilibrium P in solution. The isotherm data were interpreted in the terms of following equation as under:

Langmuir equation**:**

$$C/x/m=1/Kb+C/b$$

C = equilibrium concentration of P in solution (mg L^{-1})

X/m= amount of P adsorbed in soil solution per unit mass of soil (mg kg^{-1})

b= adsorption maxima (mg kg^{-1})

K= constant related to bonding energy (l mg^{-1})

Freundlich equation:

$$X/m=KC^{1/n}$$

X/m= amount of P sorbed in soil solution per unit mass of soil (mg kg^{-1})

C= equilibrium constant of P in the solution (mg L^{-1})

K and n is empirical constants.

Desorption studies: For desorption studies, the soil samples equilibrated with solutions of different levels of P for 6 days, were shaken with 0.01M$CaCl_2$ in 1:5 in soil solution ratio for one hour and then centrifuged and supernatant liquid was used for P determination using Ascorbic acid method. The total amount of P in given such desorption was taken as the measure of cumulative P released (Vig *et al*., 1978a, b).

Incubation studies: To study the effect of various level of P, organic matter and moisture regimes on P adsorption, incubation studies were carried out in three soil samples representing three different zones for this study. 250 gm soil in duplicate were kept in polythene bags mixed with 0, 2.5 and 5% FYM, levels of P used were 0,50 and 100 ppm in a glass house for a period of 0, 7, 14, 28, 56 and 112 days at field capacity and at saturation representing field conditions for maize which is dominant crop of the region and at saturation which is dominant crop of sub tropical irrigated zone. The soil samples were kept in duplicate and water content loss was replenished by adding water at different intervals. Inorganic P was determined in these soils using Ascorbic acid method (Vig *et al*., 1978a, b).

RESULTS AND DISCUSSION

Physico-chemical properties: The pH of the soils varied from 7.2 to 8.8, 5.8 to 8.7 and 5.9 to 7.4 in sub-tropical, intermediate and temperate soils, respectively (Table 1). The electrical conductivity (EC) values of the soils was found to be with in the safe limits averaging 0.34 (sub-tropical zone), 0.12 (intermediate zone) and 0.14 (temperate zone) ds m^{-1}. A higher level of organic carbon, ranging between 0.74 to 0.99% (averaging 0.91%), was observed in temperate zone soils followed by intermediate and sub-tropical soils. The average CEC of these soils varied from 10.17 to 14.68 Cmol (p+) kg^{-1}. Total phosphorus ranged between 340 to 364, 388 to 495 and 615 to 650 mg kg^{-1} in sub-tropical, intermediate and temperate soils, respectively. Exchangeable aluminium content varied from 2.10 to 5.70 mg/kg^{-1} with a mean value of 3.95 mg/kg^{-1} in sub-tropical zone soils. In the intermediate zone, it varied from 1.36 to 11.85 mg/kg^{-1} with mean value of 5.98mg/kg^{-1}. Amongst the three agro-climatic zones, highest content of exchangeable aluminium was in soils of temperate zone averaging 6.88 mg kg^{-1}. Free iron oxide content varied from 0.31 to 0.69% with mean value of 0.50%. Higher value of free iron oxide was in temperate zone soils which varied from 0.42 to 1.30% with mean value of 0.79%. Texturally the soils varied from loam to sandy clay loam. Higher sand content was found in soils of sub-tropical zone which ranged from 41.2 to 85.1%. Lowest sand content was found in temperate zone soils and it ranged from 31.9 to 43.4% with a mean value of 37.8 per cent. The soils of intermediate zone soils showed mean values of 46.2%. The variation in the silt was from 7.6 to 36.0, 19.0 to 46.7 and 21.8 to 32.6% with a mean value of 21.2, 30.6 and 26.9% in soils of sub-tropical, intermediate and temperate zone, respectively. The clay content ranged from 7.3 to 29.2 with a mean value of 21.1 per cent in sub-tropical zone soils, while for intermediate zone soils range was from 17.4 to 30.9 with a mean value of 23.1%. Temperate zone soils contained clay content in the range of 27.1 to 42.5% with a mean value of 35.1%.

Phosphorus adsorption and desorption: It was observed that amount of P adsorbed on its addition was sequentially as Temperate>Intermediate> Sub-tropical. It increased in all the three soils and raised upto 193.22, 496.62 and 755.55 mg kg^{-1} on addition of 350 mg L^{-1} of P in sub-tropical, intermediate and temperate soils, respectively (Table 2a).

All the soils in the present investigation exhibited a capacity to retain P. Therefore, it is important from the agriculture point of view to know whether, the adsorbed P of these soils is easily desorbed and how much of it is available to the plant growth. The amount of P desorbed varied with the levels of the applied P and increased with the increase in the adsorbed P. The amount of P released decreased with each successive extraction for all the soils under study. Highest desorption of 32.04 mg kg^{-1} was in subtropical soils followed by intermediate soils (23.85 mg kg^{-1}) and temperate soils (11.90 mg kg^{-1}) on addition of 350 mg L^{-1} of P (Table 2a). Results further revealed that in the slightly alkaline soils of subtropical zone the recovery per cent of added P was more (14.15 to 15.09%) while in intermediate zone and temperate zone it ranged from (11.64 to 12.89 %) and (8.76 to 11.66 %)

Table 1. Range and mean values of important soil properties of various agro-climatic zones representing foothills of northwest Himalayas

Parameters	Agro-climatic zone					
	Sub-tropical		Intermediate		Temperate	
	Range	Mean	Range	Mean	Range	Mean
pH	7.2-8.8	8.06	5.8-8.7	7.13	5.9-7.4	6.66
E.C (dS m^{-1})	0.05-1.47	0.34	0.01-0.91	0.12	0.02-0.28	0.14
O.C %	0.13-0.62	0.31	0.28-0.98	0.57	0.74-0.99	0.91
$CaCO_3$ %	0.36-1.98	1.20	0.21-1.76	0.81	0.41-0.79	0.60
C.E.C C mol (p+) kg^{-1}	7.73-12.33	10.17	8.02-15.08	12.42	13.9-15.39	14.68
Total P (mg kg^{-1})	340-364	348.5	388-495	418.7	615-650	629.6
Ex. Al (mg kg^{-1})	2.10-5.70	3.95	1.36-11.85	5.98	4.50-8.90	6.88
Free Fe oxide (%)	0.31-0.69	0.5	0.30-0.98	0.64	0.42-1.30	0.79
Sand %	41.2-85.1	57.59	26.4-62.2	46.28	31.9-43.4	37.86
Silt %	7.6-36	21.27	19-46.7	30.64	21.8-32.6	26.97
Clay %	7.3-29.2	21.14	17.4-30.9	23.12	27.1-42.5	35.17

respectively. In the temperate zone soils P appears to be held in clay organic complex because these soils have more organic carbon and clay content as compare to other contents. Since the soils of three agro climatic zones of north-west Himalayas are different in clay content, organic matter, free iron oxide and exchangeable Al, these must have played a pivotal role for different desorption behaviour of these soils. As the bonding energy of these soils varies it must have played role in the different desorption behaviour of soils. Further, these results suggested that the initial adsorption of P by soils is followed by slow changes that ultimately control the rate of desorption of P as a result of this adsorption and desorption do not follow the same curve. Moreover, this difference between the magnitude of adsorption and P release depends upon the time of contact of P fertilizer with soils and the intensity of P binding in the soils (Singh and Sarkar 1985; Everardo *et al.,* 2016).

On observing the association of phosphorus adsorption (Fig. 1a) as well as desorption (Fig. 1b) with added P, a positive and linear relationship was observed in soils of all the three agro-climatic zones. Increase in P adsorption with every one mg l^{-1} of added P was more pronounced in

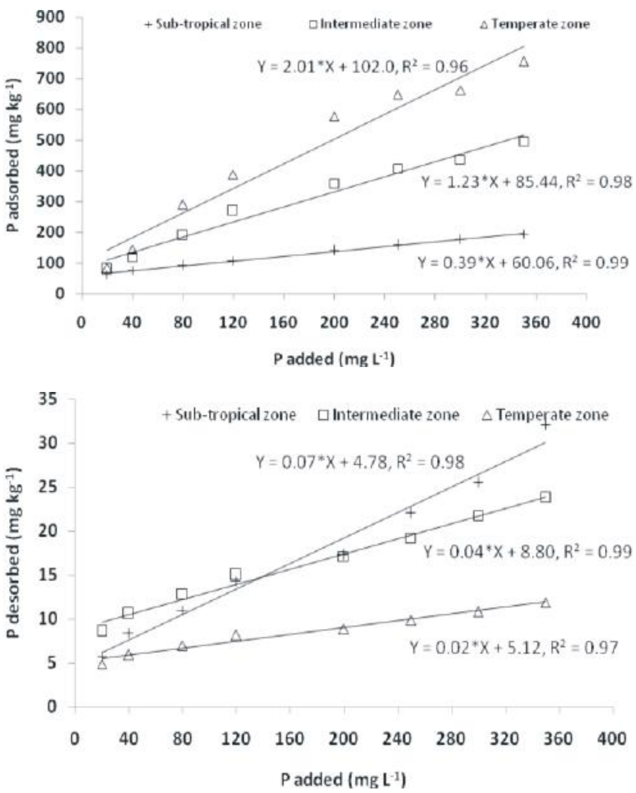

Fig. 1. Relationship between phosphorus adsorption (a) and desorption (b) with added P in soils representing different agro-climatic zones in foothills of northwest Himalayas

temperate soils (2.01 mg kg^{-1}) followed by intermediate soils (1.23 mg kg^{-1}) and sub-tropical soils (0.39 mg kg^{-1}). But so far as phosphorus desorption was concerned (Fig. 1b), a least desorption of 0.02 mg kg^{-1} with every one mg l^{-1} of added P was noticed in temperate soils. It was further observed that quantitatively desorption with every one mg l^{-1} of added P was more in intermediate soils in comparison to sub-tropical soils during the initial P addition, but the increase was steeper after 120 mg l^{-1} of added P. Less adsorption and more desorption rates in sub-tropical soils as well as more adsorption and least desorption in temperate soils could be attributed to per cent clay content and binding force of these soils.

It is now well established fact that Langmuir and Freundlich constant can be used for predicting the availability of phosphorous to crops (Singh and Sarkar, 1985). Phosphate adsorption isotherms were constituted in accordance with Freundlich and Langmuir isotherms for selected forty surface soils samples (15 each from sub-tropical and intermediate zone, and 10 from temperate zone) that were taken from 0-15 cm depth from three agro-climatic zones of northwest Himalayas. The agro-climatic zone wise adsorption isotherms have been presented in figure 2 & 3. The phosphate adsorption data had an excellent fit to Langmuir and Freundlich isotherm as indicated by highly significant R^2 value which varied from 0.89 to 0.99 and 0.95 to 0.99 respectively for all the three agro climatic zones (Table 2b). These value revealed that soils of entire area under investigation fitted in Langmuir as well as Freundlich isotherm. Mondal *et al.* (2004) reported similar finding for subtropical zone of this region. However, Finka *et al*. (2015) reported that Freundlich equation provided a better description of phosphate sorption than Langmuir equation in soils at wide range of P concentration in equilibrium solution.

Phosphate adsorption maxima (b), bonding energy (K) and maximum buffering capacity (M.B.C.) were calculated from slope and intercept of the curves. Similarly Freundlich K and 1/n were calculated from the Freundlich equation and are presented in Table 2b. These constant varied in the three agro climatic zones. In subtropical zone, adsorption maxima (b) varied from 101.0 mg kg^{-1} to 344.9 mg kg^{-1}. In the intermediate soils, P adsorption maxima varied from 384.6 mg kg^{-1} to 775.2 mg kg^{-1}. Highest adsorption maxima were recorded in soils falling in temperate agro climatic zone. Higher adsorption maxima in the temperate zone soils could be explained on the higher amounts of clays, organic matter, exchangeable Al and iron oxide in these soils. The role of organic matter in augmenting the P sorption in soils has been attributed to the association with possible stabilization of the soil organic matter by the free sesquioxide (Sanyal and De Datta, 1991).

The values of bonding energy (K) varied from 12.0 l kg^{-1} to 56.0 l kg^{-1} in subtropical zone soils, 14.0 to 23.0 l kg^{-1} for intermediate soils and 17.0 l kg^{-1} to 22.0 l kg^{-1} for temperate zone soils. These values were much higher in subtropical zone than in intermediate zone (Table 2b), conversely the adsorption maxima values were greater in upper regions than in the lower region. Arranging the soil in b and K values, it is obvious that they do not follow the same pattern, these values are not interdependent, and rather they have been influenced in a complex manner by a number of factors viz. pH, organic matter, C.E.C, $CaCO_3$, Al, iron oxide and available P content of the soils.

The maximum buffering capacity (M.B.C) of P varied by soils of subtropical zone, it varied from 2.62 to 5.66 L kg^{-1}, in intermediate zone soils it range from 8.69 to 10.85 L kg^{-1} and 17.0 to 20.0 L kg^{-1} in temperate zone soils. This indicates that the effect of organic matter was appreciable on Langmuir energy constant as the range was highest in the temperate agro climatic zone.

P adsorption constants derived from Freundlich equitation (Table 2b) showed that K varied from 19.49 to 44.51 l kg^{-1}, 38.88 to 42.32 l kg^{-1} and 39.81 to 47.64 l kg^{-1} in subtropical, intermediate and temperate zone soils respectively Again temperate zone soils had highest P adsorption constant as compare to other two zones and this could be because of higher clay, organic matter and lower pH of these soils. The Freundlich 1/n varied from 0.13 to 0.41, 0.37 to 0.50 and 0.524 to 0.56 in subtropical, intermediate and temperate zone soils, respectively.

Relationship between P adsorption and soil properties: In order to assess the individual influence of soil properties on P adsorption maxima, bonding energy constants, simple coefficient of correlation were computed and are given in Table 3. An analysis of data in table 3 reveals that pH had a significant and negative co relationship with adsorption maxima (b), the coefficient of correlation being -0.750 in soils of three agro-climatic zones, thus confirming that P adsorption was pH dependent. Increasing pH increases net negative charge of variable charge soils and decreases the activity of Fe^{++} and Al^{+++} in acid soils and Ca^{++} in neutral soils, thereby reducing adsorption. The P adsorption maxima (b) was positively and significantly correlated with organic carbon, C.E.C and clay, the coefficient of correlation being 0.892, 0.900 and 0.935 in three agro-climatic zones. Adsorption maxima was positively correlated with exchangeable Al and free iron oxides, the correlation coefficient being 0.587 and 0.534, respectively. The texture of the soils is an important parameter in influencing P

Table 2 (a). Phosphorus adsorption and desorption in agro-climatically dissimilar soils in foot hills of northwest Himalayas

P added (mg L^{-1})	P adsorbed (mg kg^{-1})			P desorbed (mg kg^{-1})		
	Sub-tropical zone	Intermediate zone	Temperate zone	Sub-tropical zone	Intermediate zone	Temperate zone
20	62.22	80.95	83.97	5.76 (14.52)	8.57 (12.48)	4.85 (8.76)
40	76.47	119.79	144.92	8.46 (15.09)	10.59 (12.52)	5.92 (10.15)
80	92.72	189.44	290.13	10.99 (14.84)	12.90 (12.45)	6.98 (11.56)
120	108.97	269.11	388.36	14.33 (14.15)	15.04 (12.13)	8.16 (11.47)
200	141.47	359.01	577.00	17.28 (14.83)	17.07 (11.64)	8.90 (10.35)
250	158.72	407.73	646.96	22.04 (14.52)	19.23 (12.89)	9.86 (10.33)
300	175.03	437.13	662.11	25.49 (14.36)	21.74 (12.63)	10.80 (10.77)
350	193.22	496.62	755.55	32.04 (14.28)	23.85 (12.05)	11.90 (11.66)

Note: Values in parentheses are % desorption of the adsorbed P

Table 2 (b). Phosphorus adsorption parameters of soils of different agro-climatic zones in foothills of northwest Himalayas

Agro-climatic Zone	Langmuir Constants				Freundlich Constants		
	P adsorption maxima (b) (mg kg^{-1})	Bonding energy (L kg^{-1})	Maximum buffering capacity (L kg^{-1})	R^2	K (mg kg^{-1})	1/n	R^2
Sub-tropical	214.34 (101.0-344.9)	25.36 (12.0-56.0)	4.21 (2.62-5.66)	0.95 (0.89-0.99)	31.20 (19.49-44.51)	0.29 (0.13-0.41)	0.96 (0.95-0.98)
Intermediate	577.93 (384.6-775.2)	17.05 (14.0-23.0)	9.50 (8.69-10.85)	0.95 (0.92-0.98)	39.81 (38.88-42.32)	0.45 (0.37-0.50)	0.98 (0.97-0.99)
Temperate	896.09 (805.1-1000.0)	20.70 (17.0-22.0)	18.48 (17.0-20.0)	0.98 (0.97-0.99)	46.00 (39.81-47.64)	0.54 (0.52-0.56)	0.97 (0.96-0.98)

Note: Values in parentheses is range

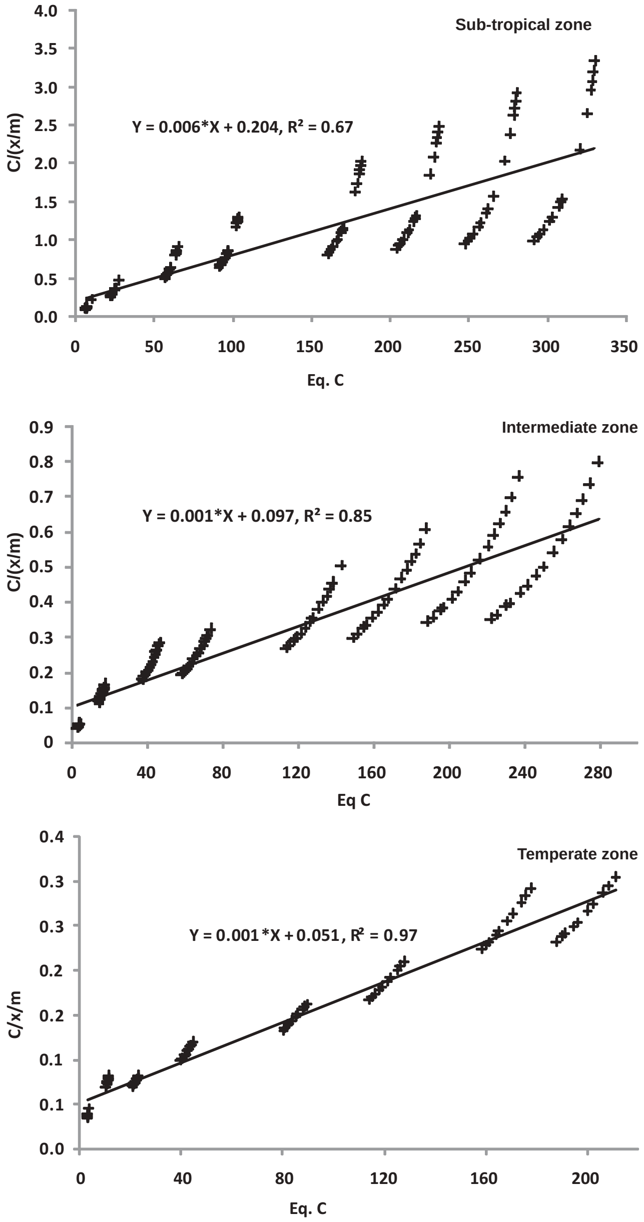

Fig. 2. Langmuir adsorption isotherms for soils representing different agro-climatic zones in foothills of northwest Himalayas

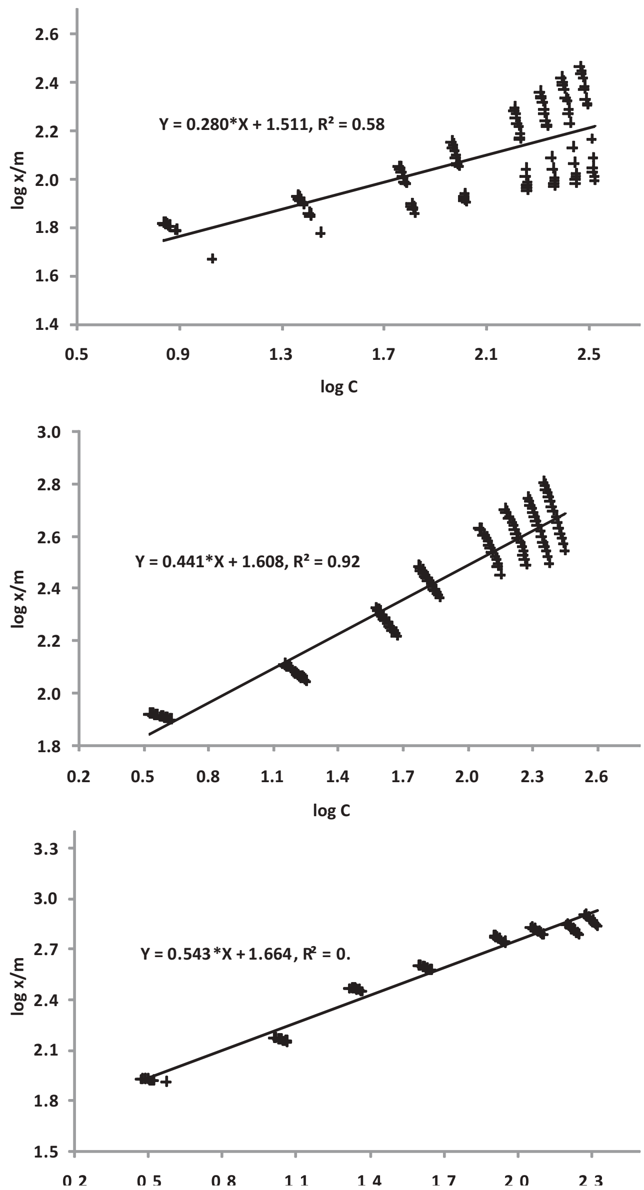

Fig. 3. Freundlich adsorption isotherms for soils representing different agro-climatic zones in foothills of northwest Himalayas

adsorption for areas with soils of relative similar mineralogy. Since the soils under study have similar mineralogy i.e., by and large contain Illite (48 to 60%), followed by Kalonite (26 to 42%) and Vermiculite (2 to 13%) (Sharma, 2006), the relationship between clay content and P adsorption is understandable. The significant positive correlation with organic carbon, available Al and iron oxide suggests maximum P adsorption was due to sesquioxides, clay and organic matter content of the soils. Further it has been suggested that organic matter increases the availability of phosphate by chelating the phosphate fixing cations (Al^{+++}, Fe^{++}, and Ca^{++}). The role played by clay fixation in P adsorption in soils has been attributed to the abundance of Fe and Al in clay. It has been observed that the clay forms a part of the complex jell as proposed by Venkatesan *et al*. (2013), which consist of hydrated Fe_2O_3, small amounts of organic matter, Al_2O_3 associated Si $(OH)_2$ and P. The complex jell has been considered as a major site of P adsorption. According to Fox and Kamparth (1970) phosphorus adsorption per gram of clay increases with increasing clay content and suggested that phosphate had easier access to clay surfaces when the clay was dispersed.

Table 3. Coefficient of correlation (r) between adsorption parameters and soil properties of different agro-climatic zones of northwest Himalayas

Soil Parameters	P adsorption maxima (b)	Bonding energy (k)	Maximum buffering capacity	Freundlich K	Freundlich 1/n
pH	-0.750**	0.206	-0.743**	-0.578**	-0.688**
EC	-0.379*	-0.153	-0.385*	-0.502**	-0.238
OC	0.892**	-0.156	0.966**	0.745**	0.774**
$CaCO_3$	-0.509**	0.168	-0.572**	-0.433**	-0.493**
CEC	0.900**	0.420**	0.877**	0.560**	0.883**
Total P	0.877**	-0.107	0.974**	0.688**	0.748**
Exchangeable Al	0.587**	-0.097	0.585**	0.429**	0.495**
Free Fe oxide	0.534**	-0.236	0.519**	0.333*	0.532**
Sand	-0.823**	0.556**	-0.678**	-0.374*	-0.847**
Silt	0.366*	-0.351*	0.219	0.202	0.399*
Clay	0.935**	0.532**	0.849**	0.392*	0.941**

Table 4. Relative influence of physico-chemical properties on Freundlich and Langumier constants

Equation	Intercept	pH	EC	OC	$CaCO_3$	CEC	Total P	Ex. Al	Free Fe oxide	Silt	Clay	R^2
P adsorption maxima (b)	570.6	-8.39	-175.6**	-32.52	33.75	10.05	0.50	12.63	99.99	4.11	22.67**	0.96**
Bonding energy (k)	0.057	-0.0012	-0.0061	-0.0074	-0.00016	-0.003*	0.00016**	0.00043	-0.010	0.0001	-0.0019**	0.85**
MBC	-10.11	-0.20	-1.78*	5.25	0.74	0.22	0.03331**	0.13	-0.097	0.0068	-0.004	0.98**
Fred. K	35.61	-0.95	-4.01	37.11*	2.84	-0.17	0.02272	0.23	-0.93	0.0387	-0.86**	0.79**
Fred. 1/n	-0.14	0.0039	-0.033	-0.0083	0.0085	0.021*	-0.00044	0.00198	0.088	0.0006	0.0150**	0.95**

** significant at 1% level of significance; * significant at 5% level of significance

In the multiple regression analysis (Table 4) the combined influence of pH, EC $CaCo_3$, CEC, total P, exchangeable Al, free iron oxide, silt and clay on P adsorption maxima (b) indicated that 96% of the total variation in the amount of the P adsorbed could be accounted for by these variables out of which only clay was significant and this could be major factor contributing to the P adsorption in the three agro climatic zones.

The affinity constant K, which reflects the bonding energy of P with soils particle was positively and significantly correlated with clay and CEC, the coefficient of correlation being 0.532 and 0.420, respectively in all the soils under study. Equation 2 in Table 4 indicated that 85 per cent variation in bonding energy could be accounted for the variation in clay content pH , EC, organic carbon, $CaCo_3$, total P, CEC, exchangeable Al, free iron oxide and silt content, out of which clay, total P and CEC were significant and this could be the major factor contributing to affinity of P to be held in soils. Negative correlation has also been observed between bonding energy and electrical conductivity, organic carbon, total P exchangeable Al, iron oxide but the correlation were not statistically significant. Maximum buffering capacity (MBC) had significant negative correlation with pH (r=-0.743), a significant positive correlation with clay, exchangeable Al, free iron oxide, organic carbon and CEC the coefficient of correlation being 0.849, 0.585, 0.519, 0.966 and 0.877 respectively. Multiple regression analysis indicated (Table 4, equation 3) 98 per cent variation by combined effect of these on maximum buffering capacity but out of all this total P and EC were significant.

Freundlich K (extent of adsorption) had a positive and significant correlation with clay (r=0.392), exchangeable Al (r=0.429) and free iron (r=0.333) but negative correlation with pH (r = -0.587**). Further, the rate of adsorption (1/n) exhibited a positive correlation with organic carbon, cation exchange capacity, exchangeable Al, free iron oxide and clay the coefficient of correlation being 0.774, 0.883, 0.495, 0.532 and 0.941, respectively. The Freundlich constant was significantly and negatively correlated with pH and $CaCO_3$. Multiple regression analysis (Table 4, equation 4&5) indicated 79 and 95% variation in extent and rate of P adsorption due to the variation in pH, EC, OC, $CaCO_3$, CEC, total P, exchangeable Al, free iron oxide, silt and clay contents of these soils, out of which only clay and organic matter could play a major factor contributing to phosphorus adsorption in the three agro climatic zone.

Effect of various levels of phosphorus, organics and moisture regimes on phosphate adsorption: In the subtropical zone soil of northwest Himalayas value of bonding energy K (L kg^{-1}) decreased from 15.1 at 0 days to 8.6 at 112 days with 0 tonne FYM ha^{-1} at field capacity. Similar decreasing trends were found at saturation point where the value of Langmuir constant K (L kg^{-1}) decreased from 12.6 at 0 days to 7.5 at 112 days with 0 tonne FYM ha^{-1}. In sub-tropical soils the value of Langmuir constant K (bonding energy) decreased after FYM application, the values decreased from 15.1 (0 ton FYM ha^{-1}) to 13.4 on application of 5 ton FYM ha^{-1} at 0 days incubation under field capacity and 12.6 (0 ton FYM ha^{-1}) to 10.2 (5 ton FYM ha^{-1}) under saturated conditions . The value of K decreased from 15.1 to 13.6, 14.8 to 12.8 and 13.4 to 12.3 on 100 ppm P application in 0, 2.5 and 5 ton FYM ha^{-1} treatments. Incubation period do had its affect on K. Values of K decreased from 13.4 (0 days) to 7.8 (112 days) and 12.7 (0 days) to 7.2 (112 days) on P addition of 0 and 100 ppm, respectively on application of 5 ton FYM ha^{-1}. Under saturated conditions also the trend of bonding energy or Langmuir constant K in response to FYM application, incubation period and P addition was similar to field capacity but the values were relatively low. The value of bonding energy K (L kg^{-1}) decrease from 18.2 at 0 to 13.4 at 112 days at field capacity and 15.4 at 0 to 10.6 at 112 days at saturation in intermediate soils. The result suggested that decomposition products of manure help in solubilisation of native P. Consequently, the concentration of P in soil solution is favourably affected and increased. Similar results were observed by Abedin and Salaqua (1998).

In temperate zone soils bonding energy (K) decreased from 23.6 at 0 to 20.2 at 112 days at field capacity with 0 tonne FYM ha^{-1} and 16.8 at 0 to 14.0 at 112 days at saturation with 0 tonne FYM ha^{-1}. Lower value of K under saturation can be attributed to loosening of bound P due to more water under saturated conditions. It was observed that, although the values of K decreased with incubation period, FYM application and P addition in intermediate and temperate soils too, but the values were comparatively higher in temperate soils followed by intermediate soils and sub-tropical soils. This can be due to more adsorption sites because of more clay content and consequently more surface area of temperate soils in comparison to other two.

The adsorption maxima (b) followed the similar trend as that of Langmuir constant K and thus were more under field capacity than saturation as reported by Sarmenio Saliba *et al*. (2016). The value of adsorption maxima (b), in sub-tropical soils, also showed a decrease from 299.4 at 0 to 148.1 at 112 (mg kg^{-1}) and 202.4 at 0 to 133.4 at 112 days (mg kg^{-1}) with 0 tonne FYM ha^{-1} at field capacity and per cent saturation. The adsorption maxima decreased with FYM doses and are in agreement with the finding of Kuo *et al*. (1988).

In other soils also similar trend in adsorption maxima was observed. As was for bonding energy, the values were higher for temperate soils followed by intermediate and sub-tropical soils. The same reason as that for bonding energy holds good for such type of trend in case of adsorption maxima too.

CONCLUSION

Present investigation revealed that P adsorption followed the sequence as; temperate >intermediate>sub-tropical zone soils. Understanding of phosphorus adsorption/desorption behaviour as influenced by physical, chemical, biological and agro-climatic properties/ parameters, exposed in present investigation, will help the researchers, planners and policy makers to design strategies to make economically efficient use of phosphatic fertilizers. It is further concluded that the use of Farm Yard Manure (FYM) can help in catalyzing the P supply to crops, as was proved through incubation studies, thereby increasing the yield and consequently the socio-economic status of the farming community.

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 706-712

Manuscript Number: 2361
NAAS Rating: 4.47

Assessment of Vegetation Structure and Above Ground Biomass Carbon Pools in Semi-evergreen, Dry Deciduous and Scrub Forests in Belgaum District of Western Ghats, India

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***Abstract*:** Floristic diversity, above ground biomass (AGB) and carbon density was compared between different vegetation types of Belgaum district in Western Ghats. Results revealed significant differences across different vegetation types for different parameters studied. Maximum species richness (32 species) and diversity (H'=3.15) was recorded in semi-evergreen forest followed by deciduous (25 species, H'=2.67) and scrub forest (17 species, H'=2.21). On the other hand, maximum density of 350 stems ha^{-1} was recorded in dry deciduous forest followed by semi-evergreen (245 stems ha^{-1}) and scrub forest (220 stems ha^{-1}). However, higher basal area of 12.16 m2 ha^{-1} was recorded in semi-evergreen forest and lowest in scrub forest (1.68 m2 ha^{-1}). The tree layer contributed most (29.68-220.78 Mg ha^{-1}) to the total AGB among different vegetation types followed by shrub (10.13-21.19 Mg ha^{-1}) and herb layer (0.81-1.31 Mg ha^{-1}). Carbon density ranged between 19.09-114.34 Mg C ha^{-1} across different forest types. The majority of AGB and carbon pool in our study was found within taller trees and trees with a larger diameter therefore, their removal substantially alters the C storage and dynamics in this region. Land-use systems with higher C sequestration potential are currently supported under REDD+ projects that focus on forest conservation and management.

Key Words: Above-ground biomass (AGB), Belgaum district, Biodiversity, Carbon density, Western Ghats

India's Western Ghats landscapes are the unique mosaics of natural forests interspersed with agricultural lands, agro forests, coffee and tea plantations, mono-culture plantations and various other tree based production systems which are known to be the most species diverse terrestrial ecosystems. The majority of the 34 global biodiversity hotspots identified worldwide occur within tropical regions and Western Ghats in South India is one among them (Meyers *et al*., 2000). Forests of Western Ghats contain the most diverse plant communities, with up to 350-400 tree and liana species coexisting in a single hectare (Ganesh *et al*., 1996; Swamy *et al*. 2010; Murthy *et al*., 2016). In addition to the rich biodiversity, these forests are also acting as natural sinks of carbon, with a sequestration potential of 80-150 Mg C ha^{-1} (Devagiri *et al*., 2013) and thus playing a fundamental role in the global carbon cycle.

Biodiversity loss and climate change due to habitat destruction and fragmentation are the current environmental challenges. Understanding the pattern of tree diversity and above-ground biomass (AGB) in natural forests is essential for conservation planning and climate change mitigation strategies. Biomass assessment is important for national development planning as well as for scientific studies of ecosystem productivity, carbon budgets etc. (Zheng *et al*., 2004; Pande *et al*., 2010). Biomass analysis is an important element in the carbon cycle especially, carbon sequestration. Recently biomass is being increasingly used to help quantify pools and fluxes of green house gases (GHG) from terrestrial biosphere associated with land use and land cover changes (Cairns *et al*., 2003). The importance of terrestrial vegetation and soil as significant sinks of atmospheric CO_2 and its other derivatives is highlighted under Kyoto Protocol (Wani *et al*., 2010). Vegetation especially, forest ecosystems store carbon in the biomass through photosynthetic process, thereby sequestering carbon dioxide that would have been present in the atmosphere. Undisturbed forest ecosystems are generally highly productive and accumulate more biomass and carbon per unit area compared to other land use systems like agriculture. It is estimated that the carbon stored globally in the forest biomass amounts to 240439 Mt with an average carbon density of 71.5 t ha^{-1}. A recent estimate indicates that tropical forests account for 247 Gt vegetation carbon, of which 193 Gt is stored above ground (Saatchi *et al*., 2011). Many researchers have estimated biomass and C stocks present in India's forests. Hingane (1991) estimated total phytomass carbon pool and carbon density of India's forests at 2587 Tg C and 49.2 Mg C ha^{-1}, respectively based on ecological studies and mean phytomass density for each forest type. Ravindranath *et al*. (1997) estimated the standing biomass (both above and below ground) in India to be 8375

Mt for the year 1986, of which the carbon storage was reported to be 4178 Mt. The total carbon stored in forests of India including soil was estimated at 9578 Mt. Dadhwal *et al*., (1998) using FAO inventory for ecological zones estimated the carbon pool at 3117 Tg C and carbon density at 60.2 Mg C ha^{-1}. However, these estimates exhibit large temporal and spatial variation in biomass and C stocks. Hence, developing appropriate biomass estimation methods for accurate and consistent reporting of forest carbon inventories is important. This study was under taken in Belgaum district which lies in the northern part of the Western Ghats of Karnataka with a research hypothesis that floristic diversity and AGB are expected to vary among forest types with the highest diversity and AGB expected in semi-evergreen forests which enjoys more protection status and then expected to decrease with increasing land-use intensity and disturbances in dry deciduous forest and scrub forest. In accordance with the set hypothesis we aimed at three important objectives to (1) assess and compare the tree species diversity, structure and dominance among different forest types (2) examine how the basal area, AGB and carbon density differs between forest types and (3) know which diameter classes and species contribute more to AGB and carbon.

MATERIAL AND METHODS

This study was conducted in three forest types of Belgaum district which lies in the northern Western Ghats region N 16^0 12' 57.2" and E 74^0 5' 30.3") covering an area of 432510 ha. The notified forest area is 123,046.792 ha, with is 28.4% of the geographical area. The study area, with an altitudinal range of 1038 m to 660 m above MSL, receives average annual rainfall ranging from 307.3 mm to 109 mm with maximum rainfall during monsoon season (June to September). April and May have the highest mean maximum temperature (41^{0}C), while December and January have the lowest mean minimum temperature (14^{0}C). Soils are lateritic to red loamy, which have a mature profile and main rock formation belongs to the most ancient Archaean system with rock composed of peninsular gneiss, gneissic granites and gneiss.

Three forest type's namely semi-evergreen forest (SEF), dry deciduous forest (DDF) and scrub forest (SF) were selected for the present study and location of the selected sites within each forest type is depicted in Fig 2. Nested two stage sampling approach was adopted for collection of data on trees, herbs and shrubs and one super plot of 250 m x 250 m size was laid in each forest type and four sample plots, each of 31.6 m x 31.6 m (0.1 ha) size, were laid in each super plot. Thus, the total sample size consisted of 3 super plots and 12 sample plots across different forest types and this sampling scheme was implemented for representing spatial heterogeneity of super plots in each forest type.

In each of 0.1 ha plots, all the woody plants were counted and identified as far as possible *in-situ* at species level using field keys of Flora of Karnataka (Saldanha, 1996). Voucher specimens of species, which could not be identified in the field, were collected for identification at College of Forestry, Ponnampet with help of taxonomist. Height and Diameter at Breast Height (DBH) of all the trees with ≥10 cm DBH in four sample plots within each super plot were measured using Blume Leiss Hypsometer (which is based on the trigonometric method) and digital tree caliper (Haglof, Sweden), respectively.

Species richness (SR) was estimated by counting individuals of different species per unit area using species area accumulation curve as suggested by Chazdon *et al*. (1999). Species diversity (Shannon–Wiener diversity index-H') and dominance (Simpson's index-D) were calculated as per Magurran (1988). Tree population structure was characterized using DBH and total tree height classes. Importance Value Index (IVI) for each species was computed and expressed as the sum of relative density, relative dominance and relative frequency of the species within and among plots (Curtis, 1959). Based on the IVI values, we identified top ten species for estimation of density (stems ha^{-1}) and basal area m^2 ha^{-1}) and their contribution to AGB (Mg ha^{-1}) and carbon density (Mg C ha^{-1}).

The strata considered for the estimation of AGB were trees, shrubs and herbs. The data collected on tree parameters such as DBH (> 10 cm) and height were used for volume estimations using volume equations published by Forest Survey of India (FSI 2006). We used local as well a regional volume equations depending on the availability for each species and mostly these regression equations follow general linear model (GLM) of the form of $V= a+bD+D^2$ or $V=a+bD^2H$. Tree biomass was estimated by multiplying volume with species specific wood specific gravity values. Wood specific gravity data were obtained from Forest Research Institute (FRI 1996) (Appendix-I). AGB of stems with < 10 cm DBH was estimated by adopting the methodology developed by Devagiri *et al*. (2013) which is based on the large dataset of 1834 trees. Biomass of herbs and shrubs was estimated using destructive method. All shrubs and herbs occurring in the sample plot of 5 m x 5 m and 1 m x 1 m, respectively were harvested and oven dry weight was estimated. Biomass thus obtained from four sample plots (each 0.1 ha) in different stratum for each land-use type was summed up to obtain total AGB and expressed in t-dry wt. ha^{-1}. Finally, based on the assumption that living biomass (tissues) is composed of 47% carbon, we calculated above-ground carbon stock as 0.47 x AGB and expressed as Mg C ha^{-1} for different forest types (Dadhwal *et al*., 2009)

RESULTS AND DISCUSSION

Across different vegetation types, floristic diversity, tree density and basal cover varied considerably (Table 1). Maximum species richness (32 species) and diversity (H'=3.15) was recorded in semi-evergreen forest followed by deciduous (25 species, H'=2.67) and scrub forest (17 species, H'=2.21). On the other hand, Simpson's index of dominance (D) was higher in scrub forest (1.18) and lowest in semi-evergreen forest (1.04). Tree height varied considerably across forest types with mean tree height ranged from 3.2 to 13.08 m (Table 1). None of the forest type showed reverse-J shaped curve for tree height

Table 1. Tree diversity, structure and above ground biomass (AGB) and carbon pool in different forest types of Belgaum district

Vegetation parameters		Vegetation type		
		Semi-evergreen	Dry deciduous	Scrub forest
Species richness		32	25	17
Shannon Weiner Index (H)		3.15	2.67	2.21
Simpson's Index (D')		1.04	1.10	1.18
Tree height (m)		13.08	4.48	3.20
Tree density (Stems ha^{-1})		245	350	220
Basal area (m^{2} ha^{-1})		12.16	3.71	1.68
AGB	Trees (Mg ha^{-1})	220.78	79.54	29.68
	Shrubs (Mg ha^{-1})	21.19	18.25	10.13
	Herbs (Mg ha^{-1})	1.31	1.02	0.81
Total AGB (Mg ha^{-1})		243.28	98.81	40.62
Above ground carbon density (Mg C ha^{-1})		114.34	46.44	19.09

ABG=above ground biomass (Mg ha^{-1})

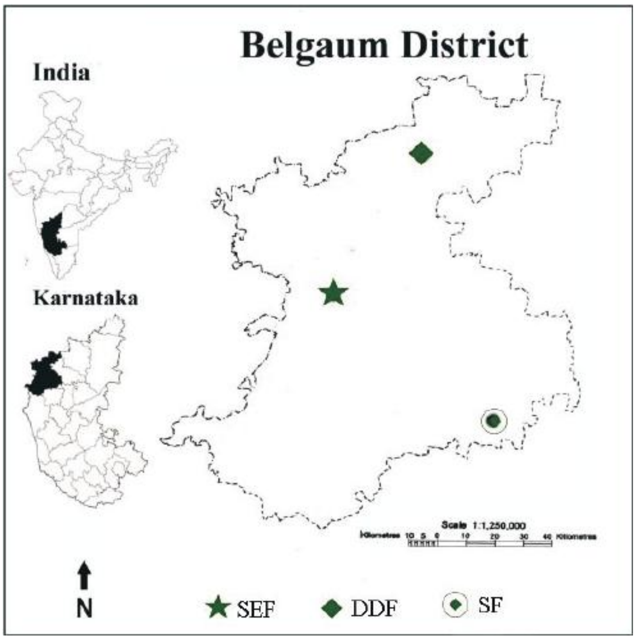

Fig 1. Map of the study area: SEF=semi-evergreen forest, DDF=dry decideous forest and SF=scrub forest

(Fig. 3a). Higher number of individuals was found in 0-5 m height-class in dry deciduous and scrub forest and comparatively taller trees (> 15 m) were noticed only in semi-evergreen forest. A comparison of size-class distribution of diameter at breast height (DBH) across the land-use types revealed significant variation. As expected a normal reverse-J shaped curve was observed only in semi-evergreen forest while near normal distribution was noticed in other two forest types for stem diameter (Fig. 3b). These results indicate that dry deciduous and scrub forests were found to be short stature as compared to semi-evergreen forests of this region. Further, we found lesser number of trees in lower diameter classes (< 10 cm and 10-20 cm DBH) and higher number of trees in intermediate class (20-50 cm DBH) in all the forests is probably due to the fact that

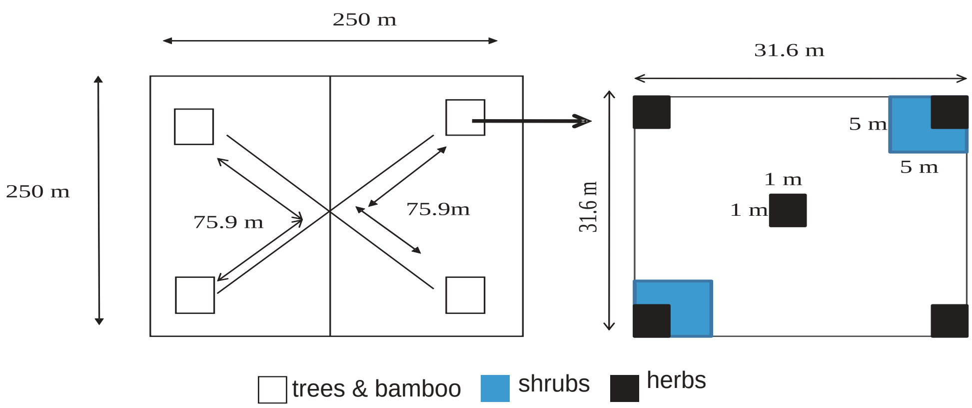

Fig. 2. Diagram showing the nested two stage sampling

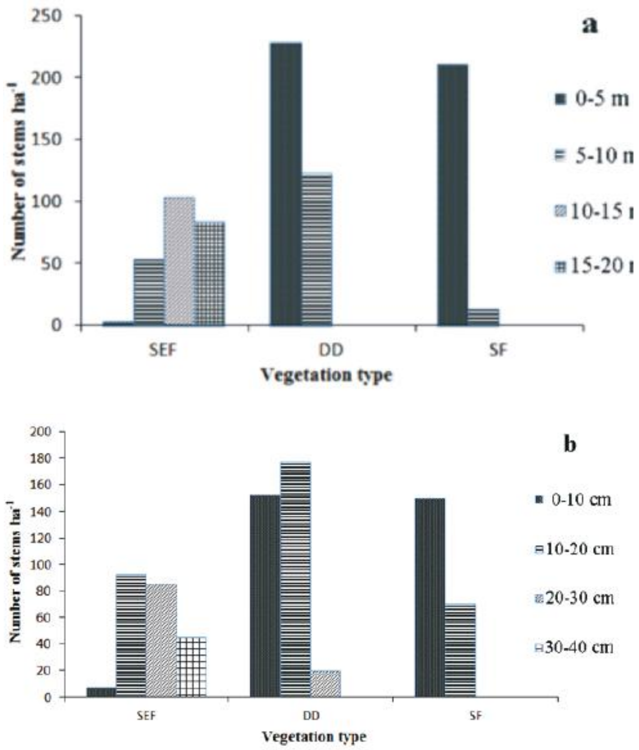

Fig. 3. Size class distribution of trees with (a) height (b) diameter across different vegetation types; SEF=semi evergreen forest, DDF=dry deciduous forest, SF=scrub forest

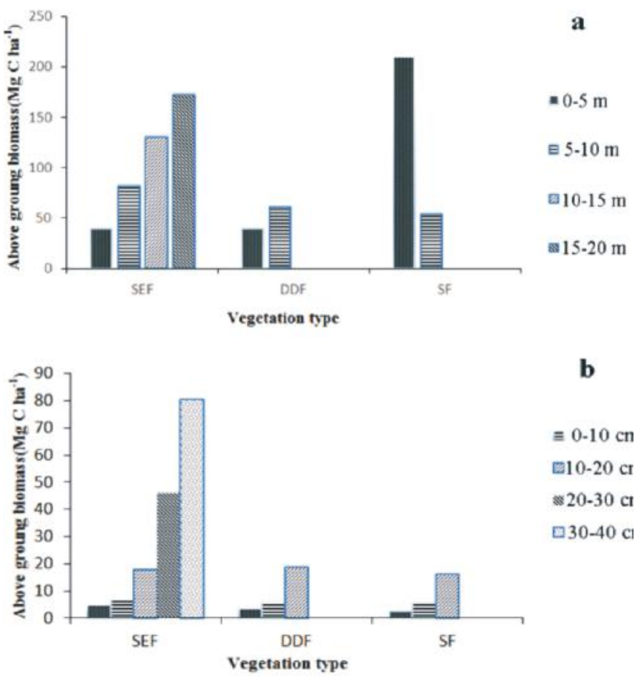

Fig. 4. Contribution of (a) diameter and (b) height to biomass across different vegetation types; SEF= semi-evergreen forest, DDF= dry deciduous forest,SF= scrub forest

these land-use types face continuous pressure in the form of wood removal, primarily fuel wood and poles for domestic use, by the people leaving in the fringe areas. Similar effects of disturbance on stem density and forest stand structure have been reported in Western Ghats (Pascal and Pelissier, 1996; Pomeroy *et al*., 2003). Similarly, maximum density of 350 stems ha^{-1} was recorded in dry deciduous forest followed by semi-evergreen (245 stems ha-1) and scrub forest (220 stems ha^{-1}) (Table 1). However, higher basal area of 12.16 m^2 ha^{-1} was recorded in semi-evergreen forest and lowest in scrub forest (1.68 m^2 ha^{-1}). These values compare with tree density and basal area reported by Devagiri *et al*., (2013) for different forest types of South-Western part of Karnataka and Swamy *et al*. (2000) for forests of Tamil Nadu. While on the higher side of the tree density range of 257-664 stems ha^{-1} and basal area range of 29-42 m^2 ha^{-1} was reported by Swamy *et al*. (2010) for tropical evergreen forests of Western Ghats region in Karnataka. Furthermore, though the density appears to be high in dry deciduous forests, the basal area was low (3.71 m^2 ha^{-1}) which indicates abundance of trees in lower diameter classes. This is consistent with many other dry deciduous forests which are characterized by the presence of lower diameter class individuals (Krishnamurthy *et al*., 2010).

Above-ground biomass (AGB) ranged between 40.62 to 243.28 Mg ha^{-1} across different vegetation types in the region (Table 1). As expected, the maximum biomass (243.28 Mg ha^{-1}) was recorded in semi-evergreen forest and minimum in scrub forest (40.62 Mg ha^{-1}). These estimates are towards the lower end of the range as compared to the Indian pattern of AGB estimates of 42-78 t ha^{-1} (Singh and Singh, 1991) and 420-649 t ha^{-1} (Rai and Proctor, 1986) and global pattern of AGB estimates of 30-273 t ha^{-1} and 213-1173 t ha^{-1} (Murphy and Lugo, 1986b) for tropical dry and wet forests, respectively. The tree layer contributed high AGB (29.68-220.78 Mg ha^{-1}) followed by shrub (10.13-21.19 Mg ha^{-1}) and herb layer (0.81-1.31 Mg ha^{-1}) to the total AGB among different vegetation types. The order of contribution of biomass by the tree layer across the types was in the order of semi-evergreen forest>dry deciduous forest>scrub. The tree layer biomass values obtained in the present study are towards the lower side as compared to the values 397-527 t ha^{-1} reported by Swamy *et al*. (2010) for evergreen forest, 46.7 t ha^{-1} reported by Singh and Singh (1991) for dry deciduous forest. Carbon density in the present study ranged from 19.09 Mg C ha^{-1} in scrub forest to 114.34 Mg C ha^{-1} in semi-evergreen forest. These results could be compared with available biomass and carbon estimates of different forest types in India. Bhat *et al*. (2003) estimated the biomass accumulation in tropical rain forests of

Table 2. Tree species composition (%) of top ten species in different forest types

Species	SEF	DDF	SF
Acacia catechu			34.09
Aegle marmelos		4.29	
Albizia amara			12.50
Anogeissus latifolia		25.71	2.27
Aporosa lindleyana	5.10		
Azadirachta indica		4.29	
Butea monosperma		3.57	
Calophyllum inophyllum	6.12		
Cassia fistula		5.00	
Chloroxylon swietenia			19.32
Diospyros melanoxylon			5.68
Emblica officinalis		5.00	
Garcinia talbotii	5.10		
Gymnosperma montana			9.09
Holigarna arnottiana	4.08		
Hopea ponga	16.33		
Lania coromandelica	4.08		
Olea dioica	8.16		
Percia macarantha	4.08		
Randia dumetorum		5.00	
Soymida febrifuga			1.14
Stereospermum chelonoides			4.55
Syzygium cumini	3.06		
Syzygium hemisphericum	3.06		
Tamarindus indica		8.57	
Terminalia alata		2.86	
Terminalia catappa			2.27
Terminalia paniculata		12.86	
Unknown			1.14

SEF=semi-evergreen forest, DDF=dry deciduous forest, SF=scrub forest

Uttar Kannada in the Western Ghats ranging from 92 to 268.49 t ha^{-1}. Chaturvedi *et al*. (2011) reported carbon density ranging from 15.6 to 151 t-C ha^{-1} in tropical dry forests of India. Srinath (2008) reported above ground biomass in the sacred groves of Kodagu district to the tune of 279.4 t ha^{-1}. According to Clark and Clark (2000), biomass accumulation in tropical forests was found to the extent of 161 to 186 t ha^{-1} while FAO (2007) estimated the average carbon density in India at 35 t ha^{-1}.

Size-class contribution to biomass was analyzed to know which diameter and height classes have contributed to total AGB. In semi-evergreen forest higher biomass was contributed by 40-50 cm DBH while in deciduous and scrub forest 20-30 cm DBH classes contributed for higher biomass (Fig. 4a). Similarly, higher biomass was accumulated in trees of 15-20 m height in semi-evergreen forest while trees having 0-10 m height contributed more to the AGB in dry deciduous and trees with 0-5 m height contributed in scrub forest (Fig. 4b). We found notable difference in species composition between forest types (Table 2). A total of 16.33% of all the trees present in semi-evergreen forest belonged to species *Hopea ponga* while, rest of the species accounted more or less uniformly to the species composition. A substantial proportion of the total tree species was contributed by a one or two species such as *Anogeissus latifolia* (25.71%) and *Terminalia paniculata* (12.86) in dry deciduous and *Acacia catechu* (34.09) *and Chloroxylon switenia* (19.32) in scrub forest. These results indicate that certain species in this area could only be found in particular forest type and not in others which calls for conservation priorities. Dawson et al. (2013) emphasized the consequences of rare species for the long-term conservation value of forest fragments. The authors argued that low density implies restrictions for regeneration, especially cross-pollination and an increased vulnerability to management interventions. Thus, the protection of existing forest fragments with specific attention to species present at low densities should have priority. Tree species contribution to density, basal area and AGB was analyzed across different forest types and presented in Table 3. In semi-evergreen forest *Hopea ponga*, with 40 stems ha^{-1} accounted for 6.59 m^2 ha^{-1} basal area and contributed 34.57 Mg ha^{-1} to the total AGB and 16.25 Mg C ha^{-1} to the carbon stock. *Olea dioca* was the next dominant tree species (20 stems ha^{-1} with 4.24 m^2 ha^{-1} basal area) which contributed 14.32 Mg ha^{-1} and 6.73 Mg C ha^{-1} of AGB and carbon stock in semi-evergreen forest. Though the stem density of *Calophyllum inophyllum* and *Aporosa lindliana* was comparatively higher in semi-evergreen forest however, these species contributed lesser AGB and carbon stock. In dry deciduous type, *Anogeissus latifolia* and *Terminalia paniculata* contributed more to AGB and carbon density while in scrub forest *Acaia catechu* and *Gymnosperma montana* species contributed higher AGB and carbon stock. Different degrees of disturbance result in forests with different AGB values and lower values are associated with more human or natural disturbance (Laumonier *et al*., 2010). In the present study disturbance intensities ranged from old-growth evergreen forests to teak monocultures. The estimated AGB and carbon values in the secondary forest, with a recovery time of almost thirty years after fire, were 2.5 times lower compared to the values in the primary forest. This is due to a lower density of stems $\geq$ 10 cm DBH, lower stand basal area and the occurrence of smaller trees in the secondary forest. Toma *et al*., (2005) compared their AGB value in the LDS (originally dipterocarp forest) with the AGB values in primary, dipterocarp forests in the region. The LDS contained 315 Mg ha^{-1}, while primary forests contained 481 to 542 Mg ha^{-1}, which means

Table 3. Species contribution to density, basal area, above ground biomass and carbon in different forest types

Species	Dry deciduous forest				Semi-evergreen forest				Scrub forest			
	D	B A	ABG	CD	D	BA	ABG	CD	D	BA	ABG	CD
Acacia catechu									75	2.15	10.67	5.01
Aegle marmelos	8	0.77	2.46	1.15								
Albizia amara									28	0.60	0.90	0.42
Anogeissus latifolia	45	3.19	17.73	8.33					5	0.17	1.12	0.53
Aporosa lindleyana					13	2.60	11.33	5.33				
Azadirachta indica	8	0.96	5.57	2.62								
Butea monosperma	6	0.59	1.97	0.93								
Calophyllum inophyllum					15	3.13	13.82	6.50				
Cassia fistula	9	0.51	4.73	2.22								
Chloroxylon swietenia									43	1.18	3.43	1.61
Diospyros melanoxylon									13	0.75	1.65	0.78
Emblica officinalis	9	0.44	1.45	0.68								
Garcinia talbotii					13	1.78	9.82	4.61				
Gymnosperma montana									20	0.90	5.32	2.50
Holigarna arnottiana					8	1.53	5.81	2.73				
Hopea ponga					40	6.59	34.57	16.25				
Lania coromandelica					10	1.97	7.16	3.36				
Olea dioica					20	4.24	14.32	6.73				
Percia macarantha					10	2.23	9.82	4.62				
Randia dumetorum	9	0.91	6.99	3.28								
Soymida febrifuga									3	0.07	0.87	0.41
Stereospermum chelonoides									10	0.35	1.04	0.49
Syzygium cumini					8	2.53	16.95	7.97				
Syzygium hemisphericum					8	2.66	17.20	8.09				
Tamarindus indica	15	2.73	15.66	7.36								
Terminalia alata	5	0.23	2.72	1.28								
Terminalia catappa									5	0.16	0.58	0.27
Terminalia paniculata	23	2.18	6.76	3.18								
Unknown									3	0.06	0.45	0.21

D= density (stems ha^{-1}), BA= basal area (m^{-2} ha^{-1}), ABG=above ground biomass (Mg ha^{-1}) and CD= carbon density (Mg C ha^{-1})

that the secondary forest contained approximately 1.5 times less AGB compared to the primary forests.

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Received 12 May, 2016; Accepted 05 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 713-718

Manuscript Number: 2362
NAAS Rating: 4.47

Moths Diversity of Kodagu District in Central Western Ghats of Karnataka, India

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***Abstract*:** Moth diversity was assessed in Kodagu district, which lies in the central Western Ghats region of peninsular India. A total of 117 species belonging to 102 genera, 28 sub-families, 17 families and 9 super families were recorded in the present study. The family Erebidae dominated with 32.48% of the total species recorded, followed by Crambidae (20.51%) and Geometridae (19.66%). Together these 3 families accounted for about 70% of the total moth diversity of the district. The next predominance of species was observed in Saturniidae and Sphingidae with 6 species in each family and Uraniidae with 4 species. These three families accounted for about 14.5% of the total moth species diversity. These results showed that 6 out of 17 families have accounted for the majority (80%) of moths diversity. Furthemore, results indicated the presence of higher species richness and diversity of moths in this region. This study is first of its kind in the peninsular region of India which has recorded and checklisted more than hundred species of moths which would form as the basis for developing strategies for conservation and management of insect diversity particularly, of moths diversity in Central Western Ghats.

Key Words: Central Western Ghats, Erebidae, Kodagu district, Lepidoptera, Moths diversity

Western Ghats region of India is the repository of diverse flora and fauna. The majority of the 34 global biodiversity hotspots identified worldwide occur within tropical regions and Western Ghats in South India is one among them (Meyers *et al*., 2000). Historically, most tropical forests have experienced varying levels of human activity and today these forests are being increasingly affected by expanding human populations, exploitation, fragmentation, and climate change. How these rapidly changing factors impact species composition, structure, and function of tropical tree communities is not well known and remain a critical gap in developing conservation plans for tropical biodiversity. As a result of disturbances at the landscape level, many species particularly, the insects become extinct. The disappearance of many species remains undocumented even before establishing their economic importance. Therefore, there is an urgent need to study the insect fauna of this region. Our knowledge on the insect fauna of India is largely based on earlier studies of Hampson (1892-1896). Although a series of revisionary studies have been subsequently carried out from different geographical regions, no exhaustive survey has so far been carried out from this region which is known for rich faunal diversity.

Among insects, the moths belonging to Lepidoptera are economically very important as the primary herbivores in the forest ecosystem. They are diverse in their habits and are adapted to variety of conditions. Being highly sensitive to change in the environment, they are more vulnerable to relatively minor disturbances and hence moths and butterflies have been considered as indicators of environmental quality. Kodagu district covering an area of 4102 km^2 is a part of the Western Ghats biodiversity hotspot and is known as highly wooded district of India with 80% of the geographical area under tree cover. In addition to forest areas the district also harbours about 1241 sacred groves with a total area of 2550 ha. The western side of the district is surrounded by three large protected areas such as Brahmagiri, Talacavery and Pushpagiri Wildlife Sanctuaries and Nagarhole National Park on the South-Eastern side. Many studies have documented the floral diversity in the district however, there is scanty information available on the insect diversity and in particular, the diversity of moths. Moths, order Lepidoptera, are one of the mega diverse groups of insects and recent reports have recorded 127000 species of moths from around the world (Alfred *et al*., 1998), of which over 12000 species have been reported from India (Chandra and Nema, 2007). The present investigation was undertaken to record the diversity of moths in the district, hitherto a less attempted task with a scanty information.

MATERIAL AND METHODS

This study was conducted in forest-coffee landscape mosaics of Kodagu district which lies in the Central Western Ghats region (70° 25' – 76° 14' E and 12° 15' – 12° 45' N). The district shares common border with Kerala in the south and is surrounded by three other districts of Karnataka *viz*., Dakshina

Kannda, Hassan, and Mysore. The eastern border of Kodagu district extends over the Mysore plateau. It has a steep West to East climatic gradients especially, for temperature and rainfall from the edge of the Ghats (Elouard, 2000). The study area, with an altitudinal range of 300-1300 m above MSL, receives average annual rainfall ranging from 1500 to 3500 mm with maximum rainfall during monsoon season (June to September). The mean maximum temperature (32°C) is observed during April and May, while December and January have the mean minimum temperature (15°C).

The study was conducted in three taluks of Kodagu district namely Virajpet, Madikeri and Somwarpet in 2014-2015. The light traps and light sheets were set in 9 locations for collection of moth specimens. The traps were set at 7 p.m. in the evening and observation /collection were made until 2AM, continuously for three days. In each place the traps were set at an interval of one month. Besides light trap and light sheet, the moths hovering around other light sources (street light, houses etc.) were also collected. Diurnal moths were also collected from the flowering plants by using insect nets. Some larval stages were also collected from their host plants and they were reared in the laboratory until their adult stage. The collected moths were brought to the laboratory at Forestry College Ponnampet, for preservation and further identification. All the specimens were identified using keys of Fauna of British India (Hampson, 1892-1896; Bell and Scott, 1937) and their current nomenclature is based on Moth of Borneo (Holloway, 1983-2011). The hierarchy of different families is based on the modern classification of insect above family level by Varshney (2003) and Van Nieukerken *et al*. (2011). Species contribution to diversity of each family was determined by calculating the dominance index = ni X 100/ N. Where (ni) is individuals of particular species and (N) is total number of species.

RESULTS AND DISCUSSION

The present study recorded 117 species belonging to 102 genera, 28 sub-families, 17 families and 9 super families (Table 1). The family Erebidae dominated with 32.48% of the total species recorded, followed by the family Crambidae (20.51%) and Geometridae (19.66%). Together these 3 families accounted for about 70% of the total moth diversity of the district. The next predominance of species was observed in Saturniidae and Sphingidae with 6 species in each family and Uraniidae with four species. These three families accounted for about 14.5% of the total diversity (Fig. 1). These results showed that about 5-6 out of 17 families accounted for the majority (80%) of moths diversity in the district. Overall higher species richness and diversity was recorded from this region.

The diversity of moth fauna as recorded by the earlier studies from different part of India showed a wide variation. Ghosh (2003) recorded an increase in the number of species from the family Larentiinae with an increase in the latitude. Similar trends were also observed with an increase in altitude in the tropics by Holloway (1993, 1997). The present investigation showed highest percentage of the species from the families of Erebidae, Crambidae and Geometridae (70 %). Similary, Kailash and Sambath (2013) have also reported the dominance of the families such as Geometridae (48%), Erebidae (26%), Drepanidae (8%) and Crambidae (7%) from Tawang district in Arunachal Pradesh .The family Geometridae being a largest family in the order Lepidoptera has recorded its dominance in Tawang district (Kailash and Sambath, 2013) similar dominance of Geometridae (260 of 460 species) was

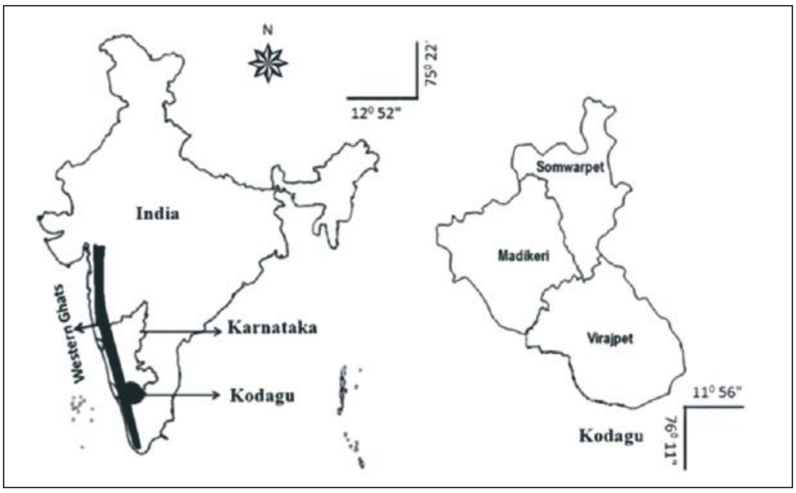

Fig.1. Map of the study area showing the location of Kodagu district of Western Ghats in Karnataka

Table 1. The diversity of moths in Kodagu district in Central Western Ghats of Karnataka, India

Super family	Family	Sub-family	No. of genera	No. of species	Species richness	Species contribution to diversity (%)
Noctuoidea	Erebidae	Arctiinae	13	16		32.48
		Calpinae	1	1		
		Erebinae	8	9	38	
		Lymantriinae	8	8		
		Aganainae	2	3		
		Hadeninae	1	1		
	Noctuidae	Noctuinae	1	1	1	0.85
	Nolidae	Eligminae	1	1	1	0.85
Bombycoidea	Bombaicadae	Bombicenea	1	1	1	0.85
	Eupterotidae	Panacelinae	1	1	1	0.85
	Saturniidae	Saturniinae	4	6	6	5.13
	Sphingidae	Macroglossinae	3	4		5.13
		Smerinthinae	1	1	6	
		Sphinginae	1	1		
Calliduloidea	Callidulidae	Callidulinae	1	1	1	0.85
Pyraloidea	Crambidae	Acentropinae	2	2		20.51
		Spilomelinae	20	22	24	
	Pyralidae	Galleriinae	2	2	2	1.71
Geometroidea	Geometridae	Desmobathrinae	2	2		19.66
		Ennominea	4	4		
		Geometrinae	6	11		
		Larentiinae	2	2	23	
		Sterrhinae	4	4		
	Uraniidae	Microniinae	4	4	4	3.42
Hyblaeoidea	Hyblaeidae	-	1	1	1	0.85
Lasiocampoidea	Lasiocampidae	Lasiocampinae	3	3	3	2.56
Cossoidea	Metarbelidae	-	1	1	1	0.85
	Cossidae	Zeuzerinae	1	1	1	0.85
Zygaenoidea	Zygaenidae	Chalcosiinae	2	2		2.56
		Eupterotinae	1	1	3	
Total 9	17	28	102	117	117	100

also recorded by Ghosh (2003) in Sikkim. In respect of the moth species from other families, there was a variation in their percentage occurrence at Kodagu district when compared with the findings of Ghosh (2003) and Kailash and Sambath (2013). Mathew *et al*. (2004) from Shendurny Wildlife Sanctuary in Kerala reported 129 species of moth from nine families, with the dominance of Noctuidae (including Erebidae) and Pyralidae the different families. These differences could be attributed to the habitat condition, floristic diversity, altitude latitude and associated factors prevailing in the respective regions.

In the present studies, one hundred and seventeen moths were recorded and would form as the basis for developing strategies for conservation and management of insect diversity particularly, of moths diversity which are the important indicators of the ecosystem function and health. However, the present investigation was only a preliminary study and species collected were only indicative but not exhaustive. Considering the area under tree cover in the Kodagu district, the sampling period and sampling sites seemed to be insufficient. Detailed exhaustive survey with different higher sampling intensity and different methods of collections may provide an ample data for preparation of check list of moths in Kodagu district.

Table 2. List of moths collected from Kodagu district

Super family	Family	Sub-family	Species
Noctuoidea	Erebidae	Lymantriinae	*Arctornis sp*
Noctuoidea	Erebidae	Lymantriinae	*Euproctis sp.*
Noctuoidea	Erebidae	Lymantriinae	*Lymantria concolor*
Noctuoidea	Erebidae	Lymantriinae	*Olene mendosa*
Noctuoidea	Erebidae	Lymantriinae	Orvasca postica
Noctuoidea	Erebidae	Lymantriinae	*Orgyia postica*
Noctuoidea	Erebidae	Lymantriinae	*Orvasca subnotota*
Noctuoidea	Erebidae	Lymantriinae	*Perina nuda*
Noctuoidea	Erebidae	Aganainae	*Asota plaginota*
Noctuoidea	Erebidae	Aganainae	*Asota caricae*
Noctuoidea	Erebidae	Aganainae	*Digama marchalii figurate*
Noctuoidea	Erebidae	Hadeninae	*Spodoptera litura*
Noctuoidea	Erebidae	Calpinae	*Eudocima mate rna*
Noctuoidea	Erebidae	Arctiinae	*Creatonotos gangis*
Noctuoidea	Erebidae	Arctiinae	*Creatonotos transiens*
Noctuoidea	Erebidae	Arctiinae	*Eressa confinis*
Noctuoidea	Erebidae	Arctiinae	*Estigmene sp*
Noctuoidea	Erebidae	Arctiinae	*Estigmene vittata*
Noctuoidea	Erebidae	Arctiinae	*Euchromia polymena*
Noctuoidea	Erebidae	Arctiinae	*Amata Sp.*
Noctuoidea	Erebidae	Arctiinae	*Hemonia orbiferana*
Noctuoidea	Erebidae	Arctiinae	*Macrobrochis gigas*
Noctuoidea	Erebidae	Arctiinae	*Mangina argus*
Noctuoidea	Erebidae	Arctiinae	*Nepita conferta*
Noctuoidea	Erebidae	Arctiinae	*Nyctemera coleta*
Noctuoidea	Erebidae	Arctiinae	*Olepa ricini*
Noctuoidea	Erebidae	Arctiinae	*Utetheisa pulchelloides*
Noctuoidea	Erebidae	Arctiinae	Cyana peregrine
Noctuoidea	Erebidae	Arctiinae	Cyana sigma
Noctuoidea	Erebidae	Erebinae	*Bastilla fulvotaenia*
Noctuoidea	Erebidae	Erebinae	*Bastilia joviana*
Noctuoidea	Erebidae	Erebinae	*Bastilla crameri*
Noctuoidea	Erebidae	Erebinae	*Chalciope mygdoni*
Noctuoidea	Erebidae	Erebinae	*Erebus ephesperis*
Noctuoidea	Erebidae	Erebinae	*Sympis rufibasis*
Noctuoidea	Erebidae	Erebinae	*Thyas coronate*
Noctuoidea	Erebidae	Erebinae	*Trigonodes hyppasia*
Noctuoidea	Erebidae	Erebinae	*Spirama sp.*
Noctuoidea	Noctuidae	Noctuinae	*Agrotis sp*
Noctuoidea	Nolidae	Eligminae	*Eligma narcissus*
Bombycoidea	Bombaicadae	Bombicenea	*Ocinara sp.*
Bombycoidea	Eupterotidae	Panacelinae	*Ganisa spp*
Bombycoidea	Saturniidae	Saturniinae	*Actias maenas*
Bombycoidea	Saturniidae	Saturniinae	*Actias selene*
Bombycoidea	Saturniidae	Saturniinae	*Actias atlus*
Bombycoidea	Saturniidae	Saturniinae	*Antheraea mylitta*
Bombycoidea	Saturniidae	Saturniinae	*Attacus taprobanis*
Bombycoidea	Saturniidae	Saturniinae	*Loepa katinka*
Bombycoidea	Sphingidae	Macroglossinae	*Daphnis nerii*
Bombycoidea	Sphingidae	Macroglossinae	*Macroglossum belis*
Bombycoidea	Sphingidae	Macroglossinae	*Theretra aldenlandis*
Bombycoidea	Sphingidae	Macroglossinae	*Theretra nessus*
Bombycoidea	Sphingidae	Smerinthinae	*Marumba dyras*
Bombycoidea	Sphingidae	Sphinginae	*Acherontia lachesis*
Hyblaeoidea	Hyblaeidae	-	*Hyblaea puera*

Cont.......

Lasiocampoidea	Lasiocampidae	Lasiocampinae	*Gastropacha pardale*
Lasiocampoidea	Lasiocampidae	Lasiocampinae	*Trabala vishnou*
Lasiocampoidea	Lasiocampidae	Lasiocampinae	*Lebeda nobilis*
Cossoidea	Metarbelidae	-	*Indarbela quadrinotata*
Cossoidea	Cossoidae	Zeuzerinae	Polyphagozerra coffeae
Zygaenoidea	Zygaenidae	Chalcosiinae	*Eterusia aedea*
Zygaenoidea	Zygaenidae	Chalcosiinae	*Yclosia papilionaris*
Zygaenoidea	Zygaenidae	Eupterotinae	*Eupterote spp*
Colliduloidea	Collidulidae	Collidulinae	*Tetragonus calamitus*
Geometroidea	Geometridae	Desmobathrinae	*Eumelea ludovicata*
Geometroidea	Geometridae	Desmobathrinae	*Naxa sp.*
Geometroidea	Geometridae	Ennominea	*Fascellina plagiata*
Geometroidea	Geometridae	Ennominea	*Hypomecis sp.*
Geometroidea	Geometridae	Ennominea	*Ourapteryx sp*
Geometroidea	Geometridae	Ennominea	*Scardamia spp*
Geometroidea	Geometridae	Geometrinae	*Agathia hilarata*
Geometroidea	Geometridae	Geometrinae	*Agathia laetata*
Geometroidea	Geometridae	Geometrinae	*Agathia magnifica*
Geometroidea	Geometridae	Geometrinae	*Agathia sp. 1*
Geometroidea	Geometridae	Geometrinae	*Agathia sp. 2*
Geometroidea	Geometridae	Geometrinae	*Berta sp*
Geometroidea	Geometridae	Geometrinae	*Betra chrysolineata*
Geometroidea	Geometridae	Geometrinae	*Comostola laesaria*
Geometroidea	Geometridae	Geometrinae	*Dysphania percota*
Geometroidea	Geometridae	Geometrinae	*Maxates sp.*
Geometroidea	Geometridae	Geometrinae	*Pelagodes sp*
Geometroidea	Geometridae	Larentiinae	*Chloroclysta truncate*
Geometroidea	Geometridae	Larentiinae	*Eustroma melancholicum*
Geometroidea	Geometridae	Sterrhinae	*Chrysocraspeda sp*
Geometroidea	Geometridae	Sterrhinae	*Problepsis sp*
Geometroidea	Geometridae	Sterrhinae	*Scopula opicata*
Geometroidea	Geometridae	Sterrhinae	*Traminda mundissima*
Geometroidea	Uraniidae	Microniinae	*Acropteris sp.*
Geometroidea	Uraniidae	Microniinae	*Micronia aculeata*
Geometroidea	Uraniidae	Microniinae	*Pseudomicronia sp*
Geometroidea	Uraniidae	Microniinae	*Acropteris sp.*
Pyraloidea	Crambidae	Acentropinae	*Eoophyla sp*
Pyraloidea	Crambidae	Acentropinae	*Parapoynx stagnalis*
Pyraloidea	Crambidae	Spilomelinae	*Leucinodes orbonalis*
Pyraloidea	Crambidae	Spilomelinae	*Maruca vitrata*
Pyraloidea	Crambidae	Spilomelinae	*Agrotera basinotata*
Pyraloidea	Crambidae	Spilomelinae	*Scirpophaga sp.*
Pyraloidea	Crambidae	Spilomelinae	*Eurrhyparodes bracteolalis*
Pyraloidea	Crambidae	Spilomelinae	*Agathodes ostentalis*
Pyraloidea	Crambidae	Spilomelinae	*Batyodes flavibasalis*
Pyraloidea	Crambidae	Spilomelinae	*Cirrhochrista brizoalis*
Pyraloidea	Crambidae	Spilomelinae	*Cnaphalocrocis medinalis*
Pyraloidea	Crambidae	Spilomelinae	*Conogethes punctiferalis*
Pyraloidea	Crambidae	Spilomelinae	*Cydalima spp*
Pyraloidea	Crambidae	Spilomelinae	*Diaphania indica*
Pyraloidea	Crambidae	Spilomelinae	*Filodes fulvidorsalis*
Pyraloidea	Crambidae	Spilomelinae	*Glyphodes sp1*
Pyraloidea	Crambidae	Spilomelinae	*Glyphodes sp2*
Pyraloidea	Crambidae	Spilomelinae	*Glyphodes sp3*
Pyraloidea	Crambidae	Spilomelinae	*Nausinoe geometralis*
Pyraloidea	Crambidae	Spilomelinae	*Omiodes indicata*

Cont.......

Pyraloidea	Crambidae	Spilomelinae	*Parotis marginata*
Pyraloidea	Crambidae	Spilomelinae	*Pygospila tyres*
Pyraloidea	Crambidae	Spilomelinae	*Talanga sp.*
Pyraloidea	Crambidae	Spilomelinae	*Terastia meticulosalis*
Pyraloidea	Pyralidae	Galleriinae	*Achroia grisella*
Pyraloidea	Pyralidae	Galleriinae	*Galleria mellonella*

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Received 23 June, 2016; Accepted 20 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 719-723

Manuscript Number: 2363
NAAS Rating: 4.47

Effect of Regulated Irrigation at Delayed Intervals and Calcium Sprays on Yield and Quality of Litchi (*Litchi chinensis* Sonn.) Cv. Dehradun

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Abstract: An experiment was conducted to study the effect of calcium sprays on yield and quality of litchi Cv. Dehradun under regulated irrigation at delayed intervals. Trees were subjected to regulated irrigations at 3, 6, 9 and 12 days intervals and were sprayed with $CaCl_2$ @ 1, 1.5 and 2% concentration and compared with irrigation at 3 days interval without any $CaCl_2$ spray. The irrigation at 6 days intervals and sprayed with 2% $CaCl_2$ (T_4) was the best treatment with least fruit cracking (8.27%) and fruit drop (61.33%) and maximum fruit yield (53.09 kg/tree), fruit weight (20.36 gm), fruit length (3.81 cm), fruit diameter (3.43cm), pulp weight (11.29 gm), ascorbic acid (47.07 mg/100gm) and pectin content (0.74%), this was followed by T_3 (Irrigation at 6 days interval +1.5 % $CaCl_2$) which recorded 18.50 gm fruit weight, 3.48 cm fruit length, 3.04 cm fruit diameter, 10.75 gm pulp weight, 46.14 mg/100gm ascorbic acid and 0.65 (%) pectin with 9.9% fruit cracking and 66.91% fruit drop.

Key Words: Calcium chloride, Irrigation, Litchi, Yield and quality

Litchi requires optimum soil moisture for its optimum growth, development and fruit production. An average litchi plant requires 600-800 mm water, but the water requirement may vary with plant age or size as well as seasons (Spohrer *et al*., 2006). The vegetative and reproductive growth can be manipulated by differential management of irrigation. While ample water helps in faster growth, mild water stress may promote the reproductive phase, especially at the time of fruit bud differentiation. The litchi plants generally require regular irrigation at intervals of 2-3 days. Efficient water management can overcome several physiological disorders such as poor sex ratio, poor fruit set, heavy fruit drop and fruit cracking.

Heavy fruit drop, fruit cracking and short harvesting period are the major problems of litchi orcharding. Calcium has been reported to improved fruit quality in litchi. The foliar application of $CaCl_2$ increase the calcium content of the litchi fruit skin with a concomitant increase in skin strength and fruit cracking (Haq and Rab, 2012). The increase in calcium during early stages of fruit development provides a good basis of fruit pericarp development and the final increase in protopectin content in the pericarp ensures good fruit pericarp quality (Peng *et al*., 2004). Litchi flowers in March and the fruit matures during the month of June, a season characterized by high temperatures and relatively low rainfall (Khurshid *et al*., 2004). Thus, water deficit is a major limiting factor in litchi fruit production. Due to ground water depletion and changing climate, water has become scarce thus the present investigation was undertaken to find out best combination of irrigation interval and calcium concentration to optimize fruit yield and quality of litchi with less irrigation.

MATERIAL AND METHODS

The experiment was carried out at the FoA Udheywalla, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India during 2013 on twenty year old plant of litchi cv. Dehradun were maintained under uniform cultural practices. The experiment was Randomised Block Design with ten treatments each replicated thrice with single tree as unit per treatment. Pre-harvest sprays of calcium chloride salt at 1, 1.5 and 2 per cent. $Cacl_2$ was given at fruit set stage and at 21 days intervals thereafter till harvest and with spray volume of 7 litres plant^{-1}. The total number of sprays was four and total no. of irrigations was 25, 14, 11 and 8 at 3, 6, 9 and 12 days intervals, respectively. Irrigation due to rainfall was uniform in all the treatments. The control plants were sprayed with water alone. Mature fruits under various treatments were harvested at the same time and were analysed for various physico-chemical characteristics. The percentage of fruit drop and cracking was recorded on the basis of fruit set on tagged branches of the tree. For fruit yield, total number of fruits and weight on recorded for yield tree^{-1}. The size of the fruits and specific gravity was measured by a vernier caliper and water displacement method. Pulp weight was obtained by subtracting the seed weight + peel weight from the total fruit weight. Total soluble solids of the fruit juice were determined by hand refractometer. Titratable acidity (%) and ascorbic acid (mg/100gm pulp) were estimated by titration method as described in AOAC (1990). The TSS/acid ratio was determined by dividing total soluble solids with titratable acidity. Anthocyanin content (mg/100ml) was estimated according to the method given by Ranganna (1995). Pectin was extracted by the method of Rangana (1977).

RESULTS AND DISCUSSION

Physiological parameters: The irrigation at 6 days intervals and Calcium sprays @ 2% was most effective in reducing the incidence of fruit cracking (8.27%) and fruit drop (61.33%) and resulted into highest yield (53.09 kg tree^{-1}). This was followed by irrigation at 6 days interval and 1.5% $CaCl_2$, which recorded 9.90% fruit cracking, 66.91% fruit drop and 50.36 kg tree^{-1} yield. Irrigation at 12 days intervals and calcium chloride sprays @ 1% showed maximum incidence of fruit cracking (22.71%) and fruit drop (79.37 %) and minimum yield (37.45 kg tree^{-1}) followed by T9 i.e., 21.50 % fruit cracking, 78.47% fruit drop and 38.33 kg tree^{-1} yield which was significantly lower than control i.e. 14.51 %, 75.71% and 42.70 kg tree^{-1} of fruit cracking, fruit drop and fruit yield, respectively. In the present study calcium helped to control fruit cracking and fruit drop even at longer irrigation intervals when compared to control. Without calcium sprays fruit cracking in litchi increases with a longer irrigation interval as observed in the present study and the same fact has been corroborated by Mitra and Pathak (2010) and Rab and Haq (2012), but calcium at all concentration (1, 1.5 and 2%) helped to control fruit cracking and fruit drop till 6 days irrigation intervals and when irrigation intervals were further increased to 9 and 12 days effect of calcium was overcome by water stress. Batten *et al.* (1994) also reported that water deficits experienced by the unirrigated trees significantly reduced fruit drop in litchi. This may have been due to suppression of vegetative growth due to irrigation. In the present study also reduction in fruit drop upto 6 days might due to mild water stresses or synergistic effect of calcium sprays and mild water stress and increase in fruit drop with further increase in irrigation interval to 9 and 12 days (78.47% and 77.65%, respectively) might be due to excessive water deficit. The effect of calcium treatments in reducing pre harvest drop percentage in comparison to control was reflected on increasing the number of retained fruits per trees. Therefore, the increase of the total yield (kg tree^{-1}) as a result of Ca treatments was mainly due to increasing the number of retained fruits tree^{-1}. Veverka and Pavlacka (2012) observed that increase in irrigation interval to 9 and 12 days resulted into excessive water stress and also nullified the effect of calcium sprays.

Morphological characters: Irrigation at 6 days intervals and calcium sprays @ 2 % showed maximum fruit weight (20.36 g), fruit length (3.81 cm), fruit diameter (3.43 cm) and pulp weight (11.29 gm), which was significantly higher than other treatments as well as control i.e 15.38 gm, 3.07 cm, 2.66 cm and 9.08 gm of fruit weight, fruit length, fruit diameter and pulp weight, respectively. This was followed by T_3 (irrigation at 6 days interval and 1.5% $CaCl_2$) which recorded 18.50 gm fruit weight, 3.48 cm fruit length, 3.04 cm fruit diameter and 10.75 g of pulp weight. Irrigation at 12 days intervals and calcium chloride sprays @ 1% showed minimum fruit weight, fruit length (2.86 cm), fruit diameter (2.53 cm) and pulp weight (8.37 g), which was significantly lower than control i.e., 15.38 g, 3.07 cm, 2.66 cm, 9.08 g of fruit weight, fruit length, fruit diameter, and pulp weight, respectively (Alila and Achumi, 2012 in litchi) Present results reveal that calcium helped to increase fruit weight and corresponding fruit length and fruit diameter and subsequent pulp weight even at longer irrigation intervals as compared to control. Increase in irrigation interval from 3 to 6 days resulted into increased fruit weight and corresponding fruit length and fruit diameter and subsequent pulp weight.

Specific gravity (Table 1) was that it was maximum when the trees were irrigated at 9 days interval and sprayed with 2% calcium chloride and it was significantly higher than other treatments. However, with the foliar application of calcium chloride, fruits with maximum specific gravity of 1.199 have been produced in T_7 followed by T_6 (1.187). Calcium chloride sprays in the present study have helped in increasing fruit weight more predominantly as compared to its volume, which might have resulted in fruits with increased specific gravity. Haq and Rab (2012) observed specific gravity of litchi fruit was higher with longer irrigation intervals.

Biochemical parameters: Irrigation at 9 days interval and 2% $CaCl_2$ showed maximum TSS (18.94%) followed by Irrigation at 9 days intervals and calcium chloride spray @ 1.5% (18.87%) and minimum TSS was found in control (14.66%). The increase in total soluble solids with the application of calcium has been attributed to the conversion of starch and other polysaccharides to sugars (Singh, 1988). Increase in TSS with the increase in irrigation interval was observed during the present study. These results are in line with the findings of Al- Yahyai and Al- Kharusi (2012), who have reported that TSS was highest in weekly irrigated tress and lowest in fruits of daily irrigated trees in dates. The amount of reducing sugars, total sugars and sucrose were lowest in fruits from weekly irrigated trees. Further increase in irrigation interval from 9 to 12 days decreases TSS content (17.36%). This may be due to extreme water stress that reduced photosynthate (Edwards and Dixon, 1995) and carbohydrate accumulation in fruits of severely stressed trees in dates.

Maximum titratable acidity was recorded in control (irrigation at 3 days interval) i.e., 0.69% followed by Irrigation

Table 1. Effect of irrigation intervals and calcium sprays on physiological characters of litchi (*Litchi chinensis* Sonn.) cv. Dehradun

Treatments	Fruit cracking (%)	Fruit drop (%)	Fruit yield (kg tree^{-1})	Fruit weight (gms)	Fruit length (cm)	Fruit diameter (cm)	Pulp weight (gms)	Specific gravity
T_1 (Irrigation at 3 days interval [control])	14.51	75.71	42.70	15.38	3.07	2.66	9.08	1.042
T_2 (Irrigation at 6 days interval +1 % $CaCl_2$)	10.48	67.64	49.27	17.59	3.35	2.93	10.36	1.078
T_3 (Irrigation at 6 days interval +1.5 % $CaCl_2$)	9.90	66.91	50.36	18.50	3.48	3.04	10.75	1.080
T_4 (Irrigation at 6days interval +2 % $CaCl_2$)	8.27	61.33	53.09	20.36	3.81	3.43	11.29	1.088
T_5(Irrigation at 9 days interval +1 % $CaCl_2$)	13.69	69.72	42.83	16.71	3.10	2.73	9.69	1.183
T_6 (Irrigation at 9 days interval +1.5 % $CaCl_2$)	12.59	68.52	43.31	16.83	3.16	2.75	9.78	1.187
T_7(Irrigation at 9 days interval +2 % $CaCl_2$)	12.25	67.73	44.54	17.35	3.27	2.84	9.87	1.199
T_8 (Irrigation at 12 days interval +1 % $CaCl_2$)	22.71	79.37	37.45	`12.56	2.86	2.53	8.37	1.058
T_9(Irrigation at 12 days interval +1.5 %$CaCl_2$)	21.50	78.47	38.33	13.43	2.91	2.57	8.48	1.068
T_{10} (Irrigation at 12 days interval +2 % $CaCl_2$)	19.72	77.65	39.26	14.30	2.96	2.64	8.55	1.070
CD (p=0.05)	1.38	1.45	1.47	1.52	0.16	0.15	1.53	0.012

Total no. of irrigations: At 3 days interval-25; At 6 days interval-14; At 9 days interval- 11; At 12 days interval-8
Total no. of sprays of $cacl_2$: 4 no's

at 12 days interval and spray with 1% $CaCl_2$ i.e., 0.67% and minimum value was recorded in irrigation at 6 days interval and spray with 2% $CaCl_2$ i.e., 0.43%. The reason for decrease in acidity content of fruit with the foliar application of nutrients might be due to increase in translocation of carbohydrates and increase in metabolic conversion of acid to sugars. The results obtained in the present study can be substantiated with the pattern of conversion of acids into sugars. Similar results have been obtained with calcium by Vishwakarma *et al*. (2013) in aonla. With the increase in irrigation interval from 3 to 12 days, acidity of the litchi fruit was also increased (0.67%) but was less than control (0.69%). These results are in accordance with the findings of Bryla *et al*. (2009) who reported that irrigation treatments that received less than enough water to maximize production (and therefore probably experiencing water stress) often had higher titratable acidity in Highbush blueberry.

The maximum TSS: Acid ratio of 43.20 was recorded in irrigation at 6 days interval and spray with $CaCl_2$ 2% followed by irrigation at 6 days interval and spray with $CaCl_2$ 1.5% i.e., 39.37. Minimum value was recorded in irrigation at 12 days interval and spray with $CaCl_2$ 1% i.e., 26.27, which was even higher than control (21.41). The reason could be that all the treatments increased the total soluble solids and reduced acidity considerably as compared to control. With the increase in irrigation interval from 3 to 6 days TSS: acid ratio of litchi fruit also increased. The present study also inconsonance with the findings of Sptiropoulos *et al.* (2010) who stated that regulated deficit irrigation increased soluble solids/ acid ratio in clingstone peaches as compared to control.

Maximum ascorbic acid of 47.07 mg/100gm was observed in irrigation at 6 days interval and spray with 2% $CaCl_2$ followed by irrigation at 6 days interval and spray with 1.5% $CaCl_2$ i.e., 46.14 mg/100gm, which was significantly higher than control (44.15 mg/100 gm). irrigation at 12 days interval and spray with 1% $CaCl_2$ showed less content of ascorbic acid i.e. 43.42 mg/100 gm. The beneficial effect of calcium on ascorbic acid content is due to increased synthesis of L- ascorbic acid from its precursor glucose-6-phosphate. Increase in irrigation interval from 3 to 6 days resulted into increased in ascorbic acid content but when irrigation interval was further increased to 9 and 12 days a significant decrease in ascorbic acid content was recorded. The results are in agreement with those obtained by Kumar *et al.* (2001) in litchi. The reason for low ascorbic acid content at longer irrigation intervals might be due to the reason that calcium uptake depends on water availability and transpiration hence low water content might have neutralized the beneficial effect of calcium in increasing ascorbic acid content.

The anthocyanin content of litchi fruit was influenced by irrigation intervals and calcium sprays. Irrigation at 9 days interval and spray with $CaCl_2$ 1 %) showed maximum anthocyanin content (55.27 mg/100 ml) followed by irrigation at 9 days interval and spray with $CaCl_2$ 1.5% i.e., 54.59 mg/100 ml and irrigation at 12 days interval and spray with $CaCl_2$ 1% recorded minimum anthocyanin content i.e., 46.51 mg/100 ml, which was even lower than control (50.05 mg/100 ml). The reason for increase in anthocyanin content of litchi pericarp may due to calcium, since calcium increases skin colour of litchi. These results also corroborate with the findings of Kadir (2005) in 'Jonathan' apples who indicated that skin colour of apple fruits was improved by spraying the trees with calcium. Increase in irrigation intervals to 6 and 9

Table 2. Effect of irrigation and calcium sprays on various biochemical parameters of Litchi (*litchi chinensis* Sonn.) cv. Dehradun

Treatments	TSS (%)	Titratableacidity (%)	TSS: Acid ratio	Ascorbic acid (mg/100gm)	Anthocyanin content (mg/100ml)	Pectin content (%)
T_1 (Irrigation at 3 days interval [control])	14.66	0.69	21.41	44.15	50.05	0.42
T_2 (Irrigation at 6 days interval +1 % $CaCl_2$)	16.58	0.48	34.99	45.71	51.77	0.61
T_3 (Irrigation at 6 days interval +1.5 % $CaCl_2$)	17.54	0.47	39.37	46.14	52.38	0.65
T_4 (Irrigation at 6days interval +2 % $CaCl_2$)	18.28	0.43	43.20	47.07	53.25	0.74
T_5 (Irrigation at 9 days interval +1 % $CaCl_2$)	18.63	0.59	32.32	45.60	54.14	0.46
T_6 (Irrigation at 9 days interval +1.5 % $CaCl_2$	18.87	0.57	33.20	45.73	54.59	0.48
T_7 (Irrigation at 9 days interval +2 % $CaCl_2$)	18.94	0.51	39.81	45.91	55.27	0.56
T_8 (Irrigation at 12 days interval +1 % $CaCl_2$)	17.36	0.67	26.27	43.42	46.51	0.32
T_9 (Irrigation at 12 days interval +1.5% $CaCl_2$)	17.53	0.65	27.32	43.56	47.82	0.35
T_{10} (Irrigation at 12 days interval +2 % $CaCl_2$)	17.79	0.62	28.81	43.74	48.54	0.38
CD (p=0.05)	1.42	0.16	10.12	0.95	5.81	0.16

Total no. of irrigations: At 3 days interval-25; At 6 days interval-14; At 9 days interval- 11; At 12 days interval-8
Total no. of sprays of $cacl_2$: 4 no's

days a significant increase in anthocyanin content (55.27 mg/100 ml) was recorded. These results are in line with the finding of Roby *et al.* (2004) who has reported that limited water deficit can also enhance proportional anthocyanin content. Although some of this due to increased skin/pulp ratio, part of it is independent of size influences. It is suspected that this is due to differential growth sensitivity of the inner pulp vs. the skin. ^{0}Brix and anthocyanin contents increases the berry size, but not proportional to berry enlargement, resulting in a concentration effect. Maximum pectin content of 0.74% was recorded in T_4 (irrigation at 6 days interval and spray with $CaCl_2$ 2%) followed by irrigation at 6 days interval and spray with $CaCl_2$ 1.5% i.e., 0.65% and it was observed to be significantly higher than control (0.42%) and irrigation at 12 days interval and spray with $CaCl_2$ 1% recorded minimum pectin content i.e. 0.32%. The increased content of pectin in litchi fruits with the spray of calcium has been found to correlate with the fruit firmness. These findings substantiate the earlier reports on the aspects by Yadav *et al*. (2003) in ber and Rajput *et al.* (2008) in guava.

Increase in irrigation interval from 3 to 6 days results into increased pectin content but when irrigation interval was further increased to 9 and 12 days a significant decrease in pectin content was recorded. The possible reason for initial increase in pectin content when irrigation interval was increased from 3 to 6 days might be due to the low levels of hydrophobic groups (methylester and O- acetyl) and the less intensive degradation of the hydrophilic galactan, arabinan and arabinogalactan in the cell wall may be implicated in maintaining the hydration status of the cells under water deficit. These results are in conformity with the results of Gribaa *et al.* (2012) in date palm. Thus, synergistic effects of mild water deficits and calcium application resulted into improved biochemical quality parameters of litchi but with further increase in irrigation intervals from 6 to 9 and further to 12 days caused severe water stress and resulted into loss in quality.

CONCLUSION

Thus, it can be suggested that if litchi is sprayed with 2% $CaCl_2$ better fruit yield and quality can be obtained even with less irrigation thereby, optimising the use of precious input. It was observed that better quality fruits (in terms of yield, fruit weight, fruit length, fruit diameter, pulp weight, ascorbic acid and pectin content with less fruit cracking and fruit drop) in litchi can be produced with 4 sprays of 2% $CaCl_2$ with 14 irrigation i.e. 11 less irrigations than recommended.

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Received 22 March, 2016; Accepted 22 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 724-729

Manuscript Number: 2364
NAAS Rating: 4.47

Performance of Garlic under Agri-Horti-Silvicultural System in Relation to Physiological Behaviour and Yield

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Abstract: The garlic crop was evaluated for yield and eco-physiological behavior under agri-horti-silvicultural model involving different combination of fruit trees and poplar (*Populus deltoides* Bartr. Ex Marsh.). Net photosynthesis, stomatal conductance and transpiration rate in garlic were recorded higher in partial shading of pear x plum combination than in highly shaded area of poplar trees. Garlic showed better performance under partial shade in yield and yield contributing parameters, but decreased as canopy advanced with age. These parameters showed inverse relationship with canopy age and vice versa with more yield reduction under sixth year old canopy followed by preceding years and control. Micro-climatic interaction and resultant effect on physiology, yield and economics of garlic under canopy are presented in this paper. The transpiration (E) rate of garlic was lowest under shade conditions leading to more water use efficiency in shade conditions than in open. It is suggested that to minimize resource competition and improve physiological processes of crops, canopy management is essential to ensure better yield under pear-poplar based agri-horti-silvicultural system.

***Key Words*: ** Garlic, Inter-cropping, Poplar, Physiology, Shade, Yield

Agricultural crop inputs are subsidized in India (varies from state to state) and governments are under pressure to phase out the subsidies to reduce the fiscal burden. It may result in to increase in cost of cultivation per unit area. Therefore, farmers are looking for best alternative options. Moreover monoculture of rice-wheat rotation not only depleted the water table but also over exploiting the nutrients and deteriorates the soil structure. The present situation demands diversification towards more remunerative field crops. Many alternatives including cultivation of horticultural crops have been suggested, but despite all efforts, area under horticulture crops is not increasing at desired rate of policy planners. Long juvenile period in fruit crops, high production cost and shrinking of agricultural land are the major contributing factors besides many other factors viz. shortage of water, labour shortage, population pressure, low cost benefit ratio and poor soil health etc. under such circumstances it is essential to develop appropriate farming system, which should improve the economical status of farmers, provide the employment opportunities and support the development of agro-base industry in the region. It is becoming important to treat agricultural land as business unit, which may increase output in terms of biomass and evenly distribute income year around. Above all, the efficient land use system must cater to diverse needs of ever growing population such as food, fiber, fodder, fruit, timber, etc. Obviously, such requirements can be fulfilled by an integrated farming system involving agriculture, horticulture, forestry and/or animal husbandry (Chauhan and Ritu, 2005).

Farmers tried many alternatives to rice-wheat rotation which includes oilseeds, cash crops, fruits and vegetables etc. Although not much success was achieved because of inadequate technical and financial support (Chauhan and Mangat, 2006). Even though, horticulture can emerge as one of the major growth engine in shifting large area from wheat-paddy cultivation. It may solve many socio-economic and ecological problems of North-western states of India i.e. insufficient storage space for wheat and rice, declining soil health, depleting underground water resources, indiscriminate use of agrochemicals, etc. The major problem faced by farmers in shifting towards orchard involves a high initial investment and monetary gains are possible only after few years of juvenile period. This can be conquer as initial 3 to 4 years after their establishment fruit trees develop appreciably low tree canopy and vacant space available between the rows and trees can be effectively utilized for growing various intercrops or short duration timber trees. This enhances the income of the orchardists during pre-bearing stage and maintains soil health by altering physico-chemical properties of soil (Dhillon *et al.,* 2012).

Likewise, the modifications in micro-environment due to growing of timber and fruit trees, directly or indirectly influence various vital physiological processes of the inter-cultivated plants grown under tree canopy. Generally photosynthetically active radiation (PAR) and temperature are reduced, while the humidity is increased (Chauhan *et al.,* 2010; Dhillon *et al*., 2011). Among these, PAR is important as the radiant energy captured by plants is utilized in the photosynthesis, which is the primary process governing inter-cultivated crop biomass production and yield (Baig and Gill, 2005). Therefore, the study highlighted the physiological response of under-storey crops and biological/economic performance of garlic under different fruit tree based multi-cropping system.

MATERIAL AND METHODS

The experiment was conducted at New orchard of Department of Fruit Science, Punjab Agricultural University, Ludhiana, situated at latitude of 30.45° N, longitude of 75.85° E and at an altitude of 244 m above mean sea level. The climate is subtropical with dry season from October to first fortnight of June. The layout was prepared to accommodate different fruits and poplar plants between the recommended spacing of pear (6 m × 6 m) to make use of inter-spaces during the initial juvenile phase of fruit plants. The total area of experiment accommodated one hundred twenty plants of pear and thirty plants of each fruit crop as intercrop with pear and twenty plants as sole control in three replications. Fruit plants including peach cv. Shan-i-Punjab, plum cv. Satluj Purple, guava cv. Allahabad Safeda and Kinnow mandarin and poplar ETPs (Entire Trans Plants of G48 clone) were planted in between two pear plants in a row such that distance between pear and fruit tree is 3 m within row. Garlic was sown in the month of October in the inter-row spaces of different intercrops planted in north-south direction in completely randomized design with three replications. This experiment was laid out with the objective to evaluate interaction between different intercrops with garlic. Control plots of garlic with pear were also maintained simultaneously for comparison. The statistical analysis was done with SAS 9.3. The data on yield and physiological parameters *viz.,* photosynthetic active radiation (PAR), stomatal conductance, intercellular CO_2 and transpiration rate, using portable photosynthesis system (CID 340, CID Inc., USA) on fully expanded leaves were recorded repeatedly at 10.0 am, 1.0 pm and 4.0 pm for both experimental as well as control plots. Water use efficiency was measured as ratio of net photosynthesis to transpiration with same units. The orchard soil was deep, well drained and loamy sand. All the trees received uniform and recommended doses of fertilizers and other cultural practices during the course of these investigations. The light intercepted by tree was calculated as the reduction in the average light intensity under tree cover over control. The crop yield and yield contributing parameters were recorded on quadrat basis (1m x 1m) to estimate the yield on acre basis and economics was worked out for comparison.

RESULTS AND DISCUSSION

Garlic grown under different tree combinations behaved differently for eco-physiological parameters (Table 1) but trend was uniform during both the years. Maximum PAR values (491.76 and 503.05) were observed for garlic when grown with pear alone as control and it was significantly higher than all other combination during both the years. However, minimum PAR (413.29 and 422.57) was observed under pear + poplar combination and it was significantly lower than all other combination. The differential PAR under different combinations was due to the varied tree canopy cover and light interception. All parameters viz., net photosynthesis rate, water transpiration, stomatal conductance, etc. were highly influenced by light interception. Maximum photosynthesis values in garlic (5.71 and 5.89 $\mu molm^{-2}s^{-1}$) were recorded with pear as a pure crop which was at par with pear + plum combination during both the years and significantly higher than all other combinations. In other words, these values were directly related to the PAR, which was limiting factor in pear combination with poplar. Transpiration and stomatal conductance recorded the same trend of photosynthesis. All these parameters are interdependent and regulated with light, moisture and temperature. Chauhan *et al.* (2013) had reported decreasing

Table 1. Eco-physiological parameters of garlic grown under different intercrops

Intercrops	PAR ($\mu molm^{-2}s^{-1}$)		Photosynthesis (Pn) ($\mu molm^{-2}s^{-1}$)		Transpiration ($mmolm^{-2}s^{-1}$)		Inter cellular carbon dioxide Ci (ppm)		Stomatal Conductance ($mmolm^{-2}s^{-1}$)		Water use efficiency (WUE)		Carboxylation efficiency (Pn/Ci)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Pear + Kinnow	439.65^{d}	449.68^{d}	5.06^{d}	5.25^{d}	2.70^{d}	2.87^{d}	328.16^{c}	320.62^{c}	0.218^{d}	0.223^{d}	0.0019^{ab}	0.0018^{bc}	0.0167^{d}	0.0177^{c}
Pear + guava	440.01^{d}	450.01^{d}	5.20^{c}	5.38^{d}	2.58$_{f}$	2.74$_{f}$	343.16^{b}	335.62^{b}	0.223^{c}	0.229^{d}	0.0020^{a}	0.0020^{a}	0.0164^{d}	0.0173^{c}
Pear + peach	448.35^{c}	458.50^{c}	5.36^{b}	5.68^{c}	2.90^{c}	3.09^{c}	347.18^{a}	335.84^{b}	0.230^{b}	0.241^{c}	0.0018^{bc}	0.0018^{bc}	0.0184^{c}	0.0201^{b}
Pear + plum	458.08^{b}	468.45^{b}	5.67^{a}	5.99^{a}	2.98^{b}	3.17^{b}	316.75^{d}	306.83^{d}	0.244^{a}	0.255^{a}	0.0019^{ab}	0.0019^{ab}	0.0211^{a}	0.0229^{a}
Pear + poplar	413.29^{d}	422.57^{d}	4.42^{d}	4.61$_{f}$	2.84^{d}	3.03^{d}	354.83^{a}	347.29^{a}	0.190^{d}	0.196$_{f}$	0.0016^{d}	0.0015^{d}	0.0135^{d}	0.0143^{d}
Pear alone	491.76^{a}	503.05^{a}	5.71^{a}	5.89^{b}	3.10^{a}	3.29^{a}	305.11^{d}	300.16^{d}	0.245^{a}	0.250^{b}	0.0019^{ab}	0.0018^{bc}	0.0193^{b}	0.0202^{b}
CD (p=0.05)	5.79	5.44	0.06	0.08	0.04	0.04	7.74	8.05	0.002	0.003	0.0001	0.0001	0.0004	0.0005

trend in stomatal conductance with increasing atmospheric temperature and decreasing relative humidity.

Water use efficiency was recorded maximum in pear + guava combination during both the years, which was at par with pear + plum combination and minimum (0.0016 and 0.0015) was recorded in pear + poplar. This high WUE is mainly due to less transpiration rate in case of pear + guava and high photosynthesis rate in pear + plum combination. However, intercellular CO_2 showed inverse relationship with photosynthesis. Carboxylation efficiency (0.0211 and 0.0229) was highest in garlic under pear + plum combination and minimum (0.0135 and 0.0143) under pear + poplar inter cropping system. Higher carboxylation efficiency of any crop indicates its higher productivity potential. Pn/Ci is positively correlated with stomatal conductance and water use efficiency indicating the usefulness of these traits for selecting plant genotypes for higher productivity under shade conditions. Carboxylation efficiency of under storey crops declined with heavy shade as there was decline in photosynthesis efficiency and increase in inter-cellular carbon dioxide in shade.

Irrespective of crop combinations and month of observation, the diurnal variations in eco-physiological parameters like photosynthetically active radiation (PAR), transpiration rate, photosynthetic rate and stomatal conductance was higher during afternoon (Table 2). Reduction in solar radiation influences the physiological processes more specifically the photosynthesis, which is light dependent. Plants responses to light include adaptation at physiological and biochemical levels (Wigington and Mcmillan, 1979). All the under storey crops in general show changes in photosynthetic rate with a maximum photosynthetic activity during afternoon depending upon prevailing weather conditions during their growth period (Dhillon *et al.,* 2009 and Chauhan *et al.,* 2011). However, WUE was found higher during morning hours than noon or afternoon. Minimum values of WUE were observed during evening time due to less photosynthesis and more transpiration rate.

As far as monthly variation is concerned, the photosynthetic active radiation (PAR) and transpiration rate decreased initially up to January and increased thereafter irrespective of tree components. However, photosynthesis rate was higher initially and later on decreased with maturity of leaves and recorded minimum in the months of April under all tree combinations (Fig. 1). Similarly, Leech and Baker (1983) observed that photosynthesis was low for young, rapidly expanding leaves and maximum at some intermediate age, followed by a gradual decline as leaves aged. Transpiration rate and stomatal conductivity was also high initially and decreased thereafter due to less PAR received by the garlic crop (Fig. 2).

Mean weight of garlic was also found maximum (34.41g) when it was grown along with pear as a sole crop, however, yield potential was found at par when grown with pear + plum and pear + peach combinations and it differed significantly from all the other intercropping system and minimum (21.81g) weight was under pear + poplar intercrop, which was 36.62 per cent less. Size and yield of the garlic followed the same trend. The yield reduction was more under 6 year canopy as compared to 5 year canopy in all the crop combination. Gill *et al.* (2004) had also recorded yield reduction in turmeric with the increase in age of inter-planted fruit and timber tree but Sarangi *et al.* (2007) recorded least affected on quality under shade. The yield reduction in intercrops in the later stages appears due to lesser availability of photosynthetically active radiation (PAR) transmitted through tree canopy. However yield reduction of crops in agroforestry system is not only due to shading effect of system but also due to sharing of other important resources like moisture, nutrient, space, etc. Bijalwan (2012) had reported the yield reduction in crops grown in association after the age of 2- 3 years with fruit trees of apple, pear and peach. Competition for water and nutrients may primarily be responsible for tree depression at the tree crop inter-phase in agroforestry. Under the isoclimatic conditions, Saroj *et al*. (2004) reported that the reduction in yield of intercrops was more under the tree canopy than away from the tree canopy. Non-significant reduction in yield in garlic under pear + peach and pear + plum intercropping system in comparison to pear

Table 2. Diurnal variation in eco-physiological parameters of garlic (mean of all intercrops)

Intercrops	PAR (µmolm-^{2}s-^{1})		Photosynthesis (Pn) (µmolm-^{2}s-^{1})		Transpiration (mmolm-^{2}s-^{1})		Inter cellular carbon dioxide Ci (ppm)		Stomatal Conductance (mmolm-^{2}s-^{1})		Water use efficiency (WUE)		Carboxylation efficiency (Pn/Ci)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
9-10AM	424.87	427.11	5.81^b	6.14^b	2.67^b	4.33^a	293.72^b	283.91^b	0.250^b	0.261^b	0.0022^a	0.0022^a	0.0206^b	0.0223^b
1-2PM	745.18	763.56	6.41^a	6.67^a	4.09^a	2.85^b	415.82^a	407.40^a	0.276^a	0.284^a	0.0019^b	0.0019^b	0.0235^a	0.0249^a
4-5PM	175.52	185.45	3.49^c	3.58^c	1.80^c	1.93^c	288.05^c	282.25^b	0.150^c	0.152^c	0.0015^c	0.0015^c	0.008^c	0.0090^c
CD (p=0.05)	4.09	3.85	0.04	0.05	0.03	0.03	5.48	5.69	0.002	0.002	0.0004	0.0002	0.0003	0.0003

Table 3. Yield and yield related parameters of garlic grown under different intercrops

Intercrops	Weight (g)			Length (cm)			Size (cm)			Yield (q acre^{-1})			Net income Rs acre^{-1}		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Pear + Kinnow	31.64^{b}	28.54^{ab}	30.09^{b}	2.75^{bc}	2.81^{ab}	2.78^{b}	3.67^{bc}	3.64^{a}	3.66^{bc}	18.07^{a}	16.49^{b}	17.28^{b}	26896.58	22449.75	24673.17
Pear + guava	30.77^{b}	24.38^{c}	27.58^{b}	2.65^{c}	2.28^{c}	2.47^{bc}	3.57^{c}	3.11^{c}	3.34^{c}	15.88^{b}	15.53^{bc}	15.70^{bc}	20728.39	19724.27	20226.33
Pear + peach	33.62^{b}	27.91^{b}	30.76^{ab}	2.98^{b}	2.73^{b}	2.86^{b}	3.90^{b}	3.56^{b}	3.73^{b}	17.72^{ab}	17.31^{ab}	17.51^{a}	25892.46	24744.89	25318.67
Pear + plum	35.34^{ab}	29.09^{a}	32.21^{a}	3.18^{ab}	2.88^{a}	3.03^{a}	4.10^{a}	3.71^{a}	3.91^{ab}	17.97^{a}	17.41^{ab}	17.69^{a}	26609.69	25031.78	25820.74
Pear + poplar	24.48^{c}	19.13^{d}	21.81^{c}	1.92^{d}	1.61^{d}	1.77^{d}	2.84^{d}	2.44^{d}	2.64^{bc}	14.81^{b}	14.36^{c}	14.58^{d}	17716.02	16425	17070.51
Pear alone	38.79^{a}	30.03^{a}	34.41^{a}	3.58^{a}	3.00^{a}	3.29^{a}	4.50^{a}	3.83^{a}	4.17^{a}	20.11^{a}	19.19^{a}	19.65^{a}	32634.43	30052.4	31343.42
CD (p=0.05)	3.95	2.04	4.05	0.41	0.27	0.32	0.42	0.21	0.33	3.02	2.41	2.23	-	-	-

alone indicates suitability of the crop under partial shade and more availability of PAR during their growth period due to the deciduous nature of these fruit trees. The root crops respond well to the changed micro-climate under tree canopy i.e., soil/air temperature, relative humidity, light (quality/quantity), etc. Therefore, it is essential to promote light conditions under canopy through managing geometry of plantations or exerting judicious pruning and identification of suitable crops/their specific varieties under prevailing light conditions because when photon flux density decreases to approximately 40 per cent, the carbon assimilation becomes light limited (Cohen *et al.,* 2005). Proportional changes in photosynthesis rate in crops with available PAR have been reported earlier also, which was not observed in open condition so yield was low in pear x poplar intercropping system. The difference between different intercropping systems was mainly due to changes in microclimatic condition, which ultimately affect the physiological processes in the under-story crops thus affecting the crop yield. PAR availability varies with the tree species due to their behavior (deciduous or evergreen) and this in turn affects the growth and productivity of under story crop (Baig and Gill, 2005).

Productivity cannot be the sole criteria for making comparison in different farming systems. Farmers adopt the system on its economic stability/sustainability. The income from garlic was higher when grown with pear alone as compared to all other intercropping system. Moreover garlic is less affected under partial shade and the additional income from the system makes the rotation more remunerative. The reduced yield of the crops under the tree canopy, lowers down the annual profitability margin than sole crop cultivation but the overall profitability of the intercropping system after tree harvesting is substantially high than traditional crop cultivation (Chandra, 2011; Dhillon *et al*., 2007). Short rotation timber trees substantially compensate the crop loss, thus encouraging the framers to invest in this low risk asset in near future (Chauhan *et al.,* 2007; Bangarwa and Wuehlich, 2009) to diversify the natural resource depleting rice-wheat rotation.

The crop yield is certainly affected with the limited PAR in tree-crop combinations but the resource use efficiency was better under trees than in open conditions. Though the productivity of garlic was better in the open area than in tree inter-cropping but the eco-physiological parameters viz., photosynthesis, stomatal conductance, water use efficiency, etc. and yield were found at par with intercrop. The deciduous nature of the trees and shedding leaves during winter coincides with the active growth period of garlic so effect on the yield and related parameter was positive. The stage of intercrop decides availability of PAR,

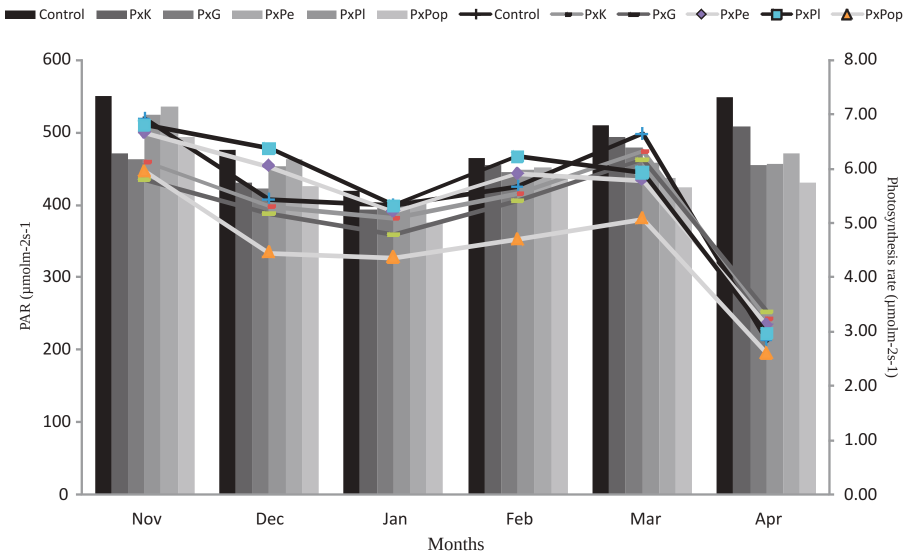

Fig. 1. Monthly variation of PAR and photosynthesis rate in garlic

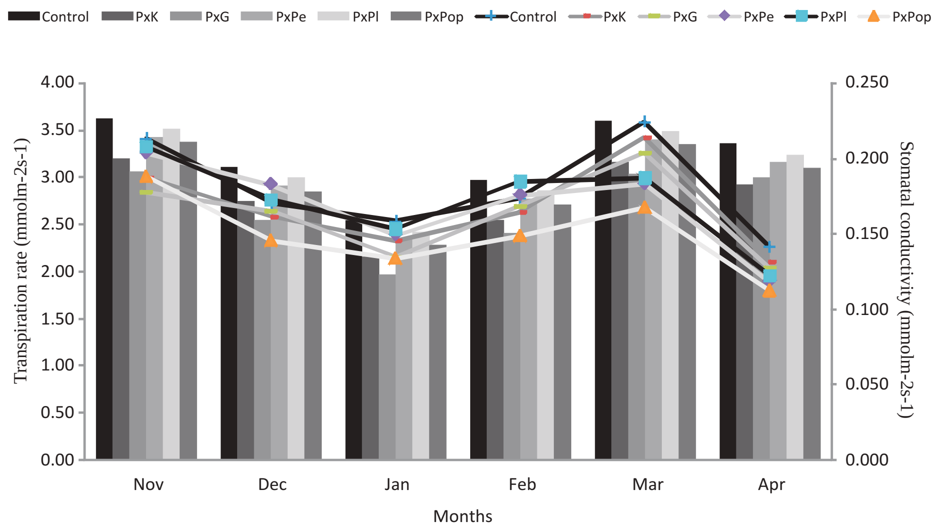

Fig. 2. Monthly variation of transpiration rate and stomatal conductivity in garlic

and thus changes the microclimate of the area, which affects the eco-physiological parameters and ultimately the yield. In the changing climate scenario, tree-crop interface may be an adoption strategy, and the carbon market may add to the profitability margins, which are yet not realized but the environmental payments are a global issue.

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Received 20 February, 2016; Accepted 14 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 730-733

Manuscript Number: 2365
NAAS Rating: 4.47

Correlation and Path Analysis in Chilli (*Capsicum annuum* l.)

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Abstract: The present investigation was carried out to find out the association among various yield attributing traits of 64 diverse genotypes of chilli to get a reliable set of traits for indirect selection. Results of correlation coefficients revealed that the fruit yield per plant exhibited significant positive association with only nine quantitative traits i.e. fruit length, average fruit weight, number of fruits per plant, average seed weight per fruit, seed yield per plant, number of branches per plant, 100 seed weight, plant height, fruit diameter. The path coefficient analysis revealed high direct positive effect on fruit yield via average fruit weight, seed yield per plant, number of fruits per plant, fruit length, fruit diameter, number of branches per plant, revealing their importance in selection.

Key Words: Correlation, Chilli, Path analysis, Temperate environment

India is the largest producer, consumer and exporter of chilli and contributes 25% of total world production. In India, Chilli is cultivated on an area of 173 thousand hectares with the production of 1992 thousand metric tonnes contributing one-fourth to the total quantity of chilli exported in the world. Yield is a quantitative trait and is highly influenced by environment. Chilli is sensitive to excess moisture and heavy rains during crop period may damage the crop. The rainfall had significant positive correlation with production and productivity of chilli when rainfall was1000mm. Temperature had significant positive correlation, while other weather parameters had negative correlation when rainfall was 750-1000 mm, whereas rainfall in winter season had significant negative correlation (Sarada *et al.,* 2015). The yield is of utmost economic importance which a plant breeder has always to keep in view in his attempt to evolve improved cultivars of any crop. Knowledge of the association of quantitative characters specifically for yield and its attributes is of immense practical value in order to obtain an optimal selection index for yield improvement. A knowledge regarding association of various characters among themselves and with economic character is necessary for making indirect selection for improvement of economical characters. Correlation studies pave way to know the association prevailing between highly heritable characters with most economic characters and gives better understanding of the contribution of each trait in building up the genetic makeup of the crop. Path analysis measures the direct influence of one variable upon another variable which permits the separation of correlation coefficients into components of direct and indirect effects. The selection of one character will lead to indirect change (s) of other character (s) if the two are correlated. Therefore, the knowledge of correlation and path analysis is important for a plant breeder. The present study was undertaken to study the association of various yield components in order to develop a reliable set of traits for indirect selection.

MATERIAL AND METHODS

Materials comprised of sixty four diverse genotypes of chilli (Table 1.) being maintained at SKUAST-K, Shalimar and were characterized for various agro-morphological traits. The experiment was laid in square lattice design with four replications during *Kharif*-2013. Each replication was divided into eight blocks with eight genotypes per block. The genotypes were planted in three rowed plots of 2.4 x 1.8m at a spacing of 45 x 45 cm. Observations were recorded on different plant characters (Table 2) on five randomly selected plants for each entry per replication. Estimate of genotypic and phenotypic variances and co-variances were substituted in the formula as given below, suggested by Panse and Sukatme (1985) to calculate correlation co-efficient between all possible pairs of characters. The standard methodology was adopted while to estimate path coefficient analysis.

RESULTS AND DISCUSSION

The estimates of genotypic correlation coefficients were slightly higher than phenotypic correlation showing that masking effects of the environment was little indicating the presence of inherent association between various characters (Table 2). In all instances, however, more reliance may be placed on the genotypic correlations. The nature of genotypic correlation was more or less similar to phenotypic correlation under study. Similar results were reported by Mathew *et al*.

Table 1. Chilli (*Capsicum annuum* L.) genotypes used in study

S. No.	Genotypes	S. No.	Genotypes	S. No.	Genotypes
1.	SH-P-17	23.	SH-SC-7	45.	SH-P-50
2.	SH-SC-2	24.	SH-SC-1008	46.	SH-SC-14
3.	SH-SC-106	25.	SH-SC-30	47.	SH-SC-29
4.	SH-SC-1114	26.	SH-SC-7-104-2	48.	SH-SC-11
5.	SH-SC-82	27.	SH-SC-277-1	49.	SH-SC-13
6.	SH-SC-1003-3	28.	SH-SC-965-5	50.	SH-SC-16
7.	SH-SC-910	29.	SH-SC-9	51.	SH-SC-505
8.	SH-SC-1002-1	30.	SH-P-101	52.	Kashmir Long-1
9.	SH-SC-1	31.	SH-SC-24	53.	SH-SC-15
10.	SH-SC-6	32.	SH-SC-108	54.	SH-SC-28
11.	SH-SC-25	33.	SH-SC-101	55.	SH-SC-115
12.	SH-P-5	34.	SH-SC-31	56.	SH-SC-26
13.	SH-SC-3	35.	SH-SC-23	57.	SH-SC-12
14.	SH-SC-22	36.	SH-P-29	58.	SH-SC-17
15.	SH-SC-115-1	37.	SH-P-12	59.	SH-SC-1001
16.	SH-SC-27	38.	SH-SC-8	60.	SH-SC-105
17.	SH-SC-863-2	39.	SH-SC-814	61.	SH-SC-19
18.	SH-SC-277	40.	SH-SC-502	62.	SH-SC-21
19.	SH-P-20	41.	SH-SC-1003-2	63.	SH-SC-18
20.	SH-SC-4	42.	SH-SC-578-1	64.	SH-SC-20
21.	SH-SC-5	43.	SH-SC-885		
22.	SH-SC-10	44.	SH-SC-254-1		

(2004).

The fruit yield exhibited significant and positive association with fruit diameter, fruit length, number of fruits plant^{-1}, average fruit weight, number of branches plant^{-1}, average seed weight per fruit, seed yield plant^{-1} and 100 seed weight. These results suggested that that selection for these characters are useful for improvement upon fruit yield in chilli. These findings were supported by Temphurne *et al*. (2008) for number of branches plant^{-1}, number of fruits plant^{-1}, fruit diameter; Yatung *et al.* (2014) for fruit weight, fruit length, number of branches and number of fruits plant^{-1}; Jabeen *et al.* (2009) for plant height, number of branches plant^{-1} and number of fruits plant^{-1}; Mathew *et al.* (2004) for fruit diameter, fruit length, fruit weight and 1000 seed weight. The similar findings were observed by Ganeshreddy *et al*. (2008) for number of fruits plant^{-1}, number of branches plant^{-1} and plant height. Days to first fruit set, Days to First flower, and plant spread showed negative association with fruit yield plant^{-1}, which was supported by Krishna *et al*.(2007) for days to first flower; Ganeshreddy *et al*.(2008) for plant spread. Average fruit weight and fruit size besides exhibiting positive correlation with fruit yield plant^{-1} were also positively

Table 2. Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among different growth characters in chilli (*Capsicum annuum* L.)

Parameters	Days to first flower	Days to first fruit set	Days to first green fruit harvest	Days to first ripe fruit harvest	Plant height (cm)	Plant spread (cm)	Number of branches plant^{-1}	Fruit length (cm)	Fruit Diameter (cm)	Average fruit weight (g)	Number of fruits plant^{-1}	Average seed weight fruit^{-1} (g)	Seed yield plant^{-1} (g)	100 seed weight (g)	Fruit yield plant^{-1} (kg)
Days to first flower	1.00	0.951**	0.675**	0.680**	-0.1216	0.1065	-0.147	-0.003	0.036	0.073	-0.201*	0.040	-0.152	-0.071	-0.073
Days to first fruit set	.947**	1.00	0.686**	0.658	-0.106	0.108	-0.127	0.050	0.023	0.052	-0.210*	-0.044	-0.220*	-0.096	-0.094
Days to first green fruit	.656**	0.662**	1.00	0.948**	-0.166	- 0.087	-0.049	0.062	-0.005	0.026	-0.046	-0.129	-0.105	-0.131	0.057
Days to first ripe fruit harvest	.668**	0.644**	0.914**	1.00	-0.121	-0.040	-0.024	0.058	-0.004	0.056	-0.080	-0.083	-0.107	-0.137	0.065
Plant height (cm)	-0.121	-0.104	-0.161	-0.119	1.00	0.095	0.005	0.153	0.0028	0.187	-0.111	-0.061	-0.202*	0.143	0.192
Plant spread (cm)	0.106	0.107	-0.084	-0.040	0.094	1.00	0.085	-0.058	0.016	-0.108	0.108	-0.023	-0.019	0.092	-0.134
Number of branches plant^{-1}	-0.144	-0.121	-0.045	-0.022	0.003	0.083	1.00	-0.123	-0.105	-0.053	0.175	-0.248*	-0.167	-0.173	0.239*
Fruit length (cm)	-0.003	0.050	0.061	0.057	0.151	-0.058	-0.119	1.00	-0.0002	0.385**	-0.222*	0.083	-0.080	0.277	0.346**
Fruit Diameter (cm)	0.036	0.023	-0.007	-0.004	0.003	0.016	-0.101	-0.0004	1.00	0.200*	-0.083	0.311**	0.143*	0.150	0.451**
Average fruit weight (g)	0.073	0.052	0.025	0.055	0.186	-0.107	-0.053	0.385**	0.200*	1.00	-0.447**	0.660**	0.034	0.575	0.643**
Number of fruits plant^{-1}	-0.200*	-0.210**	-0.044	-0.078	-0.111	0.108	0.173	-0.221*	-0.082	-0.447**	1.00	-0.272*	0.638**	-0.063	0.576*
Average seed weight fruit^{-1} (g)	0.040	-0.044	-0.127	-0.081	-0.061	-0.022	-0.241**	0.083	0.310**	0.659**	-0.271**	1.00	0.489**	0.451**	0.406**
Seed yield plant^{-1} (g)	-0.153*	-0.219**	-0.102	-0.105	-0.200**	-0.018	-0.163	-0.080	0.143	0.034	0.638**	0.488**	1.00	0. 164	0.526**
100 seed weight (g)	-0.069	-0.094	-0.125	-0.131	0.139	0.091	-0.166	0.274**	0.146	0.566**	-0.062	0.464**	0.443	1.00	0.473**
Fruit yield plant^{-1} (kg)	-0.072	-0.093	0.053	0.063	0.191	-0.133	0.234*	0.344**	0.450**	0.640**	0.575**	0.404**	0.524**	0.463**	1.00

Table 3. Genotypic path analysis showing direct (diagonal) and indirect (off diagonal) effects of different yield parameters on yield in chilli

Parameters	Days to first flower	Days to first fruit set	Days to first green fruit harvest	Days to first ripe fruit harvest	Plant height (cm)	Plant spread (cm)	Number of branches plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Number of fruits plant^{-1}	Average seed weight fruit^{-1} (g)	Seed yield plant^{-1} (g)	100 seed weight (g)
Days to first flower	- 0.0263	-0.025	-0.0178	-0.0179	0.0042	-0.0028	0.0039	0.0001	-0.0010	-0.0019	0.0053	-0.0011	0.0040	0.0019
Days to first fruit set	-0.0023	-0.0024	-0.0016	-0.0016	0.0003	-0.0003	0.0002	-0.0001	-0.0001	-0.0001	0.0005	0.0001	0.0005	0.0002
Days to first green fruit	-0.0723	-0.0734	-0.0179	-0.1016	0.0378	0.0093	0.0053	-0.0067	0.0005	-0.0027	0.0049	0.0138	0.0112	0.0141
Days to first ripe fruit harvest	0.1108	0.1073	0.1546	0.1629	-0.0097	-0.0066	-0.0040	0.0095	-0.0007	0.0091	-0.0131	-0.0136	-0.0174	-0.0223
Plant height (cm)	-0.0004	-0.0004	-0.0006	-0.0004	0.0056	0.0003	0.0001	0.0005	0.0002	0.0007	-0.0004	-0.0002	-0.0007	0.0005
Plant spread (cm)	-0.0047	-0.0048	0.0039	0.0018	-0.0042	-0.0444	-0.0038	0.0026	-0.0007	0.0048	-0.0048	0.0010	0.0008	-0.0041
Number of branches plant^{-1}	0.0067	0.0057	0.0022	0.0011	-0.0002	-0.0039	0.0456	0.0056	0.0247	0.0024	-0.0034	0.0113	0.0076	0.0079
Fruit length (cm)	-0.0002	0.0026	0.0032	0.0030	0.0090	-0.0030	-0.0064	0.0517	0.0001	0.0200	-0.0063	0.0043	-0.0042	0.0144
Fruit Diameter (cm)	0.0015	0.0009	-0.0002	-0.0002	0.0001	0.0007	-0.0042	0.0001	0.0502	0.0081	-0.0033	0.0125	0.0058	0.0060
Average fruit weight (g)	0.0752	0.0540	0.0264	0.0577	0.2131	-0.1110	-0.0551	0.3972	0.3261	1.0300	-0.2609	0.6804	0.0350	0.5930
Number of fruits plant^{-1}	-0.0457	-0.0478	-0.0104	-0.0183	-0.0154	0.0247	0.1172	-0.0278	-0.0189	-0.1020	0.3279	-0.0621	0.1456	-0.0144
Average seed weight fruit^{-1} (g)	-0.0219	0.0237	0.0703	0.0453	0.0574	0.0123	0.1452	-0.0452	-0.0593	-0.3593	0.1481	-0.5439	-0.2660	-0.2452
Seed yield plant^{-1} (g)	-0.0917	-0.1322	-0.0628	-0.0640	-0.111	-0.0112	-0.0004	-0.0482	0.0960	0.0204	0.3834	0.2935	0.6002	0.0987
100 seed weight (g)	-0.0016	-0.0022	-0.0030	-0.0032	0.0053	0.0021	-0.0040	0.0064	0.0335	0.0133	-0.0015	0.0104	0.0038	0.0231
Genotypic correlation with yield plant^{-1}	-0.073	-0.094	0.057	0.065	0.192	-0.134	0.239*	0.346**	0.451**	0.643**	0.576**	0.406**	0.526**	0.473**

*Residual effect = 0.3601

correlated with each other. The number of fruits plant^{-1} exhibited negative significant association with fruit length and average fruit weight. The number of fruits plant^{-1} was also positively and significantly associated with number of branches plant^{-1}. This was in agreement with the study of Jabeen *et al*. (2009).

The path coefficient analysis (Table -3) revealed appreciable amount of direct positive effect of average fruit weight followed by seed yield plant^{-1}, number of fruits plant^{-1}, first ripe fruit harvest, fruit length, fruit diameter, number of branches plant^{-1}, 100 seed weight and plant height on fruit yield plant^{-1}. Significant positive genotypic correlation coefficients of average fruit weight, number of fruits plant^{-1}, fruit length, number of branches plant^{-1}, seed yield plant^{-1}, plant height, 100 seed weight and fruit diameter with fruit yield reveal that these traits can be used to develop an optimally reliable selection index for realizing improvements in fruit yield of chilli. The direct effect of rest of the component traits viz. days to first flower, days to first fruit set, days to first green fruit harvest, plant spread, on fruit yield plant^{-1} were negative..

The selection for those characters showing significant positive correlation with fruit yield along with direct positive effect on yield are useful for improvement upon fruit yield in chilli. Moreover in the present investigation the number of predictor variables need to be increased to minimise the residual effects in analysis.

Received 18 May, 2016; Accepted 24 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 734-737

Manuscript Number: 2366
NAAS Rating: 4.47

Evaluation of Some Tomato Genotypes and Their Hybrids for Yield and Component Traits under Mid Hill Agro Climatic Zone of Himachal Pradesh

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Abstract: Six diverse tomato genotypes were crossed in a diallel fashion (excluding reciprocals) during *Kharif* 2014-15 and in the next year fifteen crosses along with 6 parents and one standard check (Naveen 2000+) were evaluated. Analysis of variance showed significant differences for all the traits under study. Three parents while four crosses performed better than standard check for earliness. For plant height, two parents and six crosses surpassed the performance of standard check. Similarly, three parents and three cross combinations were found to be superior to standard check for most of the yield and component traits. Cross combinations *viz.,* Solan Lalima x EC-1055, Solan Lalima x EC-1057 and EC-1057 x EC-1058 were found to be superior to standard checks for all traits included in this study and thus recommended for multi-location testing.

***Key Words*:** Evaluation, Hybrids, Mean performance, Tomato, Yield and component traits

Tomato, *Solanum lycopersicum* L. (2n = 2x = 24), belongs to the large and diverse family Solanaceae, which includes more than 3,000 species. All related wild species of tomato are native to the Andean region that includes parts of Chile, Colombia, Ecuador, Bolivia and Peru India is the second largest producer of tomato after China with an annual production of 18.73 million tons from an area of 0.88 million ha and 21.2 t/ha productivity. In Himachal Pradesh it is grown over an area of 10.37 thousand ha with an annual production of 430.79 thousand tons and with a productivity of 41.54 t/ha (Anonymous, 2015).To meet the ever-increasing demand for this vegetable in fresh market and processing industries, it is imperative to develop such hybrids having a complex of valuable attributes *viz.*, earliness, uniformity, good quality, high yield, resistance to diseases and adaptability to wider environment conditions. The present investigation was designed for a comparative evaluation of local as well as exotic genotypes of tomato and their crosses under mid hill zone of Himachal Pradesh.

MATERIAL AND METHODS

Present investigation was conducted at Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) during *Kharif* 2014-15 and 2015-16. Geographically, it is located at an altitude of 1276 meters above mean sea level at a longitude of $77^0\ 11^{'}\ 30^{''}$ E and a latitude of $30^0\ 52^{'}\ 30^{?}$ N. The experimental material consisted of six genetically diverse tomato inbred lines *viz.,* Solan Lalima, UHF-55, EC-2798, EC-1055, EC-1057 and EC-1058 which were crossed in half diallel fashion to get F_1 seeds while Naveen 2000+ was used as standard check during evaluation of hybrids. All the 22 genotypes (6 parents, 15 F_1 hybrids and 1 standard check) were field evaluated using randomized complete block design with three replications. The seedlings were transplanted at a spacing of 90 cm x 30 cm. Recommended cultural practices and plant protection measures were followed. Weather conditions of growing period were recorded.

The observations were recorded on five randomly taken plants from each entry in each replication and their average was worked out to record the data. The observations were recorded on following characters: The days to first harvest was recorded from the date of transplanting to the date of first marketable harvest of fruits at breaker stage or turning stage. The plant height was measured from the ground level to the highest tip of the plant at the final harvest and average was taken to record plant height (cm). Fruit clusters per plant and number of fruits in each cluster of five plants was counted. Similarly, the marketable fruits harvested from randomly taken plants were counted at each harvest, summed up and averaged to obtain number of fruits per plant. Ten fruits were taken randomly from 10 plants at the second harvest and their polar length and breadth measured in centimeters with the help of vernier calliper. Fruit size (cm^2) = fruit length (cm) x fruit width (cm) Total weight of fruits from five randomly taken plants at every picking was recorded. The days were counted between first picking to final harvest of marketable fruits in each entry to record the data on harvest duration. The pickings were made at half ripe stage or breaker stage for recording fruit yield per plant. Fruit yield was recorded at every picking in grams and added up for all the pickings to arrive at the total yield per plant.

RESULTS AND DISCUSSION

The analysis of variance indicated highly significant differences among the genotypes for all the traits studied (Table 1). The data pertaining to mean performance of genotypes are presented in Table 2.

Days to first harvest: The days to first harvest ranged from 54.00 (EC-1055) to 70.00 days (UHF-55) in parents. Among the crosses, days to first harvest ranged from 57.33 (Solan Lalima X EC-1057) to 83.00 days (EC-2798 X EC-1058). Former was statistically at par with Solan Lalima X EC-1058 (58.00 days) and Solan Lalima X EC-1055 (59.33 days). Out of fifteen cross combinations four cross combinations, Solan Lalima X EC-1057, Solan Lalima X EC-1058, Solan Lalima X EC-1055 and EC-1057 X EC-1058 were significantly earlier in flowering to standard check (Table 2). Rana and Vidyasagar (2005) have also reported hybrids taking lesser time to first fruit harvest as compared to the respective better parents and standard check.

Plant height (cm): Plant height (cm) ranged from 69.67 (EC-1058) to 207.67 (EC-2798) in parental lines (Table 2). Among the crosses plant height (cm) ranged from 74.76 (EC-1057 X EC-1058) to 213.33 cm (Solan Lalima x EC-1055). Six crosses were found to be statistically tallest over standard check. Earlier Chaudhry and Malhotra (2001) have also reported about 20-40 per cent of the hybrids in their experiments exceeding the standard check variety in plant height.

Fruit clusters plant^{-1}: The fruit clusters per plant in lines ranged from 4.37 (EC-1058) to 8.75 (Solan Lalima). Among crosses, Solan Lalima x EC-1055 had fruit clusters per plant (9.28), which were statistically at par with Solan Lalima x EC-1057 (9.07) and Solan Lalima x EC-1058 (9.03), while cross EC-1055 x EC-1057 showed minimum fruit clusters per plant (5.20). There were three crosses superior to standard check for this trait. Similar trend was noticed by Duhan *et al.* (2005).

Number of fruits cluster^{-1}: The mean number of fruits per cluster among parents was minimum in EC-1058 (2.92) while maximum in Solan Lalima (4.19), later one was found statistically at par with EC-2798 (4.05). Among F_1^s, number of fruits per cluster ranged from 2.29 (EC-2798 x EC-1057) to 4.55 (Solan Lalima x EC-1055) and later one was found statistically at par with Solan Lalima x EC-1057 and Solan Lalima x EC-1055. Four crosses performed better than standard check.

Number of fruits plant^{-1}: The minimum number of fruits per plant was observed in EC-1058 (15.16) while maximum in Solan Lalima (40.25) among parents. Amongst the crosses, number of fruits per plant varied from 15.30 (EC-1055 x EC-1057) to 46.94 (Solan Lalima x EC-1055), later one statistically at par with 45.37 (Solan Lalima x EC-1057). Standard check (Naneen 2000+) recorded 34.48 fruits per plant which was found to be less than seven other cross combinations in this study. Kumar *et al.* (2013) have also reported some of the crosses superior to the standard checks used in their studies.

Fruit size (cm^2): The mean fruit size for parents ranged from 30.11 (EC-2798) to 37.47 (EC-1055). Among F_1s the mean performance was minimum in EC- 2798 x EC-1058 (28.28) and maximum in EC-1055 x EC-1057 (38.22), later one was found at par with EC-1057 x EC-1058 (38.02). The maximum fruit size was statistically at par with EC-1057 x EC-1058 (38.02). Seven crosses were found to be superior to standard check for fruit size (Table 2).

Average fruit weight (g): The parent EC-2798 recorded lowest average fruit weight (62.83g) and EC-1058 recorded highest average fruit weight (75.53g), later one is statistically at par with EC-1055 (74.21). Amongst F_1s it was lowest in cross Solan Lalima x EC -2798 (64.43g) and highest in cross Solan Lalima x EC-1058 (78.36g) which was statistically at par with UHF-55 x EC-1058 (77.98g). Nine cross combinations observed increase in comparison to standard check for fruit weight (Table 2).

Harvest duration (days): Minimum harvest duration (days) were recorded in parent EC-1058 (38.27) while maximum in Solan Lalima (71.55). Amongst F_1s minimum harvest duration (days) were recorded in EC-1057 x EC-1058 (40.49) while maximum in Solan Lalima x EC-1055 (91.96) followed by Solan Lalima x EC-1057 (85.28). Both these cross combinations were found to be superior to Naveen 2000+ for harvest duration (Table 2). Joshi *et al.* (2005) could not record

Table 1. Analysis of variance of parents and crosses for various traits in tomato

Source of variation	d.f	Days to first harvest	Plant Height (cm)	Fruit Cluster per plant	Number of fruits per	Number of fruits per plant	Fruit size	Average fruit weight (g)	Harvest duration (days)	Fruit Yield (Kg/plant)
Replication	2	0.97	27.70	0.17	0.08	5.96	1.00	0.54	3.68	0.0001
Treatment	21	159.07*	7446.62*	7.69*	1.52*	344.68*	23.18*	59.15*	669.75*	1.37*
Error	65	1.94	7.80	0.09	0.04	4.97	0.80	1.50	5.17	0.0010

*Significant at 5% level of significance

Table 2. Mean performance of parents, crosses and standard check for yield and component traits in tomato

Parents	Days to first harvest	Plant height (cm)	Fruit cluster plant^{-1}	Number of fruits cluster^{-1}	Number of fruits plant^{-1}	Fruit size (cm^2)	Average fruit weight (g)	Harvest duration (days)	Fruit yield (Kg plant^{-1})
Solan Lalima	67.33	198.67	8.75	4.19	40.25	32.87	68.82	71.55	2.64
UHF-55	70.00	164.33	7.59	3.47	26.02	34.05	68.71	64.93	2.45
EC-2798	69.00	207.67	7.25	4.05	33.36	30.11	62.83	67.33	2.05
EC-1055	54.00	85.33	4.60	3.09	17.00	37.47	72.00	41.40	1.55
EC-1057	57.00	75.67	4.69	3.15	17.33	35.09	74.21	42.47	1.34
EC-1058	61.00	69.67	4.37	2.92	15.16	33.79	75.53	38.27	1.06
Solan Lalima X UHF-55	71.67	194.67	7.63	2.98	24.42	28.81	71.69	62.58	2.56
Solan Lalima X EC-2798	71.33	205.00	8.27	3.21	28.94	30.96	64.43	70.41	2.53
Solan Lalima X EC-1055	59.33	213.33	9.28	4.55	46.94	36.54	73.98	91.96	3.15
Solan Lalima X EC-1057	57.33	201.67	9.07	4.51	45.37	36.18	74.76	85.28	3.04
Solan Lalima X EC-1058	58.00	194.67	9.03	4.32	42.38	34.04	78.36	66.71	2.95
UHF-55 X EC-2798	73.67	182.67	7.48	2.95	24.94	33.57	65.99	64.70	2.44
UHF-55 X EC-1055	65.00	174.33	7.94	3.81	31.00	36.55	74.72	67.96	2.94
UHF-55 X EC-1057	66.67	182.00	7.89	3.75	30.79	36.40	74.55	67.99	2.93
UHF-55 X EC-1058	68.33	176.33	7.21	2.77	22.41	34.32	77.98	56.61	2.65
EC-2798 X EC-1055	64.00	193.67	7.64	4.31	37.41	33.86	68.53	70.50	2.04
EC-2798 X EC-1057	79.67	187.33	6.05	2.29	16.19	35.92	64.53	66.33	1.98
EC-2798 X EC-1058	83.00	153.00	5.30	2.68	16.59	28.28	68.50	60.27	1.76
EC-1055 X EC-1057	64.67	115.67	5.20	2.63	15.30	38.22	75.14	41.40	1.47
EC-1055 X EC-1058	68.33	90.67	5.48	2.78	17.63	36.18	73.16	40.97	1.34
EC-1057 X EC-1058	60.00	74.67	5.32	2.69	16.66	38.02	67.87	40.49	1.13
Naveen 2000+ (Check)	64.00	192.22	8.51	4.20	39.88	34.48	71.27	73.48	2.72
Population mean	66.06	160.60	7.02	3.42	27.54	34.35	71.25	61.53	2.22
CD(p=0.05)	2.28	4.56	0.48	0.34	3.65	1.46	2.00	3.72	0.05

any increase in harvest duration in the hybrids studied by them in comparison to the standard check.

Fruit yield (kg plant^{-1}): The parent Solan Lalima had maximum (2.64) while EC-1058 had minimum (1.06) fruit yield (Kg plant^{-1}). Among crosses, it ranged from 1.13 to 3.15 Kg plant^{-1} in EC-1057 x EC-1058 and Solan Lalima x EC-1055, respectively. Five cross combinations surpassed the performance of standard check for this trait. Kumari *et al.* (2010), Kumari and Sharma (2011), Singh and Shastry (2011), Ahmed *et al.* (2011) and Singh *et al.* (2012) also reported tomato hybrids performing better than standard check for fruit yield.

CONCLUSION

Based on the mean performance of parents and their hybrids in the present investigation, it is concluded that the cross combinations Solan Lalima x EC-1055, Solan Lalima x EC-1057 and Solan Lalima x EC-1058 performed best for most of the yield and yield component traits over other entries and standard check. Therefore, these are recommended for multi-location testing in the different regions of state.

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Received 02 June, 2016; Accepted 25 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 738-742

Manuscript Number: 2367
NAAS Rating: 4.47

Diversity and Abundance of Pollinator Fauna on Underutilized Fruit, Bael [*Aegle marmelos* (L) Corr.]

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Abstract: An experiment was conducted to investigate the diversity and abundance of various insects on bael [*Aegle marmelos* (L) Corr.]. Total 24 insect visitors belonging to eight families of four orders were recorded on bael flowers during flowering period. Among the insect visitors, lepidoptera (11 spp.) was found to be dominating followed by hymenoptera (9 spp.), order coleoptera (2 spp.) and diptera (2 spp.). Hymenopterans were the most abundant followed by lepidoptera, diptera and coleoptera. Irrespective of different day hours, significantly maximum number of *Apis dorsata* was recorded from bael flowers followed by *Belenois aurota*, *Catopsilia pyranthe, Megachile cephalotes*, *Apis florea, Eristalinus obscuritarsis* and *Apis mellifera* during 2014. Same trend was observed during 2015. Insect abundance was low at both initiation and cessation of flowering but remained high during full bloom period. Present study revealed that order lepidoptera was more diversified and hymenoptera was more abundant. Among the all insect visitors of bael, *A. dorsata* was the most abundant.

Key Words: Abundance, Bael, Diversity, Hymenoptera, Insect, Pollinators

A large number of underutilized edible fruits exist in tropic and subtropics of the world, but their full potential has not been harnessed. Out of these, Bael (*Aegle marmelos* (L) Corr.) is indigenous to India and belongs to the family Rutaceae. It is found growing wild in dry forests on hills and plains of Central and Southern India and Pakistan, Srilanka, Myanmar, Thailand, Indonesia, the Philippines, Vietnam and Bangladesh. In India, it is common in the States of Uttar Pradesh, Orissa, Bihar, West Bengal and Madhya Pradesh. It is also cultivated on a limited scale in North India. Several workers had reported pharmalogical and phytochemical activities and its potentialities as a medicinal plant (Nadakarni, 2000; Kesari *et al*. 2006). However, scanty information is available on underutilized fruit crops as bee forage. The information on these plants as bee forage is need of the hour as they serve as good source of nectar and/or pollen. Pollination is one of the principal mechanisms in the maintenance and conservation of biodiversity. Over 80% pollination activities are performed by insects and bees. Therefore, it is necessary to harness eco-friendly resources like bee pollination to the maximum for increasing yield. Proper management of insect pollination services can reduce risks in production and increase rewards by addressing pollination deficits (Abson and Termansen, 2011). Many investigators have studied the pollination requirements of commercial horticultural crops. Keeping this in view, *Aegle marmelos* (L) Corr. was selectedfor recording the diversity, abundance and their importance as nectar/pollen forager crop.

MATERIAL AND METHODS

To record the diversity of insect visitors and pollinators of *Aegle marmelos*, flowers were collected by hand net with 30 cm ring diameter during their flowering period. For this, sweeps were made throughout flowering period of the crop at two hourly intervals from the morning to the evening (0600-1600h) during May month. Captured insects were killed by using ethyl alcohol and preserved as dry specimens and were got identified from authentic source.

Abundance of different insect visitors/pollinators, number of visitors m^{-2} branch of a tree/5minutes was recorded from five randomly selected branches. The abundance was recorded at two hourly intervals, starting from commencement to the cessation of insect activity and repeated at weekly intervals starting from commencement to the cessation of the flowering on the experimental trees.

RESULTS AND DISCUSSION

Diversity and abundance of insect pollinators of bael: In all, twenty-four insect species belonging to eight families of four orders were recorded from the Bael flowers, in which, nine belonging to order hymenoptera, eleven to lepidoptera, two to coleoptera and two to diptera. The hymenopterans were the major floral visitors comprising four families *viz*., Apidae (*Apis florea, Apis dorsata, Apis cerana, Apis mellifera* and *Xylocopa pubescence*), Megachilidae (*Megachile* sp.), Vespidae (*Delta esuriens* and *Eumenes dimidatipennis*) and Formicidae (*Monomorium* sp.). They were followed in order of diversity by lepidopterans from five families *viz*., Papilionidae (*Papilio demoleus*), Nymphalidae (*Danaus chrysippus*, *Junonia almana*, *Junonia lemonias*, *Venessa cardui* and *Phalanta phalantha*), Pieridae (*Catopsilia pyranthe* and *Belenois aurota*), Lycaenidae (*Lampides boeticus*) and Arctiidae (*Utetheisa pulchella* and *Amata* sp.). Two coleopterans *viz*., Coccinellidae (*Coccinella septempunctata*) and Meloidae *(Mylabris pustulata*) and two species from one family of Diptera *viz*., Syrphidae (*Eristalinus obscuritarsis* and *Eristalinus obliquus*). Among the insect pollinators, *A. dorsata*, *B. aurota*, *C. pyranthe*, *Megachile* sp. and *E. obscuritarsus* were the most frequent pollinators. Similar findings were reported by Singhal *et al*. (2011) who observed only eight insect species i.e. *Apis dorsata*, hover fly, *Amata cyssea*, *Anaphaei saurota*, *Pieris brassicae*, *Polestis herbreus*, *Solenopsis geminata*, *Xylocopa pubescens* growing in Patiala region. On the other hand only six insect species namely, *Apis dorsata*, *Apis* sp., hover fly, *Amata cyssea, Solenopsis geminata* and an unidentified weevil were recorded in Kangra. Similarly,Wadhwa and Sihag (2012) observed ninteen insect species belonging to lepidoptera and hymenoptera in *Rauvolfia serpentina*. Among them, 11 were hympenopterous (*Xylocopa fenestrata, X. pubescens*, *Xylocopa* sp., *Mellisodes* sp., *Pithitis smargdula*, *Megachile bicolor* and *Megachile* sp., *Apis dorsata*, *A. mellifera*, *A. florea* and P*olistes hebreaus*) and 8 were lepidopterous insects (*Papilio demoleus*, *P. polytes*, *Danaus aglea creamer*, *Danaus chrysippus*, *Pieris brassicae*, *Eurema hecabe*, cabbage butterfly (it is *P. brassicae* which has already been mentioned) and *Pedis skipper*).

During 2014, seven species of flower visiting insects belonging to three orders, namely hymenoptera (4), lepidoptera (2) and diptera (1) were collected from the bael flowers. The majority belonged to Hymenoptera comprising honey bees (*A.dorsata, A. mellifera and A. florea*) and *M.cephalotes*. Among honey bees, maximum mean population was of *A. dorsata* (7.40 bees/m^2 branch/5min) followed by that of *A. florea* (Table 2). Saini (2011) reported that *A. dorsata* was the most abundant pollinator followed by *A. mellifera, A. florea* and *Sarcophaga*. Contrary to the above results in ber, Kumar (1990) found *A. florea* as the most abundant pollinator followed by *A. mellifera* and *A. dorsata* under Hisar conditions.

Time and week wise, the highest population of *A. dorsata* (13.00 bees/m^2 branch/5min) was at 0800h -1000h during 2nd week of May, 2014 which was significantly different with 1st week and 3rd week. Similarly, maximum population of *A. florea* (4.00 bees/m^2 branch/5min) was recorded at 1000 h -1200h during 2nd week which was significantly different with 1st week and 3rd week. The highest population of *A. mellifera*

Table 1. Insect visitors/pollinators on flowers of bael at Hisar during May 2014 and 2015

Insect Species	Family
Hymenoptera (Top)	
Apis dorsata Fabricius	Apidae*
Apis florea Fabricius	Apidae*
Apis mellifera Linnaeus	Apidae*
Apis cerana Fabricius	Apidae*
Megachile cephalotes Smith	Megachilidae*
Delta esuriens Fabricius	Vespidae**
Monomorium sp.	Formicidae**
Xylocopa pubescensce Spinola	Apidae**
Eumenes dimidatipennis Sauss	Vespidae**
Lepidoptera (Top and side)	
*Papilio demoleus*Linnaeus	Papilionidae*
Danaus chrysippus Linnaeus.	Nymphalidae**
Junonia alomana Linnaeus	Nymphalidae*
Junonia lemonias Linnaeus	Nymphalidae*
Catopsilia pyranthe Linnaeus	Pieridae*
Belenois aurota Fabricius	Pieridae*
Venessa cardui Linnaeus	Nymphalidae**
Phalanta phalantha Drury	Nymphalidae*
Lampides boeticus Linnaeus	Lycaenidae**
Utetheisa pulchella Moore	Arctiidae**
Amata sp.	Arctiidae**
Diptera (Top)	
Eristalinus sp.	Syrphidae*
Eristalinus obliquus Wiedemann	Syrphidae*
Coleoptera (Top)	
Coccinella septempunctata Linnaeus.	Coccinellidae**
Mylabris pustulata Thunberg	Meloidae**

*- Insect Pollinator, **- Insect visitor

(2.40 bees/m^2 branch/5min) on flowers was at 1000h -1200h during 3rd week which was significantly different with that of the 1st k and 2nd week Table 2. Minimum activity of all honey bee species was between 0600h - 0800h and 1400 - 1600h. Peak activity was at 0800h -1000h and 1000h – 1200h irrespective of weeks.

Among other hymenopterans, in addition to *Apis* spp. the next most abundant species was *M. cephalotes*. Mean population of *M.cephalotes* recorded was (3.01 bees m^{-2} branch/5min).Time and week wise, the highest population of *M. cephalotes* (6.00 bees m^{-2} branch/5min) was at 1000h -1200h during 1st week which was significantly different with 2nd week and 3rd week. Minimum activity of *M. Cephalotes* was between 0600hto1000h. Peak activity was observed at 1000h -1200h and 1400h -1600h irrespective of weeks (Table 2).

Among lepidopterans, maximum mean population

Table 2. Abundance of insect visitors onflowers of *A.marmelos* during 2014

Insect visitors	Mean number of insect visitors/m^2 branch/5 min																					
	4/5/14 (WK1)						Overall mean	11/5/14 (WK2)						Overall mean	18/5/14 (WK3)						Overall mean	Pooled mean
	0600h - 0800h	0800h - 1000h	1000h - 1200h	1200h - 1400h	1400h - 1600h	1600h - 1800h		0600h - 0800h	0800h - 1000h	1000h - 1200h	1200h - 1400h	1400h - 1600h	1600h - 1800h		0600h - 0800h	0800h - 1000h	1000h - 1200h	1200h - 1400h	1400h - 1600h	1600h - 1800h		
Apis dorasta	2.60 (1.88)	10.60 (3.40)	9.20 (3.19)	9.60 (3.25)	5.00 (2.44)	5.60 (2.56)	7.10 (2.79)	3.20 (2.04)	13.00 (3.74)	12.60 (3.68)	10.40 (3.37)	7.60 (2.93)	5.40 (2.52)	8.70 (3.05)	1.20 (1.47)	10.80 (3.43)	9.00 (3.16)	7.20 (2.86)	6.00 (2.64)	4.20 (2.27)	6.40 (2.64)	7.40 (2.82)
A. florea	0.40 (1.16)	2.40 (1.83)	4.00 (2.22)	1.60 (1.60)	0.80 (1.33)	0.00 (1.00)	1.53 (1.52)	0.80 (1.29)	1.80 (1.66)	2.40 (1.83)	1.40 (1.54)	0.60 (1.24)	0.00 (1.00)	1.16 (1.43)	0.20 (1.08)	0.80 (1.33)	1.60 (1.60)	1.20 (1.47)	1.20 (1.45)	0.00 (1.00)	0.83 (1.32)	1.17 (1.42)
A. mellifera	0.20 (1.08)	1.40 (1.54)	1.80 (1.66)	1.00 (1.39)	0.40 (1.16)	0.00 (1.00)	0.80 (1.30)	0.20 (1.08)	1.00 (1.41)	2.00 (1.71)	1.20 (1.47)	1.20 (1.45)	0.00 (1.00)	0.93 (1.35)	0.40 (1.16)	0.40 (1.16)	2.40 (1.82)	0.60 (1.24)	0.80 (1.33)	0.20 (1.08)	0.80 (1.30)	0.84 (1.32)
Megachile cephalotes	0.00 (1.00)	2.20 (1.78)	6.00 (2.64)	3.20 (2.04)	3.20 (2.04)	1.80 (1.66)	2.73 (1.86)	0.60 (1.22)	3.60 (2.14)	4.40 (2.32)	4.40 (2.32)	3.80 (2.18)	5.40 (2.52)	3.70 (2.12)	0.60 (1.22)	2.20 (1.77)	3.00 (1.99)	2.00 (1.71)	4.60 (2.36)	3.20 (2.04)	2.60 (1.85)	3.01 (1.94)
Catopsilia pyranthe	1.80 (1.65)	4.00 (2.23)	6.20 (2.68)	3.60 (2.14)	4.00 (2.23)	2.40 (1.83)	3.66 (2.13)	3.40 (2.09)	6.60 (2.75)	9.20 (3.19)	4.00 (2.22)	4.60 (2.36)	3.60 (2.14)	5.23 (2.46)	1.60 (1.60)	3.40 (2.09)	4.60 (2.36)	3.20 (2.03)	3.60 (2.14)	4.00 (2.22)	3.40 (2.07)	4.10 (2.22)
Belenois aurota	2.40 (1.82)	7.20 (2.86)	6.40 (2.71)	2.60 (1.89)	5.40 (2.52)	1.40 (1.54)	4.23 (2.22)	3.60 (2.14)	12.80 (3.71)	8.80 (3.12)	6.60 (2.75)	5.40 (2.52)	5.80 (2.60)	7.16 (2.81)	3.00 (1.99)	4.80 (2.40)	4.60 (2.35)	3.40 (2.09)	5.60 (2.56)	2.80 (1.94)	4.03 (2.22)	5.14 (2.42)
Eristalinus obscuritarsus	0.60 (1.24)	2.40 (1.83)	2.00 (1.72)	1.20 (1.47)	1.60 (1.60)	0.20 (1.08)	1.33 (1.49)	1.20 (1.47)	2.40 (1.83)	3.20 (2.04)	2.00 (1.72)	1.60 (1.60)	0.60 (1.24)	1.83 (1.65)	0.60 (1.24)	1.40 (1.54)	1.60 (1.60)	2.00 (1.72)	2.80 (1.94)	0.60 (1.24)	1.50 (1.55)	1.55 (1.56)
Mean	1.14 (1.40)	4.31 (2.21)	5.08 (2.40)	3.25 (1.97)	2.91 (1.90)	1.62 (1.52)	3.05 (1.90)	1.85 (1.62)	5.88 (2.46)	6.08 (2.56)	4.28 (2.20)	3.54 (2.04)	2.97 (1.86)	4.10 (2.12)	1.08 (1.40)	3.40 (1.96)	3.82 (2.13)	2.80 (1.87)	3.51 (2.06)	2.14 (1.68)	2.79 (1.85)	3.31 (1.95)

*Each value represents mean of 5 observations; Figures in parentheses are square root transformed values

Factor	CD (p=0.05)
Insect visitors	0.05
Week	0.03
Time	0.04
Insect x Week	0.10
Insect visitors x Time	0.13
Week x Time	0.08
Insect visitors x Week x Time	0.22

Table 3. Abundance of insect visitors on flowers of *A. marmelos* during 2015

Insect visitors	Mean number of insect visitors/m^2 branch/5 min																					
	2/5/15 (WK1)						Overall mean	9/5/15 (WK2)						Overall mean	16/5/15 (WK3)						Overall mean	Pooled mean
	0600h-0800h	0800h-1000h	1000h-1200h	1200h-1400h	1400h-1600h	1600h-1800h		0600h-0800h	0800h-1000h	1000h-1200h	1200h-1400h	1400h-1600h	1600h-1800h		0600h-0800h	0800h-1000h	1000h-1200h	1200h-1400h	1400h-1600h	1600h-1800h		
Apis dorasta	1.80 (1.66)	13.20 (3.76)	11.00 (3.46)	9.80 (3.28)	8.20 (3.03)	6.00 (2.64)	8.33 (2.97)	2.80 (1.94)	14.60 (3.94)	11.40 (3.51)	11.20 (3.49)	8.40 (3.06)	6.80 (2.79)	9.20 (3.12)	1.40 (1.54)	11.60 (3.54)	9.60 (3.25)	8.00 (2.99)	6.60 (2.75)	5.00 (2.44)	7.03 (2.75)	8.18 (2.95)
A. florea	0.20 (1.08)	1.80 (1.65)	3.20 (2.04)	2.20 (1.77)	0.80 (1.39)	0.00 (1.31)	3.60 (2.03)	0.60 (1.22)	2.80 (1.94)	3.60 (2.14)	2.40 (1.83)	1.60 (1.60)	0.20 (1.08)	1.86 (1.64)	0.40 (1.16)	1.40 (1.54)	2.60 (1.89)	1.60 (1.60)	1.80 (1.65)	0.20 (1.08)	1.33 (1.49)	2.26 (1.72)
A. mellifera	0.40 (1.16)	0.80 (1.33)	2.00 (1.72)	0.60 (1.24)	0.60 (1.24)	0.00 (1.00)	0.73 (1.28)	0.80 (1.31)	0.80 (1.31)	2.40 (1.83)	1.20 (1.45)	1.20 (1.47)	0.40 (1.16)	1.13 (1.42)	0.60 (1.22)	0.80 (1.31)	2.00 (1.71)	1.00 (1.39)	1.20 (1.47)	0.40 (1.16)	1.00 (1.38)	0.95 (1.36)
Megachile cephalotes	0.00 (1.00)	1.00 (1.37)	5.00 (2.44)	3.60 (2.14)	3.80 (2.18)	2.20 (1.77)	2.60 (1.82)	0.40 (1.16)	3.00 (1.98)	5.40 (2.52)	4.00 (2.23)	4.60 (2.36)	4.20 (2.27)	3.60 (2.09)	0.80 (1.31)	2.20 (1.77)	4.40 (2.31)	2.60 (1.89)	4.60 (2.36)	3.20 (2.04)	2.96 (1.95)	3.05 (1.95)
Catopsilia pyranthe	1.40 (1.54)	5.00 (2.44)	6.60 (2.75)	4.20 (2.27)	5.20 (2.48)	2.80 (1.94)	4.20 (2.23)	2.40 (1.83)	7.40 (2.89)	7.20 (2.85)	5.20 (2.48)	5.40 (2.52)	4.20 (2.27)	5.30 (2.47)	2.20 (1.77)	4.00 (2.23)	5.80 (2.60)	3.40 (2.09)	4.20 (2.27)	3.20 (2.04)	3.80 (2.17)	4.43 (2.29)
Belenois aurota	2.00 (1.72)	8.00 (2.99)	7.20 (2.85)	3.60 (2.12)	6.00 (2.64)	2.60 (1.89)	4.90 (2.37)	3.60 (2.13)	11.80 (3.57)	8.20 (3.02)	6.40 (2.70)	6.40 (2.71)	4.80 (2.39)	6.86 (2.76)	2.60 (1.89)	6.20 (2.68)	6.60 (275)	3.40 (2.08)	6.60 (2.75)	4.00 (2.22)	4.90 (2.39)	5.55 (2.51)
Eristalinus obscuritarsus	0.00 (1.00)	1.00 (1.39)	1.20 (1.45)	1.00 (1.39)	1.20 (1.45)	0.60 (1.24)	0.83 (1.32)	0.00 (1.00)	1.60 (1.59)	1.60 (1.59)	1.40 (1.54)	1.40 (1.54)	1.00 (1.39)	1.16 (1.44)	0.00 (1.00)	0.80 (1.33)	0.60 (1.24)	0.60 (1.24)	1.00 (1.39)	0.80 (1.31)	0.63 (1.25)	0.87 (1.34)
Mean	0.82 (1.31)	4.40 (2.13)	5.17 (2.39)	3.57 (2.03)	4.74 (2.29)	2.88 (1.87)	3.60 (2.00)	1.51 (1.51)	6.00 (2.46)	5.68 (2.50)	4.54 (2.25)	4.14 (2.18)	3.08 (1.91)	4.16 (2.13)	1.14 (1.41)	3.85 (2.06)	4.51 (2.25)	2.94 (1.90)	3.71 (2.09)	2.40 (1.75)	3.09 (1.91)	3.31 (2.01)

*Each value represents mean of 5 observations; Figures in parentheses are square root transformed values

Factor	CD (p=0.05)
Insect visitors	0.05
Week	0.03
Time	0.05
Insect x Week	0.10
Insect visitors x Time	0.14
Week x Time	0.09
Insect visitors x Week x Time	NS

was of *B. aurota* (5.14 insects m^{-2} branch/5min) followed by that of *C. pyranthe*. The highest population of *B. Aurota* (12.80 insects m^{-2} branch/5min) was at 0800h -1000h during 2nd week which was significantly different with 1st week and 3rd week. (Table 2).

Among diptera, mean population of *E. obscuritarsus* was (1.55 insects/m^2 branch/5min).The highest population of *E. obscuritarsus* was recorded at 1000h -1200h during 2nd week which was significantly different with 1st and 3rd week. (Table 2).

During 2014, highest pooled mean abundance (7.40 bees/m^2 branch/5min) was in *A. Dorsata* followed by *B.aurota*, *C. pyranthe*, *M. cephalotes*, *E. obscuritarsus* and *A. florea*. Lowest pooled mean abundance was recorded in *A. mellifera*. Thus it proves that *A. dorsata* and other wild pollinators are most abundant in bael and need conservation to enhance the pollnation services (Table 2).

During 2015, seven species of flower visiting insects belonging to three orders, namely hymenoptera (4), lepidoptera (2) and diptera (1) were collected from the bael flowers. The majority belonged to hymenoptera comprising honey bees (*A.dorsata, A. mellifera and A. florea*) and *M.cephalotes*. Among honey bees maximum mean population was of *A. dorsata* (8.18 bees m^{-2} branch/5min) followed by that of *A. florea* Similar findings were reported by Saini (2011) who found *A. dorsata* as the most predominant species. Highest population of *A. dorsata* (14.60 bees/m^{-2} branch/5min) was recorded at 0800h -1000h during 2nd week which was significantly different with 1st and 3rd week of May. Maximum population of *A. florea* (3.60 bees/m^{-2} branch/5min) was at 1000 h -1200h during 2nd week which was significantly different with 1st and 3rd week. The highest population of *A. mellifera* (2.40 bees/m^{-2}branch/5min) on flowers was recorded at 1000h-1200h during 3rd week which was significantly different with 1st and 2nd week. Peak abundance of all honey bee species was at 1000-1200h. Minimum abundance was recorded at 0600h-0800h irrespective of weeks (Table 3).

During 2015 also, *A. dorsata* recorded highest pooled mean abundance (8.18 bees/m^2 branch/5min) followed by *B. aurota*, *C. pyranthe*, *M. cephalotes*, *A. florea* and *A. mellifera*. Lowest pooled mean abundance recorded by *E. obscuritarsus* (Table 3).

From the present pollination study, it is evident that hymenopterans were most abundant and lepidopterans were more diversified insect pollinators on bael flowers. Irrespective of different day hours, significantly maximum number of *A. dorsata* was recorded from bael flowers followed by *B. aurota*, *C. pyranthe, M. cephalotes*, *A. florea, E. obscuritarsus* and *A. mellifera.* Peak activity of *A. dorsata* was recorded between 0800h -1000h during full bloom of crop. Peak abundance of all honey bee species was recorded at 1000-1200h. Minimum abundance was recorded at 0600h -0800h irrespective of weeks. It is suggested that pesticidal sprays during during peak activity of pollinators should be avoided to conserve the pollinators and enhance their biodiversity.

Received 18 April, 2016; Accepted 16 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 743-746

Manuscript Number: 2368
NAAS Rating: 4.47

Nutritional Indices and Biology of the Armyworm, *Spodoptera litura* on Five Cotton Varieties

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Abstract: Nutritional indices and biology of the armyworm *Spodoptera litura* were studied on CB1, CB3, CB5, CB8 and CB12 cotton varieties. The *S. litura* larval food consumption indices were highest and lowest on CB5 and CB1, respectively. The larval approximate digestibility and efficiency of conversion of ingested food were higher and similar on CB5 and CB8. The efficiency of conversion of digested food was highest on CB8 and lowest on CB1. Cotton varieties did not affect pre-oviposition periods, but the moths reared on CB8 had highest fecundity. The development durations of the larval instars varied significantly, and total larval periods were found shortest and longest on CB12 and CB8, respectively. Pupal development on CB1 and CB12 were similar and longer than that on others. Egg to adult development period was shortest on CB12 and it was statistically identical and longer on CB8 and CB5. The survival rates of egg, larva, pupa and egg to adult were higher on CB5 and CB8 than on the other varieties.

Key Words: Food consumption, *Gossypium hirsutum*, Life history, *Spodoptera litura*

The polyphagous insect armyworm, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) is a highly destructive pest of cotton in Bangladesh (Tithi *et al*., 2010b; Amin *et al.,* 2011). They cause severe loss to 120 cultivated and uncultivated plant species distributed in 44 families elsewhere in the world (Pogue, 2003; Gao *et al.,* 2004; Qin *et al.,* 2004). The pest becomes resistant to many commonly used insecticides, particularly pyrethroids and carbamates, resulting in failure of effective controls (Ahmad *et al.,* 2007; Huang and Han, 2007). The effect of host plants on the biology of insects indicates host suitability of the herbivore insects. Many authors reported the biological parameters such as growth, development and survival of *S. litura* on different host plant species as well as different varieties of a crop grown under same or varied environmental conditions (Zhu *et al.,* 2000; Zhu *et al.,* 2005; Amin and Tithi, 2013). Maternal diet effects on the egg size, duration of offspring development and adult size (Jann and Ward, 1999; McIntyre and Gooding, 2000; Agarwal, 2001). Insect nutrients in the host plants and efficiency of food consumption are determining factors for growth and development of the pest insects (Browne and Raubenheimer, 2003). The chemical composition of host plants significantly affects survival, growth and reproduction of phytophagous insects (Bernys and Chapman, 1994). Amin *et al.* (2011) reared *S. litura* on CB9, CB10 and SR05 cotton varieties and observed significant variations in their feeding behavior and growth responses. The most important tool in the insect-pest management programs is the cultivation of resistant variety, which is also favorable to the environment and reduces costs of production (Liu *et al*., 2004). Morphological features and biochemical contents in the plants affect herbivore's feeding and nutrition, and deserve varietal resistance. Some related studies have been conducted on the effects of host plants apart from cotton varieties on nutritional indices of *S. litura* (Xue *et al.,* 2010). Therefore, the present study was conducted with CB1, CB3, CB5, CB8 and CB12 cotton varieties to know their effects on nutritional indices and life history of *S. litura* in laboratory condition.

MATERIAL AND METHODS

The experiment was conducted in the laboratory of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during June 2013 to March 2014. The cotton varieties namely CB1, CB3, CB5, CB8 and CB12 were cultivated in the field laboratory of the Department of Entomology. Adult male and female of *S. litura* or larvae were collected from the Cotton Research Station, Gazipur and they were reared in the laboratory for mass culture and subsequently to study their nutritional indices and biology on test varieties.

Observation of nutritional indices: Newly exuviated fifth instar larvae (approximately same size) were selected and individually placed in small petri dishes, starved them for 10 h, and then the larvae were individually weighed. Therefore, the larvae were equally divided into a control group and a treatment group. In the control group, the larvae and fresh leaves from host plants (one leaf for each larva) were individually dried in a drier at 70°C and weighed. In the treatment group, leaves detached from the host plant were provided to the larvae. The larvae were fed leaves for 48 h and starved for 6 h to allow them to defecate. The larvae, leaf tissues in each dish were dried in a drier at 70°C. The dried leaf tissues and larvae were weighed again. The following formulae were used according to Waldbaur (1968) to calculate consumption index (CI), approximate digestibility (AD), efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD):

$$CI = \frac{E}{A}$$

$$AD = \frac{E - F}{E}$$

$$ECI = \frac{P}{E}$$

$$ECD = \frac{P}{E - F}$$

Where, A = mean dry weight of insect over unit time, E = dry weight of food consumed, F = dry weight of feces produced, and P = insect dry weight gain.

Study of the biology of the insect: Twenty five adult moths were kept individually in jars containing fresh cotton flower of the test varieties and day to first egg laying was considered as pre-oviposition periods and their fecundity was recorded. Newly developed eggs were counted from egg masses. The eggs were monitored daily to determine their survival rate (% egg hatched) and period (duration between oviposition to hatching). The pre-pupation rate (% larvae turned into prepupae), pupation rate (% prepupae turned into pupae) and egg to adult survival rate (% egg turned into adult) were recorded by rearing 20 newly developed eggs in a jar containing test cotton leaves. The development durations of the stages were recorded. The larval period was counted as the duration of egg hatching to pupation.

RESULTS AND DISCUSSION

The nutritional indices of the cotton armyworm larvae fed on CB1, CB3, CB5, CB8 and CB12 varieties are presented in Table 1. Larval food consumption indices differed significantly ($F_{4, 20} = 3.1$, $p < 0.05$) and it was highest (6.1) on CB5 and lowest (4.1) on CB1. Significant differences were found in approximate digestibility ($F_{4, 20} = 3.1$, $p < 0.05$) and efficiency of conversion of ingested food ($F_{4, 20} = 3.1$, $p < 0.05$) of the larvae which ranged from 66.4 to 72.8 and 16.2 to 17.8, respectively. The larvae fed on CB5 and CB8 revealed statistically similar and higher approximate digestibility as well as efficiency of conversion of ingested food, while the larvae fed on CB1 had the lowest indices. The cotton varieties showed significant differences ($F_{4, 20} = 3.1$, $p < 0.05$) in larval efficiency of conversion of digested food, which were found highest (25.5) and lowest (23.2) on CB8 and CB1, respectively. The findings showed that the larvae were more efficiently converting all the cotton varieties into their biomass but differed in their food consumption, digestion and ingestion. The plant morphological and biochemical traits may have influenced on their feeding, and the digestion rate was affected by the activity of different enzymes. Zhu *et al*. (2005) found that *S. litura* larvae did not prefer feeding on banana leaves and had relative consumption rate, and approximate digestibility, but it had a significantly higher efficiency of conversion of ingested food and an extremely higher rate of efficiency of conversion of digested food. Naseri *et al.* (2010) reported that the nutritional requirements of the herbivore insects over different developmental periods are positively correlated with growth, and growth is directly based on nutrient input.

Table 1. Nutritional indices of *Spodoptera lituta* reared on leaves of five cotton varieties

Nutritional indices	Cotton variety				
	CB1	CB3	CB5	CB8	CB12
Consumption index	4.1	4.9	6.1	5.5	4.4
Approximate digestibility	66.4	69.6	72.4	72.8	68.2
Efficiency of conversion of ingested food	16.2	16.5	17.4	17.8	16.4
Efficiency of conversion of digested food	23.2	23.4	24.0	25.5	23.4

The development durations of the life stages of *S. litura* are presented in table 2. The egg stages did not differ significantly ($F_{4,20} = 0.50$, $p = 0.74$) but the effect of the varieties on the larval stages were significant (1st instar: $F_{4,20} = 3.7$, $p < 0.05$; 2nd instar: $F_{4,20} = 2.9$, $p < 0.05$; 3rd instar: $F_{4,20} = 4.4$, $p < 0.01$; 4th instar: $F_{4,20} = 3.5$, $p < 0.05$; 5th instar: $F_{4,20} = 4.5$, $p < 0.05$). These findings are supported by Tithi *et al.* (2010a) who observed significant variations in larval instars of *S. litura* when reared on three cotton varieties. In this study, the first, third and the fourth instars had significantly longer durations on CB5 and CB8. In contrast, the second and fifth instars development took longer durations on CB8. The total larval development period ranged from 26.0 to 30.8 days and was significantly affected by the varieties ($F_{4,20} = 10.7$, $p < 0.001$). The larvae passed the longest time on CB8 and the shortest on CB12 (Table 2). The cotton varieties did not affect the pre-oviposition periods of the moths ($F_{4,20} = 0.77$ $p = 0.56$; Table 2). The pre-oviposition periods ranged from 2.2 to 2.6 days, which are supported by Jawar *et al*. (2013) who observed the pre-oviposition periods of *S. litura* 2.47 days on *Centella asiatica* plant. Insects like to oviposit on the plants, which are suitable as shelter and diet for their immature and adult

Table 2. Development duration of the life stages, pre-oviposition periods and fecundity of *Spodoptera litura* reared on five cotton varieties

Cotton variety	CB1	CB3	CB5	CB8	CB12
Incubation period (day)	2.6	2.4	2.4	2.2	2.2
First instar larval period (day)	5.4	5.4	6.2	6.2	5.4
Second instar larval period (day)	5.8	5.8	6.2	6.6	5.8
Third instar larval period (day)	4.8	6.6	6.8	6.8	5.4
Fourth instar larval period (day)	5.4	5.4	5.8	5.8	4.8
Fifth instar larval period (day)	5.8	6.2	6.4	6.6	5.4
Total larval period (day)	27.2	28.4	30.2	30.8	26.0
Prepupal period (day)	3.8	3.6	3.2	3.6	3.6
Pupal period (day)	10.6	9.8	9.4	9.4	10.8
Egg to adult period (day)	44.2	44.2	45.2	46.0	43.0
Pre-oviposition period (day)	2.6	2.4	2.0	2.2	2.6
Fecundity (number of egg female^{-1})	995	1066	1247	1386	1063

stages. Cabezas *et al.* (2013) reported that females of *Spodoptera cosmioides* originating from larvae reared on castor bean and barbados nut leaves showed greater fecundity than did females originating from larvae reared on tung oil tree leaves. In this study, the fecundity of the moths varied from 995 to 1386 female^{-1} (Table 2) and the results differed significantly ($F_{4,\ 20}$ = 3.5, p < 0.05). The females oviposited the highest number of eggs on CB8. Amin *et al*. (2013) reared *S. litura* on SR05 cotton variety and observed 1656.8 egg female^{-1}. There was no difference in the periods of the prepupal stage ($F_{4,20}$ = 0.9, p = 0.47), but the pupal durations differed significantly ($F_{4,20}$ = 6.1, p < 0.01; Table 2). The larvae fed on CB12 revealed the longest pupal development time (10.8 days). The durations from egg to adult emergence differed significantly ($F_{4,20}$ = 3.4, p < 0.01); and the larvae fed on CB8 and CB12 showed the longest (46.0 days) and shortest (43.0 days) time, respectively. In this study, total larval period ranged from 26.0 to 30.8 days. Xue *et al*., 2010) reported the total larval durations of *S. litura* on tobacco, cabbage, cowpea and sweet potato 23.2, 17.5, 15.8 and 13.3 days, respectively, whereas, Jawar *et al.* (2013) found 14.25 days on *C. asiatica* plant. Shahout *et al.* (2011) reported larval duration of *S. litura* 15.73 days on cotton.

Xue *et al.* (2010) observed pupal durations of *S. litura* on tobacco, cabbage, cowpea and sweet potato 10.9, 10.1 10.1 and 9.5 days, respectively. Jawar *et al.* (2013) found pupal period on *C. asiatica* plant 9.52 days, and Shahout *et al*. (2011) observed 8.0 days on cotton. This study showed pupal durations from 9.4 to 10.8 days. There was observed variations in egg to adult durations, which ranged from 43.0 to 46.0 days. Cabezas *et al.* (2013) reported that the egg-to-adult development time of *S. cosmioides* was shortest when reared on castor bean leaves and longest when reared on tung oil tree leaves. The study also showed insignificant differences in the development durations of the eggs and prepupae. The durations of the incubation and prepupae ranged from 2.2 to 2.6 and 3.2 to 3.8 days, respectively and the results showed agreement with Jawar *et al*. (2013), who observed incubation period 2.25 days and prepupal period 3.37 days on *C. asiatica* plant.

In the present study egg, larvae, prepupae, pupae and egg to adult survival varied from 56.8 to 64.4, 72.1 to 81.4, 64.0 to 74.4, 60.0 to 69.2, 15.6 to 26.8% (Table 3). The survival rates were significantly affected for the egg stage ($F_{4,\ 20}$ = 3.1, p < 0.05), larva ($F_{4,\ 20}$ = 3.7, p < 0.05) and pupa ($F_{4,\ 20}$ = 3.7, p < 0.05), but prepupal stage was insignificant ($F_{4,\ 20}$ = 0.91, p = 0.48). Insects reared on CB5 and CB8 showed the highest survival rates of eggs and larvae. The pupal, and egg to adult emergence were highest on CB8. The variety CB12 revealed the lowest rate of survival for all the development stages. Xue *et al.* (2010) studied the biology of *S. litura* on different host plants and found larval and pupal survival from 49.2 to 81.6% and 91.4 to 95.9%, respectively. Qin *et al.* (2004) studied the life duration and survival rate of *S. litura* on different host plants and observed significant differences.

Table 3. Survival rates for the immature stages of development of *Spodoptera lituta* reared on five cotton varieties

Development stage	Survival (%)				
	CB1	CB3	CB5	CB8	CB12
Egg	59.2	62.4	62.8	64.4	56.8
Larva	73.2	77.6	81.4	80.8	72.1
Prepupa	66.4	71.1	68.8	74.4	64.0
Pupa	60.5	66.5	66.9	69.2	60.0
Egg to adult	17.6	22.6	23.4	26.8	15.6

The present study showed that the cotton varieties were suitable for the growth, development, survival and longevity of *S. litura* but the insects revealed variations in their nutritional indices and life history parameters.

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 747-751

Manuscript Number: 2369
NAAS Rating: 4.47

Rotifers as Bioindicators to Water Quality in Khajiyar Lake, Himachal Pradesh, India

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Abstract: Total number of rotifers showed highly significant and positive relationship with conductivity, total solids, total dissolved solids, total suspended solids and positive relation with free carbon dioxide in Khajiyar Lake, Himachal Pradesh. The relationship between free carbon dioxide and total number of rotifers can be treated as an index of eutrophication. A highly significant and positive relation of chloride concentration with rotifers was also obtained. Such an association is an indication of pollution which was indicated in values of chloride (more than 18.0mg l^{-1}). The higher concentration of free carbon dioxide (11-26.8 mg l^{-1}), chloride (20.2 – 33.1mg l^{-1}), nitrate-nitrogen (98- 485µg l^{-1}), total phosphate phosphorous (610- 2320µg l^{-1}) and their significant and positive association with total rotifers along with the presence and abundance of *Keratella cochlearis*, *Keratella volga,* and *Branchionus havanaensis* revealed that the Khajiyar lake is polluted.

***Key Words*:** Bioindicators, Eutrophication, Pollution, Rotifers

Fresh water ecosystems performs many important environmental functions like recycling of nutrients, purifying water, attenuating floods, recharging ground water and providing habitats for wild life. Presently, the natural environment suffers from the detrimental effects of pollution due to technological advancement. The discharge of industrial effluents has lead inevitably, to alterations in the quality and ecology of water bodies. This brings new challenges to both water resource managers and aquatic ecologists. Several attempts have been made to regulate and control the quality of effluents that are discharged from waste generating industries into our water systems.

A degree of water pollution is determined by physico-chemical characteristics followed by the presence and abundance of aquatic organisms. The physico-chemical characteristics of water indicate the condition where as the biological observations measure the effects on the aquatic ecosystem. Due to the geometrical increase in the environmental perturbations in aquatic ecosystems, their rapid surveillance has become imperative. The bio-monitoring using planktonic communities as indicators in relation to the physico-chemistry of the system have a definite role to play in assessing water quality quickly. Detection of pollution or eutrophication using planktonic communities has been pursued by many workers (Chawdhury *et al.,* 2007). They occupy a central position between the autotrophs and heterotrophs and form an important link in food web of the fresh water ecosystems. Zooplanktons are mainly composed of cladocerans, copepods, rotifers and ostracods. Rotifers, mostly Monogononta, occur in all types of water bodies, worldwide and are particularly diverse in the littoral zone of stagnant water bodies with soft, slightly acidic water. These play very significant role in the food chain and biological productivity of aquatic ecosystem. A few rotifers are cosmopolitan while majority of these animals are highly adapted to a wide range of freshwater conditions (Fafioye and Omoyinmi, 2006)

The dominance of rotifers in zooplanktons composition indicates rapid eutrophication in aquatic ecosystems and are excellent indicators of environmental conditions and aquatic health within ponds (Burford *et al.,* 2003). They respond to dissolved oxygen, pH, and free carbon dioxide levels etc. A good picture of current conditions of water quality in the ponds and lakes can be derived by looking at planktonic indicators and their features, such as biomass, abundance and species diversity. Rotifers used in pollution studies either as bioindicator species or as a part of the saprobic assessment system for some time. The former relies on a list of the species known to indicate pollution while the latter integrates a large number of abiotic and biotic characteristics in to a single variable determining the relative level of eutrophication. Thus, in the present investigation their presence, abundance and distribution in relation to physico-chemical characteristics has been used as an index of water quality in fresh water Khajiyar lake ecosystem.

MATERIAL AND METHODS

The Khajiyar lake about 2000 m above the sea level in the foothills of the Dhauladhar ranges of Western Himalayas situated at 32° 32' 53" N and 76° 3' 34" E was selected to study its limnology.

Estimation of physico-chemical characteristics: The surface water samples of Khajiyar Lake at three sites were collected for six months over the year in of April-May in summer, July-August in rainy season and December-January in winter from July 2011 to May 2012. The samples were analyzed and averaged for different physico-chemical characteristics like temperature, secchi disc transparency, conductivity, total solids, total dissolved solids and total suspended solids, pH, dissolved oxygen, free carbon dioxide, alkalinities, chloride, nitrates, total phosphate-phosphorus, sodium and potassium (APHA, 2000).

Qualitative and quantitative enumeration of rotifers: For qualitative and quantitative enumeration of rotifers, the samples were collected for six months over the year in April-May in summer, July-August in rainy season and December-January in winter water samples (500ml) were filtered through nylo-bolt silk cloth plankton net of small mesh size (100mesh mm^{-2}) for the enumeration. The filtered samples were fixed with 4% neutralized formaline, lugol's solution and a few drops of glycerine. Samples were allowed to settle over night. After siphoning off the supernatant without disturbing the sediments, the volume was made to 5ml. After uniform stirring, 1ml of final volume was counted in zooplankton counting chamber under planktonic microscope. The number of rotifers per litre was calculated (APHA, 2000).

Rotifers per litre = $(C \times V_{1)} / (V_2 \times V_3)$

Where, C = Number of rotifers counted; V_1, V_2 and V_3= Volume of concentrated sample, counted strips and samples filtered.

RESULTS AND DISCUSSION

Physico-chemical characteristics: The seasonal variation in qualitative and quantitative presence and abundance of zooplankton in general and rotifers in particular differ from environment to environment depending upon the physico-chemical regime of aquatic ecosystem. Thus, fresh water ecosystems, which differ in physico-chemical regime certainly differ in their biological composition.

Conductivity: Electrical conductivity was minimum (120µmhos cm^{-1}) in the month of December and Maximum (230µmhos cm^{-1}) in May. The conductivity showed highly significant and positive relationship (r = 0.966, **$p<0.01$) with total dissolved solids. There was also a highly significant and positive relationship (r = 0.984, **$p<0.01$) with chloride and significant and positive relationship (r = 0.859, **$p<0.01$) with number of rotifers per litre.

Total solids (TS): The total solids varied from 198.81 mg L^{-1} to 389.0mg L^{-1}. The maximum concentration of total solids was obtained in May and the minimum in December. Total solids showed highly significant and positive relationship (r =0.997, **$p<0.01$) with total suspended solids and total dissolved solids (r = 0.999, **$p<0.01$).

Total dissolved solids (TDS): The values of total dissolved solids ranged from 168.81mg L^{-1} to 330mg L^{-1} where maxima was May and minima December. It showed highly significant and positive relationship (r = 0.966, **$p<0.01$) with conductivity. The concentration of TDS is proportional to the electrical conductivity of the water. It also showed highly significant and positive correlation (r = 0.929, **$p<0.01$), (r = 0.825, **$p<0.01$) and (r = 0.907, **$p<0.01$) with chloride, total alkalinity and number of rotifers per litre respectively.

Total suspended solids (TSS): The suspended matter in water consists of silt, clay, fine particles of organic and inorganic matter, soluble organic compounds, plankton and other microscopic organisms. The total suspended solids varied from 30.0 mg L^{-1} to 59.0 mg L^{-1} The maximum concentration was May and minimum in December. TSS showed significant and negative relationship (r = -0.710, **$p<0.01$) with transparency. The effect of presence of total suspended solids is the turbidity due to silt and organic matter. It also showed highly significant and positive correlation (r = 0.916, **$p<0.01$) and (r = 0.866, **$p<0.01$) with chloride and total alkalinity.

Free carbon dioxide: Free carbon dioxide varied from 11mg L^{-1} to 26.8mg L^{-1}. Maximum value was month of August and minimum in the month of December during winter season. The highly significant and negative relationship (r = -0.981, **$p<0.01$) with dissolved oxygen and with secchi transparency (r = -0.989, **$p<0.01$). The high concentration of free carbon dioxide in August may be due to the rise in temperature, which enhances the microbial activities and increases bio-chemical demand.

Chloride : Chloride occurs naturally in all types of waters. In natural freshwaters, however, its concentration remains quite low and is generally less than that of sulphates and bicarbonates. The chloride ion had no definite pattern of variations throughout the course of present investigation. Its values ranged from 20.2 mg L^{-1} to 33.1 mg L^{-1}. It was recorded more than 18.0 mg L^{-1} throughout the study period. Thus, it can be said that the lake ecosystem is at an advanced stage of eutrophication.

Nitrate: Nitrate-nitrogen showed significant variation during the course of investigation varied between 0.098mg L^{-1} (December) to 0.485mg L^{-1} (July) during rainy season. It showed highly significant and positive correlation (r = 0.995, **$p<0.01$), (r = 0.995, **$p<0.01$) with air temperature and water temperature. It also showed negative correlation (r = -0.984, **$p<0.01$), (r = -0.907, ** $p<0.01$) and (r = -0.987, **$p<0.01$) with transparency, pH and dissolved oxygen. Such an association indicated nutrient enrichment of Lake Ecosystem. The high value of nitrate-nitrogen during rainy season may be attributed to the inflows of wastes from catchment area to the lake system.

Total phosphate : Total phosphate-phosphorous contents were highest during rainy season. It decreased in winter and again increased in summer season. The minimum concentration of total phosphate – phosphorus was recorded during winter season in the month of December (610µg l^{-1}). Whereas its maximum values were obtained in the month of August (2320µg l^{-1}) during rainy season. Total phosphate-phosphorous showed highly significant and positive relation with air temperature (r = 0.948, ***p<0.01*), water temperature (r = 0.976, ***p<0.01*), free carbon dioxide (r = 0.880, ***p<0.01*) and showed highly significant and negative correlation with secchi transparency (r = -0.923, ***p<0.01*). Its maximum values during rainy season may be attributed to the inflows from the catchment area consisting of forest and pasture land being disturbed by tourism activities. The minimum concentration in December during winter may be ascribed to decreased planktonic population.

Sodium: The sodium content of the lake ranged from a minimum of 4.8mg L^{-1} to a maximum of 6.5mg L^{-1} (July and December). May of the minimum value can be explained on the basis of lower microbial activity, whereas, the maximum value might be due to high rate of mineralization in the sediments, increasing sodium into the nutrient pool thereby making more sodium to solubilise. It showed significant and positive relationship (r = 0.635, **p<0.05*) with potassium.

Potassium: The potassium concentration varied from 1.0 mg L^{-1} to 2.3 mg L^{-1} where maxima was April and minima in December. It showed highly significant and positive relationship (r = 0.834, ***p<0.01*) with chloride. The increase in sodium and potassium concentration in the present study may be ascribed to the wastes inflows to the lake ecosystem.

Seasonal variation in rotifer species and their abundance in relation to Physico-chemical regime: During the course of present investigation the rotifers fauna was found to be composed of nine species viz; *Keratella cochlearis*, *Keratella*

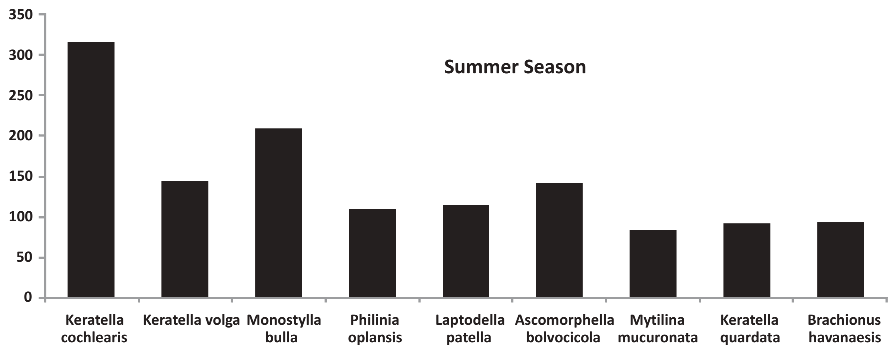

Fig. 1. Rotifers species and their dominance in summer season

Table 1. Co-efficient of correlation among physico-chemical characteristics and number of rotifers

Parameters	Dissolved oxygen (mg l^{-1})	Free carbon Dioxide (mg l^{-1})	Total solids (mg l^{-1})	Total dissolved solids (mg l^{-1})	Total suspended solids (mg l^{-1})	Total Alkalinity (mg l^{-1})	Total Phosphate Phosphorus (µg l^{-1})	Nitrate Nitrogen (µg l^{-1})	Chloride (mg l^{-1})	Sodium (mg l^{-1})	Potassium (mg l^{-1})	Number of Rotifers (org l^{-1})
Dissolved oxygen(mg l^{-1})		-0.982**	-0.675*	-0.669*	-0.710**	-0.851**	-0.938**	-0.987**	-0.690*	0.049	-0.557	-0.301
Free carbon dioxide(mg l^{-1})			0.635*	0.627*	0.679*	0.877**	0.880**	0.962**	0.588*	-0.174	0.465	0.273
Total solids(mg l^{-1})				0.999**	0.997**	0.832**	0.860**	0.783**	0.928**	0.578*	0.737**	0.904**
Total dissolved solids(mg l^{-1})					0.996**	0.825**	0.857**	0.778**	0.929**	0.586*	0.737**	0.907**
Total suspended solids(mg l^{-1})						0.867**	0.876**	0.812**	0.917**	0.532*	0.732**	0.884**
Total Alkalinity (mg l^{-1})							0.867**	0.889**	0.716**	0.154	0.688*	0.607*
Total Phosphate Phosphorous (µg l^{-1})								0.974**	0.896**	0.294	0.745**	0.561*
Nitrate-Nitrogen (µg l^{-1})									0.781**	0.814*	0.617*	0.447
Chloride (mg l^{-1})										0.682*	0.834**	0.776**
Sodium (mg l^{-1})											0.656*	0.736**
Potassium(mg l^{-1})												0.596*

volga, *Monostylla bulla, Fillinia oplansis*, *Laptodella patella*, *Ascomorphella bolvocicola, Mytilina mucuronata, Brachionus havanaensis, Keratella quardata.* *Keratella cochlear*is, *Keratella volga, Monostylla bulla, Filinia oplansis and Laptodella patella.* During summer season in the month of April and May nine species in total were recorded (Fig.1). Among these species *Keratella cochlearis* (24%) dominated and *monostylla bulla* (16%) co-dominated the population. *Mytilina mucuronata* (6%) was recorded as a species with lowest population. Almost the similar pattern was observed for their dominance in rainy season (Fig.2) except for the number of species during July and August. In winter season seven species were present (Fig.3). These species were *Keratella cochlearis, Keratella volga, Monostylla bulla, Philinia oplansis, Laptodella patella, Ascomorphella bolvocicol*a and *Mytilina mucuronata*. The *Monostylla bulla* (34%) dominated the rotifers population and lowest (5%) of *Keratella volga* and *Ascomorphella bolvocicola* each were recorded. The population dominance *of Keratella cochlearis* and *Monostylla bulla* and decrease in number of species and an increase in their population can be treated as an index of eutrophication.

Ecology of rotifers: The ecology of rotifers in the present investigation revealed that among these nine species *Keratella cochlearis* dominated the population followed by *Monostylla bulla* and *Keratella volga.* Such a pattern of dominance and co-dominance of these species indicated eutrophication in an aquatic ecosystem. The minimum population of the species in the month of December and January during winter season may be ascribed to the low temperature. These species were positively correlated with nitrate-nitrogen and significantly and positively related with total phosphate-phosphorous (r = 0.561, *$p<0.05$).

The negative relationship was obtained in between rotifer's species and secchi transparency, dissolved oxygen and also with pH. The negative relationship in the present investigation may be ascribed to the less species biodiversity of rotifers and presence and abundance of pollution indicator species like *Keratella cochlearis*, *Keratella volga* and *Branchionus havanaensis*. Thus, the presence, abundance and distribution of rotifers in a lake ecosystem play a significant role in its structural functioning. The change in their species biodiversity and abundance is greatly

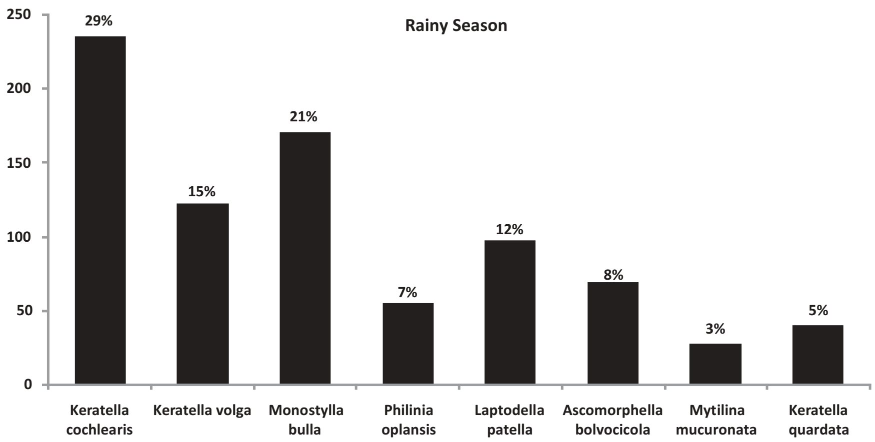

Fig. 2. Rotifers species in rainy season and their dominance in rainy season

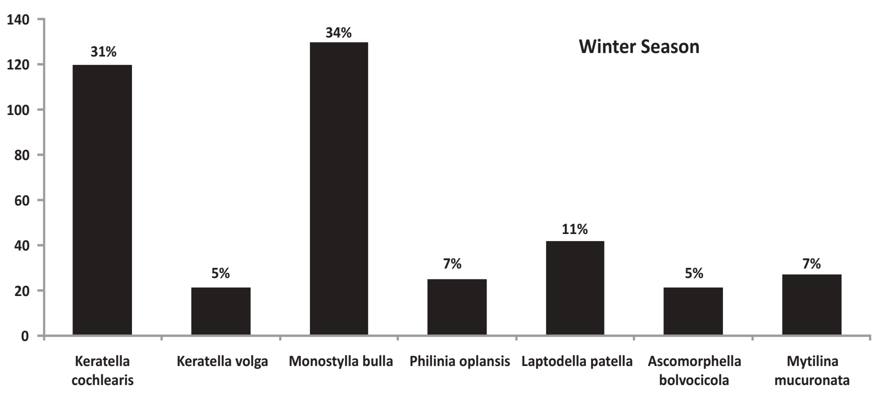

Fig. 3. Rotifer's species and their dominance in winter season

influenced by physico-chemical regime of aquatic environment thereby revealing that the Khajiyar lake is polluted.

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Received 02 February, 2016; Accepted 14 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 752-755

Manuscript Number: 2370
NAAS Rating: 4.47

Performance of Different Wheat Varieties under Poplar (*Populus deltoides*) Based Agroforestry System

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Abstract: Different wheat varieties viz., WH-1105, WH-542, HD-2967, HD-943 and DPW-621-50 were grown under 5 m × 4 m, 10 m × 2 m and 18 m × 2 m × 2 m spacings of 7 years old poplar. There were significant differences in mean values for grain yield, straw yield, total number of tillers m^{-2}, number of ear heads, number of grain/ear head and 1000 grain weight of wheat crop as a result of differential tree spacing and wheat varieties. The maximum reduction in grain yield was found in wheat variety WH-1105 (59.2%) followed by HD-943 (48.7%), WH-542 (44.6%), DPW-621-50 (42.8%) and HD-2967 (27.9%) under different spacings of poplar plantations. The best combination of spacing and variety under block plantation of poplar was 18 m × 2 m × 2 m sown with HD-2967, which produced highest growth parameters like total tillers m^{-2} (331.4), number of ear head m^{-2} (324.3), number of grain/ear head (38.1), 1000 grain weight (38.2) and maximum grain yield t ha^{-1} (3.00). Amongst different wheat varieties, variety HD-2967 was found most suitable in poplar based agroforestry system.

***Key Words*:** Agroforestry system, Growth parameters, Poplar, Spacing, Variety, Wheat

Indian agriculture is facing challenges and constraints due to growing demographic pressure, increasing food, feed and timber needs, natural resources degradation and climate change (Chauhan and Mangat, 2006; Dhyani and Handa, 2013). Diversification of existing farming systems by developing suitable agroforestry models seems to be the need of the day (Chauhan and Ritu, 2005; Dhillon *et al.* 2012). Appropriate selection of tree and crop species helps to increase yield, improve soil fertility, promote land sustainability and resource use efficiency (Sharma *et al*., 2004; Chauhan *et al*., 2013). 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). There is a growing interest among farming communities to integrate fast growing multipurpose trees in agroforestry systems to obtain early and good economic returns. *Populus deltoides,* is one such promising species recognized as important tree component in agroforestry system to prevent land degradation and obtain biological production on sustainable basis (Pandey, 2007). Due to its fast growth, high price, less competition with associated crops and pruning tolerant nature, this species has been grown by farmers in Punjab, Haryana and Uttar Pradesh, as boundary or block plantation along with agricultural crops, which improves the physico-chemical properties of soil through addition of organic matter in the soil and provides alternate sources of income and employment to the rural poor (Puri and Nair, 2004; Singh *et al.,* 2016). In poplar, leaf fall starts in October and by the month end about 13% leaves fall, which gradually increase to 27 and 84% by the end of November and December, respectively though regulated by climatic factors. The trees become totally leaf less in January and February. New flush of leaves starts appearing by end March and the trees are fully flush by end April. Wheat is one of the most important winter crops being grown in association with boundary or block plantations of poplar in India.

This is due to the ability of poplar to adapt to the wheat competition by distorting its root architecture that improves complimentarity between trees and crops. Many workers have reported the performance of different wheat varieties as intercrop under one year old poplar block plantation. Competition for below and above ground resources often changes with the increase in tree age. There is a gradual yield reduction (10-46%) of wheat, grown under poplar, with the increase in age of trees. Such yield los is often compensated by the sale of poplar wood at the end of rotation (Chauhan *et al.,* 2010; 2015). Since the maintenance of increased agricultural production along with industrial timber and firewood is essential to meet the needs of an ever-increasing population. The adoption of poplar based agroforestry system is driven by economic incentives and by the national policy to save natural forests from further deforestation. The main objective of the study was to find out partially shade tolerant/compatible wheat varieties that can be commercially grown under different spacings of poplar plantation.

MATERIAL AND METHODS

A field experiment was carried out during rabi season of 2013-14 in the research farm of Department of

Forestry, CCS Haryana Agricultural University, Hisar, Haryana, India. The research farm is located at 29° 10' N latitude and 75° 40' E longitude receiving average annual rainfall of about 400 mm. Most of the year is dominated by prolonged hot period from April to October. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and June. Hisar and the adjoining areas sometimes experience as high as 48°C temperature and the coldest in winter. Due to high temperature in the area, relative humidity remains low from March to June (41-58 %). Poplar was planted at 5 × 4 m, 10 × 2 m and 18 × 2 × 2 m (in paired row) spacing during 2007. The experiment was laid out in factorial randomized block design with three replications.

Five wheat varieties viz., WH-1105, WH-542, HD-2967, HD-943 and DPW-621-50 representing early sown varieties of north-western India were selected to test their performance under different spacing of poplar plantations in comparison to control (without poplar). At the time of sowing, half dose of N, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} were applied. The remaining half nitrogen was applied before first irrigation (crown root initiation stage). Data of wheat crop were recorded under different spacings of poplar at 5 m ×4 m, 10 m × 2 m and 18 m × 2 m × 2 m (in paired row). The total tillers m^{-2}, number of ear heads m^{-2}, number of grains/ear head and 1000-seed weight (test weight) were recorded at physiological maturity. The net plots were harvested to obtain grain and straw yield. The above parameters of wheat crop were also recorded in control field and data were suitably analysed.

RESULTS AND DISCUSSION

Yield attributes: The data presented in Table 1 revealed that different varieties of wheat grown under paired row spacing (18 m × 2 m × 2 m) had produced maximum number of tillers m^{-2}, number of ear heads, number of grain /ear head and 1000-grain weight followed by that in 10 m × 2 m and 5 m × 4 m spacing. The difference in the mean values of yield attributing characters may be due to wider tree spacings encouraging the availability of light, water and nutrients at the time of grain formation in comparison to high density of poplar plantation. The yield attributes mainly depend on the crop growth and significantly affected by tree spacings as they affect wheat growth. Similar results were reported by Kaushik and Singh (2001), Sharma *et al.* (2000) and Kumar and Rajput (2003). However, the number of tillers m^{-2}, number of ear heads, number of grain/ear head and 1000 grain weight were significantly lesser under different spacings of poplar plantation as compared to control. It was also found that wheat under poplar planted at 6×1.5 m, 6×3 m and 5×4 m spacing had produced lower number of sterile spikelets/spike in comparison to control plot (Gandhi, 2008). In present study, number of tillers/m^2, number of ear heads, number of grain/ear head and 1000-grain weight were recorded significantly higher (331.4, 310.0, 27.1 and 29.5) in wheat variety HD-2967 followed by WH-542, DPW-621-50, HD-943 and WH-1105 under all the tree spacings. The variation in effective tillers of wheat due to heterogeneity in genetic constitution has also been reported by Rawat *et al.* (2000).

Grain and straw yield: The interactions between tree spacings and wheat varieties had significant influence on yield. Among varieties, it was observed that the grain yield

Table 1. Growth and yield attributing parameters of different wheat varieties under different spacings of poplar based agri-silviculture system

Spacing (m)	Varieties					Mean
	WH-1105	WH- 542	HD-2967	HD-943	DPW-621-50	
Total tillers m^{-2} (Number of ear heads m^{-2})						
5 × 4	252.1 (245.2)	284.1 (277.0)	305.2 (297.1)	263.0 (256.0)	272.3 (265.0)	275.3 (268.1)
10 × 2	267.0 (257.3)	304.2 (297.1)	317.3 (310.0)	274.3 (266.2)	289.3 (280.0)	290.4 (282.1)
18 × 2 × 2	276.1 (267.1)	316.0 (307.9)	331.4 (324.3)	285.1 (276.3)	302.2 (294.0)	302.2 (293.9)
Control	371.4 (364.2)	356.2 (347.4)	348.6 (339.4)	329.2 (321.1)	321.1 (313.3)	345.3 (337.1)
Mean	291.7 (283.4)	315.1 (307.4)	325.6 (317.7)	287.9 (279.9)	296.2 (288.1)	
CD (p=0.05)	Spacing: 9.1 (8.9); Variety: 10.2 (10.0); Spacing x Variety: 20.5 (20.0)					
Number of grain/ear head (Test weight, g)						
5 × 4	16.0 (17.5)	24.1 (26.4)	27.1 (29.5)	19.1 (21.6)	21.1 (23.5)	21.5 (23.7)
10 × 2	20.1 (21.4)	31.1 (31.7)	34.1 (35.2)	24.1 (24.7)	27.1 (27.4)	27.3 (28.1)
18 × 2 × 2	23.1 (25.7)	33.1 (34.7)	38.1 (38.2)	26.1 (28.4)	29.1 (31.3)	29.9 (31.6)
Control	54.1 (54.6)	50.1 (50.7)	47.1 (47.4)	44.1 (44.6)	41.1 (41.4)	47.3 (47.8)
Mean	28.3 (29.8)	34.6 (35.9)	36.6 (37.6)	28.3 (29.8)	29.6 (30.9)	
CD (p=0.05)	Spacing: 1.01 (1.0); Variety: 1.13 (1.1); Spacing x Variety: 2.26 (2.3)					

Table 2. Yield of different wheat varieties (t ha^{-1}) under different spacing of poplar based agrisilviculture system and in open condition during 2013-14

Spacing	Varieties					Mean
	WH-1105	WH- 542	HD-2967	HD-943	DPW-621-50	
Grain yield*						
5 × 4	0.60 (0.90)	1.20 (1.70)	2.10 (2.50)	0.80 (1.30)	1.00 (1.50)	1.14 (1.58)
10 × 2	1.20 (1.50)	1.80 (2.20)	2.80 (3.00)	1.40 (1.70)	1.60 (2.00)	1.76 (2.08)
18 × 2 × 2	1.40 (1.70)	2.60 (3.00)	3.00 (3.30)	1.80 (2.20)	2.00 (2.40)	2.16 (2.52)
Control	5.00 (5.90)	4.70 (5.20)	4.30 (4.90)	3.90 (4.50)	3.50 (4.10)	4.28 (4.92)
Mean	2.05 (2.50)	2.58 (3.03)	3.05 (3.43)	1.98 (2.43)	2.03 (2.50)	
CD (p=0.05)	Spacing: 0.08 (0.09);	Variety: 0.09 (0.10);	Spacing x Variety: 0.19 (0.21)			

*Straw yield in parentheses

(3.00 t ha^{-1}) and straw yield (3.30 t ha^{-1}) of wheat variety HD-2967 was significantly higher than all other varieties of wheat followed by WH-542 under paired row spacing at 18 m × 2 m × 2 m than that in 10 m × 2 m and 5 m × 4 m spacing (Table 2), whereas, mean value for grain and straw yield was significantly lesser in wheat variety WH-1105 in all the spacings of poplar plantation, however, in control plot this variety showed maximum grain (5.00 t ha^{-1}) and straw yield (5.90 t ha^{-1}) and it was statistically superior to all the other varieties followed by HD-2967. Results therefore indicate that productivity of wheat crop was affected due to varying tree spacing. Trees grown in agroforestry system compete with agricultural crops for resources and result in reduction in crop yield. Hence shading by poplar leaves decreases the light intensity and ultimately it becomes one of the limiting factors for the decline in grain yield of wheat grown under poplar. Likewise, the micro-environmental modification under poplar tree canopy and the resultant effect on physiology and yield of turmeric grown under poplar canopy was studied by Dhillon *et al.* (2010) and in flower crops by Rani *et al.* (2015).

CONCLUSION

Based upon various crop yield attributing parameters, the best combination of spacing and variety was paired row planting 18 m × 2 m × 2 m with wheat variety HD-2967 followed by 10 m × 2 m spacing under poplar plantation. This gave the highest number of tillers/m^2, number of ear heads, number of grain/ear head, 1000-grain weight and maximum grain and straw yield t ha^{-1}. It was also observed that all the wheat varieties gave significantly higher yield, while planted in wider spacing of poplar and also control plot. In the closer spacing 5 m × 4 m of poplar plantation wheat crop gave lower yield due to poor grain formation.

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Received 20 April, 2016; Accepted 02 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 756-760

Manuscript Number: 2371
NAAS Rating: 4.47

Nutrient Status and Soil Chemical Properties under Different Spacings of *Eucalyptus* Based Agroforestry Systems in Semi-arid Ecosystem of India

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Abstract: Eucalyptus based agroforestry system performed better as compared to sole crop in respect of various soil chemical properties and available nutrients status in soil at different soil depths. Among different spacings organic carbon was found maximum (0.73%) under 3×3 m spacing in soil at different depths. The electrical conductivity was being lowered in soil at different depths from its initial status under different spacings of eucalyptus plantations. However, the soil pH did not show any considerable changes in all depths of eucalyptus plantation and control. The available N, P and K in soil at different depths increased significantly under different spacings of eucalyptus based agroforestry system in all the treatments from its initial values in soil at different depths. The highest available soil N (238 kg ha^{-1}), P (16.4 kg ha^{-1}) and K (315 kg ha^{-1}) were recorded in surface soil under 3×3 m spacing as compared to other spacings and sole crop under study.

Key Words: Agroforestry, Eucalyptus, Nutrient status, Spacing, Soil depth, Soil properties

Increasing human population is placing unprecedented demand for food and natural resources. This large amount of food production cannot be achieved by the agricultural sector only. The solution of this problem is through a combination of technological improvements and involvement of other natural ecosystems (Licker *et al.,* 2010). Traditional tree-integrated farming systems are adopted for security of food, fodder and fuel wood (Ndayambaje and Mohren, 2011; FAO, 2013; Chauhan and Ritu, 2005), but are unable to meet the requirement of the ever increasing population. There is a need of intensification of such tree-integrated system too to improve total land productivity (Murthy *et al.,* 2013). Agroforestry is one of the options with multifunctional value among numerous issues involved with livelihood improvement (Fukushima *et al.,* 2010). The most important benefit of agroforestry systems is the enhancement in total production by improving soil fertility (Singh, 2010). It will help in carbon sequestration and maintenance of soil productivity by reducing soil erosion and improving salt affected soils by lowering down the water table. Agroforestry can also be an appropriate technology in areas with fragile ecosystem and subsistence farming. Because of access to deeper nutrient pools than the crop, tree absorbs nutrient from deeper root zone and returns nutrients through litter fall and root turnover to the subsurface, thus helping in accumulating nutrients and improving soil physical properties (Singh and Rathod, 2006) and nutrient-use efficiency in the system (Buresh *et al.,* 2004).

Among the agroforestry tree species, eucalyptus is of paramount importance due to its fast and uniform growth, self-pruning, ability to coppice and small canopy as compared to most of the agroforestry tree species. *Eucalyptus* clones have revolutionized the productivity and profitability of the plantations in many states of our country (Lal, 2005) through integration into the various farming systems and their planting has resulted in high economic profitability compared with traditional crop production. Farmers' raised interest in eucalypt farm forestry has now caused for conversion of croplands into eucalypt woodlots (Dereje *et al.,* 2012). Eucalyptus plantation results in improvement in soil nutrient (N, P, K, and organic matter) as compared to natural soil (Jan *et al*., 1996). Also the increase in clay and silt content and decrease in sand content and an appreciable increase in the cation exchange capacity, organic carbon content, total and available nutrients were observed under eucalyptus tree plantation (Balamurugan *et al*., 2000). Eucalyptus plantation can ameliorate salinity and sodicity of soil by improving decreasing soil EC, pH and SAR (Nasim *et al.,* 2007). However, effects of eucalyptus cultivation on soil, especially the fertility-related, are not well defined. So the knowledge about the impact of eucalyptus on soil nutrient reserves as well as on soil organic matter is essential to define sustainable agroforestry practices. It is also likely that the changes in soil chemical properties, particularly in soil organic matter, differ after several eucalyptus rotations, varying with the soil type and dominant climate conditions. The purpose of this study was to evaluate effect of different spacings of eucalyptus based agroforestry system on soil chemical properties and nutrient status.

MATERIAL AND METHODS

The present study was conducted at research farm of Forestry Department, CCS Haryana Agricultural University, Hisar, Haryana, 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 mean annual rainfall is about 450 mm and the mean annual temperature ranges between 16°C and 20°C. Already established 8 years old eucalyptus plantation planted at 3×3 m, 6×1.5 m and 17×1×1 m (paired row) spacings were used to carry out the present investigation. Barley crop in rabi and dhaincha in kharif were raised in association with eucalyptus plantation with the recommended cultural practices under different spacings during the entire study period. The textural class of the soil is 'sandy loam' and the soil chemical properties and available nutrient status of soil at the time of eucalyptus plantation are depicted in Table 1 and 2.

Four soil samples were collected randomly under different spacings in three replicates from three depths (0-15, 15-30 and 30-60 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).

The experiment was conducted in randomised block design and data obtained during the course of this investigation, were analysed by using standard statistical procedure (Panse and Sukhatme, 1989).

Table 1. Initial soil chemical properties of the experimental field

Spacing (m)	pH (1:2)				EC (dSm^{-1})				Organic carbon (%)			
	Depth (cm)				Depth (cm)				Depth (cm)			
	0-15	15-30	30-60	Mean	0-15	15-30	30-60	Mean	0-15	15-30	30-60	Mean
3×3	7.3	7.5	7.6	7.5	7.9	2.8	2.3	4.3	0.56	0.44	0.37	0.46
6×1.5	7.4	7.6	7.8	7.6	7.8	2.9	2.5	4.4	0.54	0.42	0.37	0.44
17×1×1	7.4	7.8	7.8	7.7	7.4	2.7	2.4	4.2	0.50	0.37	0.32	0.40
Control	7.5	7.6	7.7	7.6	7.5	3.1	2.3	4.3	0.52	0.39	0.35	0.42
Mean	7.4	7.6	7.7		7.7	2.9	2.4		0.53	0.41	0.35	
CD (p=0.05)	Spacing (S):NS				Spacing (S):NS				Spacing (S):NS			
	Depth (D): NS				Depth (D): 0.7				Depth (D): 0.08			
	S× D: NS				S× D: NS				S× D: NS			

Table 2. Initial soil available nutrient status of the experimental field

Spacing (m)	Available N (kg ha^{-1})				Available P (kg ha^{-1})				Available K (kg ha^{-1})			
	Depth (cm)				Depth (cm)				Depth (cm)			
	0-15	15-30	30-60	Mean	0-15	15-30	30-60	Mean	0-15	15-30	30-60	Mean
3×3	169	119	105	131	13.1	9.8	8.8	10.6	225	169	151	182
6×1.5	171	122	108	133	11.2	8.4	7.5	9.0	210	158	141	170
17×1×1	165	113	101	126	10.4	7.8	7.0	8.4	215	161	144	173
Control	166	117	106	130	10.6	8.0	7.1	8.6	211	158	141	170
Mean	168	118	105		11.3	8.5	7.6					
CD (p=0.05)	Spacing (S):14				Spacing (S):1.0				Spacing (S):NS			
	Depth (D): 12				Depth (D): 0.9				Depth (D): 15			
	S× D: NS				S× D: NS				S× D: NS			

RESULTS AND DISCUSSION

The initial status of the available soil nutrients under various soil depths are given in Table 1 and 2. A nominal increase in soil pH was observed with increase in depth under different treatments of spacings. In case of electrical conductivity of soil, the significant differences were observed among different soil depths of all the spacings and control. However, among spacings, the differences were non-significant. The electrical conductivity was recorded highest in surface soil (0-15 cm) under different eucalyptus spacings and it decreased sharply from surface soil to the lower depths under all the spacings of eucalyptus plantation. The organic carbon of soil was higher under eucalyptus plantation spaced at 3×3 m. However, there was significant decrease in organic carbon with the increase in soil depth. The available nitrogen varied from 165 (control) to 171 kg ha^{-1} (3×3 m) and it decreased with the increase in soil depths. The available phosphorus in these soils is low with the mean value of 11.3 kg ha^{-1}in surface soil. As like nitrogen, available phosphorus also decreased with the increase in soil depths. The potash content did not differ significantly with spacing, however, it decreased with increase in soil depth from 0-15 to 30-60 cm.

After 8 years of plantation, the soil pH did not differ significantly from initial values in all the spacings as well as at different depths (Fig. 1). The electrical conductivity was highest in surface soil (0-15 cm) under different eucalyptus spacing and it decreased sharply from surface soil to the lower depths in all the spacings (Fig. 2). The electrical conductivity of soil decreased from its initial mean value 7.7 of surface soil to 3.9 dS m^{-1} i.e. about 50 per cent decrease. Almost similar trend was observed in deeper soil layers under different spacings as well as control. The decrease in electrical conductivity was more distinct in surface soil as compare to lower layers. The electrical conductivity of surface soil decreased from 7.9 to 4.0 dS m^{-1} under 3×3 m spacing of eucalyptus and from 7.5 dS m^{-1} to 3.8 dS m^{-1} in control. The magnitude of decrease of electrical conductivity was almost same under different spacings and it decreased with depths from its initial status. The reduction of soil EC under the tree cover can be attributed to accumulation and subsequent decomposition of organic matter which releases organic acids (Gupta and Sharma, 2009).

The soil organic carbon was significantly influenced by tree spacing as well as soil depths. It increased from its initial status under different soil depths of spacings of eucalyptus based agroforestry system and control (Fig. 3).

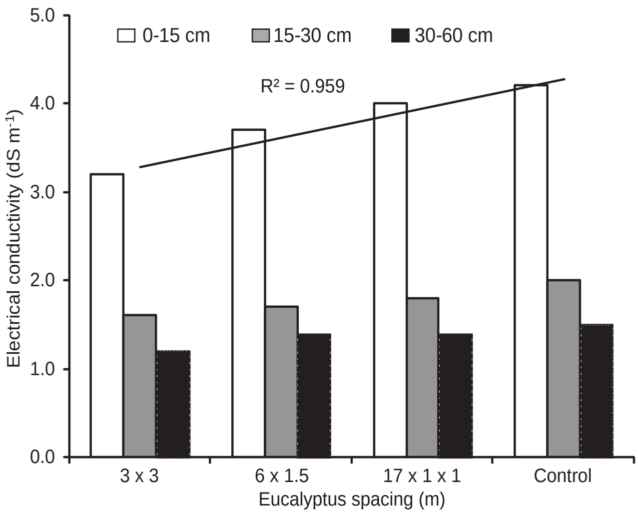

Fig. 2. Electrical conductivity (dS m^{-1}) of soil under different spacings of eucalyptus plantation and control

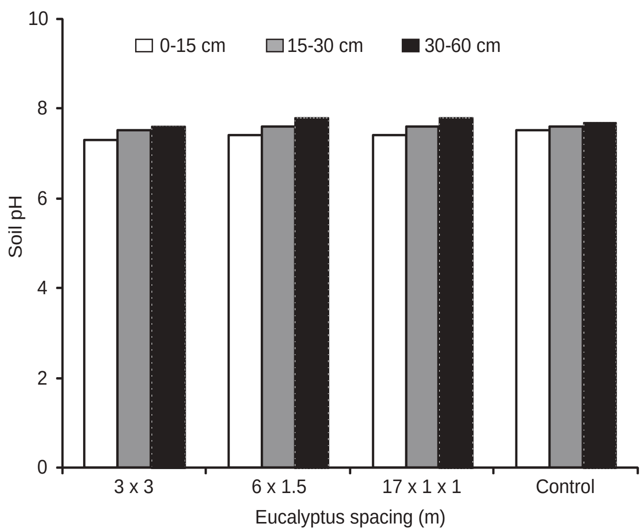

Fig. 1. Soil pH under different eucalyptus plantation and control

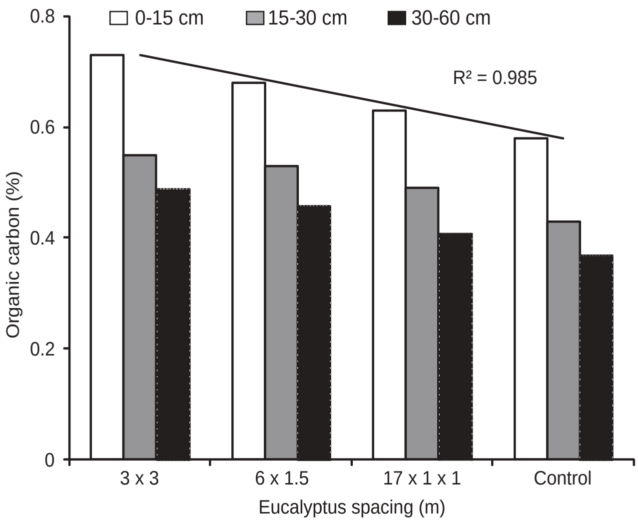

Fig. 3. Organic carbon (%) of soil under different spacings of eucalyptus plantation and control

The organic carbon in soil increased with the decrease in tree spacing and was found maximum (0.73 %) under 3×3 m of eucalyptus spacing in surface soil and it followed the order: 3×3 m> 6×1.5 m>17×1×1 m > control. Similar trend was also observed in lower depths. The lesser organic carbon content under the sole cropping systems may be attributed to continuous cropping with subsequent removal of plant residues. The organic carbon contents of surface soil under 3×3 m, 6×1.5 m, 17×1×1 m spacings increased by 26, 17, and 8% over sole crop, respectively. 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 as reported earlier by Gupta and Sharma (2009); Das and Chaturvedi (2005); Yadav *et al.* (2008).

The perusal of data presented in figure 4 depicted an improvement in available nitrogen of soil in different depths from its initial status under different spacings of eucalyptus plantation and sole crop. Available soil nitrogen increased significantly under different spacings of eucalyptus based agroforestry system and sole crop from its initial values. Available N content was maximum (238 kg ha^{-1}) in surface soil under 3×3 m spacing and it decreased with the increase in the spacings and depths. As like organic carbon, available nitrogen was significantly influenced by tree spacing because amount of available N depends upon organic matter. The magnitude of increased available N was highest under 3× 3 m spacing and lowest in control. Under 6×1.5 m and 17×1×1 m spacings, the magnitude of the increment was at par and was 28 and 26%, respectively. The trend was similar at lower depths under different spacings and control. The increase in N content of soil under eucalyptus 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).

Available phosphorus of soil also exhibited similar trend like soil nitrogen (Fig. 5). Mean available phosphorus in control was 9.6 kg ha^{-1} while, it ranged from 9.7 to 13.2 kg ha^{-1} in different eucalyptus spacings. Among all the different tree spacings, the highest available soil P (kg 16.4 ha^{-1}), was recorded under 3×3 m spacing while it was lowest under control (11.9 kg ha^{-1}) in surface soil. Among the different soil depths, available phosphorus in the soil increased significantly under different spacings and control after 8 years of eucalyptus plantation. As like N, lowest P was also recorded in 30-60 cm soil depth under different spacings.

Available potassium content of soil where eucalyptus trees were intercropped with crops was higher as compared to the sole crop (Fig. 6). Mean increases in available K were observed to 40, 25, 15 and 12 per cent under 3×3 m, 6×1.5 m, 17×1×1 m and control, respectively over its initial values.

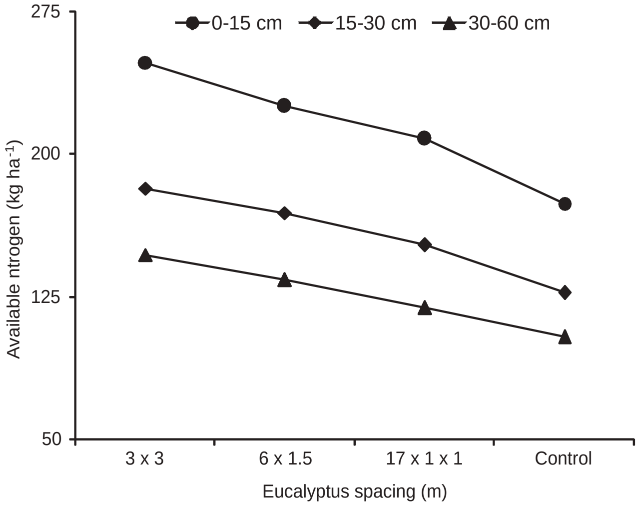

Fig. 4. Available nitrogen (kg ha^{-1}) of soil under different spacings of eucalyptus plantation and control

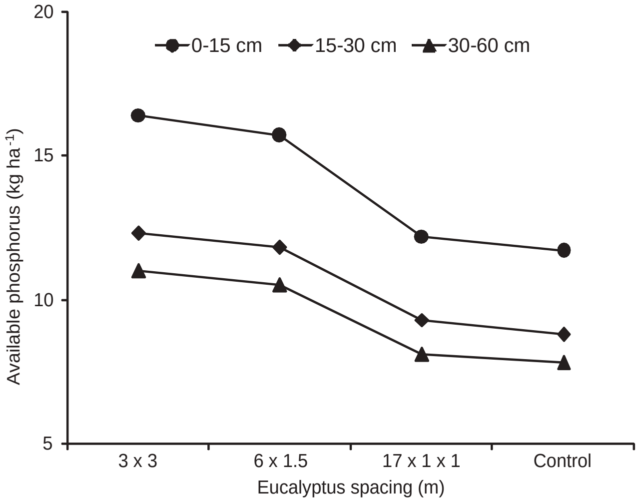

Fig. 5. Available phosphorus (kg ha^{-1}) of soil under different spacings of eucalyptus plantation and control

The higher nutrient status under closer spacings 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) in poplar. The higher available nutrient content in agroforestry system over the agriculture system may be attributed to litter-fall addition from trees as well as addition of root residues of crops and trees. These findings were supported by (Gupta and Sharma, 2009). On

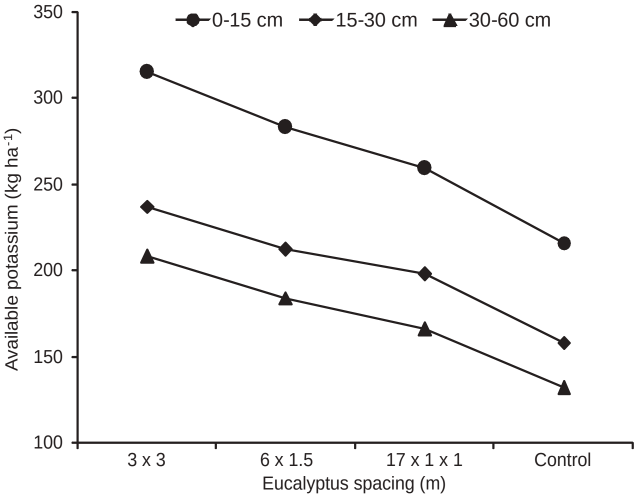

Fig. 6. Available potassium (kg ha^{-1}) of soil under different spacings of eucalyptus plantation and control

account of recycling of organic matter, higher organic carbon and available N, P and K contents were observed in the soil under intercropped eucalyptus plantations than at a site without trees and the contents varied depending upon the intercrops. 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) as well.

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 761-764

Manuscript Number: 2372
NAAS Rating: 4.47

Biomass Production of *Ulmus villosa* under Mid-hills of Himachal Pradesh – A Statistical Approach

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***Abstract*:** An attempt has been made to work out the correlation coefficients and regression models for different biomass components of *Ulmus villosa* in mid-hills of Himachal Pradesh. Green and dry biomass was positively and highly correlated with all the growth characteristics. However, highest correlation was observed with diameter at breast height. Exponential function was best fitted for the prediction of green and dry biomass. Diameter at breast height remained the best predictor of green and dry biomass.

***Key Words*:** Biomass, Correlation coefficients, Regression models, *Ulmus villosa*

Cherry-bark Elm (*Ulmus villosa* Brandis) is one of the distinctive Asiatic elms. The species is capable of remarkable longevity and belongs to the family Ulmaceae. It is a medium-to-large deciduous tree species of the north-western sub-Himalayas (Singh, 1982). The species is highly valued for its multiple uses (timber, fuel and fodder) and fast growth rate. It is considered one of the most important agroforestry tree species for the valleys and the mid-hill agro-ecosystems of the region. It has also great potential outside its natural zone for use in farm forestry and community forestry. Estimation of woody biomass is a prerequisite for determining the state of flux for biological materials in an ecosystem and for understanding the dynamics of ecosystem (Rawat and Singh, 1988). Information on biomass is not only important from the standpoint of fundamental ecology, but also relevant to planning for ecologically sustainable development of a region (Singh *et al.,* 1987). The study aims at prediction of standing biomass of *Ulmus villosa.* In this paper, an attempt has been made to predict the above ground biomass of *Ulmus villosa* under mid-hills of Himachal Pradesh.

MATERIAL AND METHODS

Two sites i.e Bagaur (Site-I) and Majhgaon (Site-II) were randomly selected at the main campus of Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh located in the mid hill zone of Himachal Pradesh. The area has an elevation of about 1250m above mean sea level. Nauni lies about 13 km from Solan with the following coordinates: latitude 30^0 51' N & longitude 76^0 11' E (Survey of India Topo-sheet No. 55F/1) according to Survey of India. The above ground biomass was estimated separately for stem, branches and leaves + twigs of *Ulmus villosa* at two sites. An optimum sample size of 135 trees was selected randomly by following a two-step approach as suggested by Stein (1945) and Cox (1958) for recording the observations on various growth parameters viz., diameter at breast height, tree height, crown height, crown length, crown width and bole height. Karl Pearson's correlation coefficient between biomass and various tree growth parameters (DBH, tree height, crown height, crown length, crown width and bole height) was worked out and tested for its statistical significance. Various regression functions linear, logarithmic, S curve, exponential and power, were fitted for biomass with diameter at breast height, tree height, crown height, crown length, crown width and bole height. Further multi-linear regression equations were also developed for tree growth characteristics on biomass of *Ulmus villosa*. Finally Adj R^2 was used to gauge the best fitted regression function.

RESULTS AND DISCUSSION

Correlation studies: Karl Pearson's correlation coefficient was worked out for different growth parameters viz., DBH, tree height, crown height, crown length, crown width, bole height, total green biomass and total dry biomass, to get pooled estimates of correlation coefficient and the results are presented in Table 1. The results reveal that total dry biomass and total green biomass were positively and significantly correlated with all tree growth parameters. It is also evident from the table that total green biomass showed a highly significant correlation with DBH (0.944) followed by tree height (0.846) and the total dry biomass showed also a highly significant correlation with DBH (0.910) followed by tree height (0.812). DBH was also found to be positively and significantly correlated with tree height (0.906).

Regression studies: Various linear (straight line) and non-linear (logarithmic, S curve, exponential and power)

Table 1. Correlation matrix indicating relationship between different tree growth characteristics

Characters	Total green biomass (kg)	Total dry biomass (kg)	DBH (cm)	Tree height (m)	Crown	Crown length (m)	Crown width (m)
Total dry biomass (kg)	0.964*						
DBH (cm)	0.944*	0.910*					
Tree height (m)	0.846*	0.812*	0.906*				
Crown height (m)	0.408*	0.396*	0.407*	0.459*			
Crown length (m)	0.773*	0.749*	0.798*	0.865*	0.095*		
Crown width (m)	0.474*	0.470*	0.549*	0.601*	0.365*	0.415	
Bole height (m)	0.384*	0.324*	0.443*	0.558*	0.628*	0.280*	0.412*

*****significant at 1% level of significance

functions have been tried on various tree growth characteristics viz., DBH, tree height (H), crown height (CH), crown length (CL), crown width (CW) and bole height (BH) to estimate green and dry biomass by taking one character at a time as independent variable.

The data were pooled to estimate total green and dry biomass using various linear and non-linear functions as the tree characters showed non-significant variation between the two sites, Adj. R^2 and standard error of estimate are also presented along with the respective fitted functions. Table 2 reveals that exponential function was the best fit for DBH to predict green and dry biomass with maximum Adj. R^2 value of 0.909 and 0.892, respectively; followed by linear function with Adj. R^2 value 0.891 for green biomass and power function with Adj. R^2 value 0.856 for dry biomass estimation.

Table 3 reveals that exponential function was the best fit for tree height to predict green and dry biomass with maximum Adj. R^2 value of 0.717 and 0.684, respectively, followed by linear function with Adj. R^2 value 0.713 for green biomass and 0.657 for dry biomass estimation.

While using crown length as independent variable, the exponential function also gave good prediction of green and dry biomass (Adj. R^2 0.604, 0.595 respectively), significantly, followed by linear function with Adj. R^2 value of 0.603 for green biomass and 0.594 for dry biomass (Table 4).

Table 5, 6 and 7 reveals that crown height, crown width and bole height did not have any significant importance in predicting either of the dependent variable i.e. green biomass and dry biomass.

Table 3. Linear and non-linear functions for green and dry biomass with tree height (H)

Green biomass (GB)	SE of estimate	Adj. R^2
GB = ?130.263 + 17.887 H	0.978	0.713
GB = ?383.142 + 192.598 ln H	13.580	0.599
$GB = e^{5.945-19.083/H}$	1.582	0.519
$GB = 2.142\ H^{2.154}$	0.134	0.659
$GB = 6.273\ e^{0.191\ H}$	0.010	0.717
Dry biomass (DB)		
DB = ?85.573 + 11.167 H	0.696	0.657
DB = ?239.350 + 118.621 ln H	9.499	0.536
$DB = e^{5.391-19.396/H}$	1.731	0.482
$DB = 1.455\ H^{2.203}$	0.141	0.620
$DB = 3.254\ e^{0.197\ H}$	0.012	0.684

Table 2. Linear and non-linear functions for green and dry biomass with DBH

Green biomass (GB)	SE of estimate	Adj. R^2
GB = ?103.117 + 13.432 DBH	0.406	0.891
GB = ?359.614 + 173.753 ln DBH	8.414	0.760
$GB = e^{5.930-21.163/DBH}$	1.107	0.731
$GB = 0.416\ DBH^{1.989}$	0.065	0.876
$GB = 8.242\ e^{0.145\ DBH}$	0.004	0.909
Dry biomass (DB)		
DB = ?69.115+ 8.417 DBH	0.333	0.826
DB = ?225.551 + 107.274 ln DBH	6.282	0.684
$DB = e^{5.423-22.130/DBH}$	1.193	0.719
$DB = 1.479\ DBH^{2.073}$	0.073	0.856
$DB = 4.177\ e^{0.151\ DBH}$	0.005	0.892

Table 4. Linear and non-linear functions for green and dry biomass with crown length (CL)

Green biomass (GN)	SE of estimate	Adj. R^2
GB = ?71.309 + 19.503 CL	3.792	0.595
GB = ?184.915 + 135.763 ln CL	13.875	0.483
$GB = e^{5.368-7.895/CL}$	0.850	0.389
$GB = 916.220\ CL^{1.530}$	0.151	0.540
$GB = 11.680\ e^{0.210\ CL}$	0.042	0.604
Dry biomass (DB)		
DB = ?49.721 + 12.282 CL	2.480	0.557
DB = ?119.309 + 84.577 ln CL	9.086	0.443
$DB = e^{4.527-8.197/CL}$	0.905	0.377
$DB = 27.669\ CL^{1.595}$	0.160	0.528
$DB = 5.984\ e^{0.219\ CL}$	0.044	0.595

Table 5. Linear and non-linear functions for green and dry biomass with crown height (CH)

Green biomass (GB)	SE of estimate	Adj. R^2
GB = 24.242 + 19.517 CH	1.386	0.160
GB = 20.349 + 63.270 ln CH	12.078	0.129
$GB = e^{4.604-0.863/CH}$	0.324	0.043
GB = 35.153 + 0.592 ln CH	0.122	0.097
ln GB = 37.186 + 0.178 CH	0.015	0.114
Dry biomass (DB)		
DB = 10.247 + 12.340 CH	0.943	0.151
DB = 8.663 + 39.341 ln CH	8.159	0.117
$GB = e^{4.031-0.855/CH}$	0.342	0.041
ln DB = 19.538 + 0.597 ln CH	0.130	0.088
ln DB = 20.653 + 0.180 CH	0.016	0.105

Table 6. Linear and non-linear functions for green and dry biomass with crown width (CW)

Green biomass (GB)	SE of estimate	Adj. R^2
GB = ?14.512 + 24.036 CW	3.873	0.219
GB = ?56.012 + 103.537 ln CW	18.051	0.192
$GB = e^{5.202-3.803/CW}$	0.729	0.164
ln GB = 13.236 + 1.138 ln CW	0.191	0.205
ln GB = 21.751 + 0.256 CW	0.041	0.218
Dry biomass (DB)		
DB = ?15.857+ 15.521 CW	2.524	0.215
DB = ?41.033 + 65.810 ln CW	11.806	0.183
$DB = e^{4.632-3.845/CW}$	0.775	0.150
ln DB = 7.164 + 1.160 ln CW	0.203	0.191
ln DB = 11.759 + 0.263 CW	0.044	0.207

Table 7. Linear and non-linear functions for green and dry biomass with bole height (BH)

Green biomass (GB)	SE of estimate	Adj. R^2
GB = 30.955 + 16.509 BH	3.443	0.141
GB = 18.146 + 61.516 ln BH	13.139	0.135
$GB = e^{4.598-0.883/BH}$	0.256	0.075
ln GB = 29.350 + 0.690 ln BH	0.139	0.150
ln GB = 34.308 + 0.182 BH	0.037	0.151
Dry biomass (DB)		
DB = 20.585 + 9.067 BH	2.294	0.098
DB = 12.234 + 34.726 ln BH	8.718	0.101
$DB = e^{4.011-0.858/BH}$	0.272	0.063
ln DB = 17.341 + 0.651 ln BH	0.149	0.119
ln DB = 20.373 + 0.169 BH	0.039	0.115

Table 8 represents the Multi-linear regression equations for green and dry biomass by taking into consideration growth parameters as explained variables. Adj. R^2 value (0.901 and 0.846, respectively) for both the regression equations were found to be highly significant.

Devi *et al.* (2013) attempted to estimate biomass production of different plantation ecosystem in north western Himalaya, India. Wani *et al.* (2014) and Wani *et al.* (2014) also estimated the biomass and 19 year old *Ulmus wallichiana* plantation under different diameter classes.

CONCLUSION

Total green biomass and total dry biomass were positively and highly correlated with all stem growth parameters and crown characteristics. The use of diameter at breast height remained the best independent variable for estimating green and dry biomass of standing trees of *Ulmus villosa* in the present study, thus making diameter as most reliable and effective estimator. Tree height remained the second important independent variable to predict green and dry biomass. Crown height, crown width and bole height did not show any significant results for green and dry biomass prediction.

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Table 8. Multi-linear regression equations for green biomass (GB) and dry biomass (DB)

Multilinear regression equations for green biomass*	Adj R^2
GB = – 102.507+13.703D – 5.306H+7.305CH+5.951CL – 1.888CW – 2.122BH (0.930) (2.370) (2.081) (1.960) (1.791) (1.701)	0.901
Multilinear regression equations for dry biomass	
DB = – 70.593+8.431D – 3.591H+6.434CH+4.374CL – 0.740CW – 3.840BH (0.755) (1.923) (1.689) (1.590) (1.453) (1.380)	0.846

*Values in parentheses are standard errors of estimated regression coefficient

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Received 11 March, 2016; Accepted 11 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 765-769

Manuscript Number: 2373
NAAS Rating: 4.47

Genetic Variability for Growth Traits of Different Half-sib Progenies of *Pinus roxburghii* Sargent

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Abstract: Variability studies for growth traits were carried out in chir pine for the better performing resin yielder progenies. There existed a significant variation for these growth traits, viz., height (18.08±1.83 m), Diameter at breast height (DBH; 34.76±2.7 cm), bark thickness (2.73±0.36 cm), crown height (7.8±1.5 m), crown length (10.28±1.36 m), among the different half-sib progenies. This variability was found under genetic control, as all these progenies of the same age are growing under same environment. Crown height had maximum heritability (45.28 %) with genetic gain of 22.45 per cen. Traits which exhibited high heritability followed by higher genetic gain can be exploited appropriately in advanced breeding programs. Association analysis can be helpful in indirect selection, as correlation was highly significant for crown height and height (0.70). Principal component analysis revealed that m*aximum weightage should be given to height, having high loading value in principal component and good heritability.*

Key Words: Correlations, Growth traits, Heritability, *Pinus roxburghii,* Principal component analysis

Pines are distributed throughout a remarkably wide range of environments, from near the arctic region having cold winters and short growing seasons to the hot tropics with full year growing season. *Pinus roxburghii* Sargent is the principal pine species among the six indigenous pine species of India, which is commercially tapped for oleoresin. Chir pine is distinguished from other pine species on the basis of its three needle shaped leaves per spur, which are slender, flabellate-triangular in cross section. Owing to its economic and ecological importance in line with the status of forests in the western Himalayas, *Pinus roxburghii* has out-numbered all other species in afforestation programmes in its natural zone of occurrence. Selection of superior genotypes and their mass multiplication is the need of the hour, for which evaluation of growth traits is required (Sehgal and Chauhan, 1995a; Singh *et al.,* 2009). It can increase pine resin productivity many fold as significant variation is expected on the basis of its natural distribution under diverse environmental conditions from the heterogeneous regions of the Shiwaliks and western Himalayas (Sehgal *et al.,* 1987). Himachal Pradesh is the most suitable region for chir pine plantation and improvement. It is the need of hour to conserve and manage genetic resources of this species. Keeping in view of these aspects, genetic evaluation of growth traits becomes necessary for the delineation of genotypes which have better growth rates and for the formulation of advanced breeding strategies. The best way to tell if a parent is of superior genetic quality is to compare the performance of the offspring against other's offspring by giving all the progenies the same environment to grow through progeny trials (Khosla *et al.,*1993) and indirect selection (Sehgal and Chauhan, 1995b). For selection and advanced breeding to generate the best quality planting stock for plantation programmes, improve forest productivity to mitigate climate change and meet the demand of local people, the present study was carried out to study the variability among the growth traits of chir pine and workout the principal component analysis for different growth traits.

MATERIAL AND METHODS

The Chir pine progenies under study have been raised in the mid-hills of western Himalayas in 1983 in the main campus of the Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, with the identification of plus trees all across the distribution range in Himachal Pradesh, India (Table 1) by Dogra (1985), Kumar (1987) and Khosla *et al.* (1993).

The progeny trial is situated at 1,150 m elevation at Solan on the south-western aspect with latitude 30' 51°N and longitude 76'11°E. The region falls under subtropical climate with moderately hot summers and cold winters. Temperature ranges from 35°C in May–June to as low as 2°C in January. Frost occurrence during winter is quite common. Average annual precipitation ranges between 1,000 and 1,300 mm, major portion of which is received as monsoon rains during July–September. Winter rains under the influence of western disturbances are common with low intensities, generally. Soil has sandy loam texture with pH 6.5. Available nitrogen, phosphorus, potassium and calcium were 273.62 kg ha^{-1}, 35.08 kg ha^{-1}, 181.23 kg ha^{-1} and 522.70 kg ha^{-1}, respectively in the soil. The growth traits were measured according to standard procedures. The general linear model (GLM) procedure of SPSS-16 was employed for analysis of variance (ANOVA). Phenotypic (Vp) and Genotypic (Vg) and environmental variances were calculated to estimate broad sense heritability (H^2) and genetic advance (GA) expected and GA as per cent of the mean (Genetic gain) assuming selection of the superior 5 per cent of the progenies. Phenotypic (r_p) and genotypic (r_g) correlations were further computed to examine inter character relationships among growth traits following Varghese *et al*. (1976). The significance of correlation coefficients were tested against 'r' values as given by Fisher and Yates (1963) at (n-2) degree of freedom. Principal component analysis or canonical (vector) analysis was carried out to study the amount of variation along different axis of differentiation (Rao, 1952).

RESULTS AND DISCUSSION

Variation in growth traits among the different half-sib progenies of Pinus roxburghii was found significant (Table 1). The results revealed that diameter at breast height (DBH) varied from 29.43 cm in progeny Jai Nagar Yellow Base PT to 39.33 cm in Chret Mansu P4. Maximum height was found in progeny, Leda P8 (20.50 m), while minimum was found in Baghthan PT Black Top (13.00 m). Bark thickness varied from 2 cm (Kaldoo P3) to 3.27 cm (Kaldoo P10). Leda P5 had maximum crown height (11 m) while Benethi PT Black Base had the minimum (5.33 m). Kuthar PT Black Centre and Baghthan PT Black Top had maximum and minimum crown length (12.67 m and 7.17 m, respectively). Some progenies

Table 1. Details of the 21 half-sib progenies of chir pine and variability among progenies in growth traits

Progeny	Range (Division)	DBH (cm)	Height (m)	Bark thickness	Crown height	Crown length
Mandi district						
Leda- 10	Kamloh (Suket)	38.97	17.50	2.23	8.00	9.50
Kaldoo P8	Kamloh (Suket)	37.20	17.67	2.50	7.97	9.70
Kaldoo P3	Kamloh (Suket)	34.10	17.67	2.00	8.33	9.33
Kaldoo P9	Kamloh (Suket)	31.73	19.67	2.37	8.50	11.17
Leda-P8	Kamloh (Suket)	38.23	20.50	2.77	8.67	11.83
Kaldoo P1	Kamloh (Suket)	34.30	18.33	2.33	8.00	10.33
Leda-P5	Kamloh (Suket)	34.93	19.83	2.83	11.00	8.83
Kaldoo P5	Kamloh (Suket)	36.63	18.17	3.10	8.67	9.50
Rakni-P8	Jungi (Saket)	34.50	19.83	2.40	9.33	10.50
Sandrohal-P5	Pangna (Suket)	33.53	15.17	2.73	6.50	8.67
Kaldoo P10	Kamloh (Suket)	31.47	17.17	3.27	7.17	10.00
Dibkon P3	Urla (Mandi)	35.87	16.67	3.20	6.50	10.17
Kangra district						
Chret Mansu P4	Palampur (Palampur)	39.33	17.33	2.93	6.83	10.50
Kopra-P5	Nurpur (Nurpur)	35.63	20.00	2.73	10.50	9.50
Sirmour district						
Banethi-PT-Black Base	Jamta (Nahan)	34.63	17.50	2.33	5.33	12.17
Bagthan-PT-Black Centre	Sarahan (Rajgarh)	33.87	19.00	3.23	9.33	9.67
Bagthan-PT-Black Top	Sarahan (Rajgarh)	31.30	13.00	2.50	5.83	7.17
Shimla district						
Jubble-PT- Green Centre	Jubbal (Rohru)	32.47	16.33	3.17	5.67	10.67
Solan disctrict						
Dhami Shimla Yellow Top-PT	Dhami (Kunihar)	33.43	18.83	2.83	7.40	11.43
Kuthar-PT-Black Centre	Kuthar (Kunihar)	38.37	19.83	2.83	7.17	12.67
Jainagar Yellow Base-PT	Arki (Kunihar)	29.43	19.67	2.97	7.17	12.50
Mean		34.76	18.08	2.73	7.80	10.28
CD (p=0.5)		5.34	3.34	0.63	2.29	2.48

were statistically at par with the best ones, as indicated by the critical difference for these traits.

The half-sib progenies were originally collected from all over the state of Himachal Pradesh over a variety of sites differing with regard to locality factors, but these are growing at one site in the same environmental conditions in the progeny trial, so the differences in the performance of all the progenies are due to genetic factors (Sehgal *et al.,* 1994; Wei *et al*., 2011; Singh *et al.,* 2016). This suggests the scope of selection of superior progenies and the progeny trial can be converted to productive seed orchard for immediate genetic gains (Sehgal *et al.,* 1995; Sehgal and Chauhan, 1995b; Sharma *et al*., 2007). Positive association has been reported between oleoresin yield and tree height, diameter, needle length and thickness (Sharma *et al.* 2013; Sehgal *et al*., 1987,1994), besides bark thickness (Lekha and Sharma, 2005), their evaluation for the diverse half-sib progenies may prove fruitful through indirect selection of chir pine (Sehgal and Chauhan, 1995b). Variation in bark type is governed primarily by developmental stage of the tree, its rate of diameter growth, site, and genetic factors (Hejtmanek, 1953).

Genetic analysis: Genetic parameters were analyzed for these growth traits (Table 2). The amount of variability can also be assessed from genotypic and phenotypic variances and their respective coefficients of variation for a trait (Thakur *et al.,* 2014). Highest coefficient of variation was observed for crown height at both phenotypic (24.06 %) and genotypic (16.19 %) levels. These traits were found moderately heritable. Crown height had maximum heritability (45.28 %), while the minimum value was observed for DBH (26.55 %). DBH had maximum genetic advance (2.07), while crown height had maximum genetic gain (22.45 %). Heritability and other genetic parameters signify the utility of variability in advanced breeding programs. Heritability provides a measure of genetic variation, upon which all the possibilities of changing the genetic composition of the species depends (Makeen *et al.,* 2007). Characters, which exhibit high heritability followed by higher genetic gain show additive genetic variation and can be exploited quiet well in advanced breeding programs, thus more effective in selecting the best genotypes for a trait (Sankhyan and Singh, 2013; Dhanwani *et al.,* 2013;Thakur and Thakur, 2015). Moderate genetic control over the quantitative traits has been revealed and has been also reported by Singh *et al*. (2009) and Mehandi *et al*. (2013). This is because of their additive genetic control and polygenic nature (Allard, 1960). The genotypic coefficient of variation was lower than the phenotypic values, probably due to modifying effect of the environment on the strong inherent association of characters at the genetic level (Singh *et al*., 2013). Heritability value changes with species, particular population, time/age and environment and progeny testing provides a good measure of heritability estimation. From the selection point of view, the realized genetic gain was 5.98 per cent for DBH, 9.14 per cent for height and 22.45 per cent for crown height over the other progenies evaluated; which clearly shows that selection followed by clonal seed orchard establishment can prove highly profitable.

Correlation is one of the important biometrical tools, which measures the degree and magnitude of association between various traits and aides indirect selection. Association analysis was carried out for these growth traits with each other (Table 3). Phenotypic and genotypic correlation coefficients amongst these half-sib progenies revealed crown length and crown height were highly correlated (at 1% level of significance) to total height (0.70). Bark thickness was also significantly correlated to DBH. This can be either due to pleiotropy or linkage effects at the genetic levels, as has been reported in Hardiyanto (1996) and Haapanen *et al.* (1997). Further, the estimation of genotypic correlation for two traits either from linkage or pleiotropy or induced mutation or genetic pleiography is only the product of gene action (Lone *et al*., 2013) and the basic knowledge of association at genotypic and phenotypic levels helps the breeder to chalk out efficient breeding strategy for higher productivity.

Principal component analysis: Principal component analysis (PCA) **-** a multivariate statistical technique, helps to reduce the data of correlated variables into a substantially smaller set of variables, through linear combination of

Table 2. Estimates of variability and genetic parameters for growth traits of among different half**-**sib progenies of *Pinus roxburghii*

Trait	Mean	Range	S.D	Coeff. of variation	C.V		Heritability (H^2 %)	Genetic advance	Genetic gain (%)
					GCV	PCV			
DBH (cm)	34.76	29.43-39.33	2.70	9.37	5.63	10.93	26.55	2.07	5.98
Height (m)	18.08	13.00-20.50	1.83	11.22	7.78	13.65	32.49	1.65	9.14
Bark thickness (cm)	2.73	2.00-3.27	0.36	14.04	10.64	17.62	36.47	0.36	13.24
Crown height (m)	7.80	5.33-11.00	1.50	17.80	16.19	24.06	45.28	1.75	22.45
Crown length (m)	10.28	7.17-12.67	1.36	14.66	10.15	17.83	32.38	1.22	11.9

Table 3. Genotypic and phenotypic correlation for growth traits among different progenies of *Pinus roxburghii*

Trait		DBH (cm)	Height (m)	Bark thickness (cm)	Crown height (m)	Crown length (m)
DBH (cm)	r_g	1.000				
	r_p	1.000				
Height (m)	r_g	0.216	1.000			
	r_p	0.216	1.000			
Bark thickness (cm)	r_g	-0.462*	-0.176	1.000		
	r_p	0.129	0.141	1.000		
Crown height (m)	r_g	0.178	0.700**	-0.252	1.000	
	r_p	0.213	0.676**	0.070	1.000	
Crown length(m)	r_g	0.076	0.501**	0.068	-0.267	1.000
	r_p	0.072	0.655**	0.118	-0.115	1.000

r_g and r_p are correlation coefficients at genotypic and phenotypic levels, respectively
*Significant at 5% level of significance; ** Significant at 1% level of significance

Table 4. Principal component analysis for growth traits among different progenies of *Pinus roxburghii*

Trait	Principal components		
	I	II	Communalities
DBH (cm)	0.428	-0.280	0.262
Height (m)	0.973	0.131	0.963
Bark thickness (cm)	-0.370	0.541	0.294
Crown height (m)	0.719	-0.537	0.806
Crown length (m)	0.518	0.770	0.861
Eigen value (ë)	1.917	1.270	
Percentage of variance	38.33	25.40	
Cumulative percentage of variance	38.33	67.73	

variables that account for most of the variation present in the original variables (Singh and Chaudhary, 1985). Table 4 shows factor pattern and summary of PCA in the growth data. It was observed that only two components had eigen value greater than one and such components were retained for further genetic analysis. These components explained 67.73 per cent variation. For component I ($ë_1$=1.917) explaining 38.83 per cent variation, height was attached with maximum loading value (0.973), followed by crown height (0.719); while as bark thickness showed negative sign (-0.370), indicating negative contribution. Component II ($ë_2$=1.917) explained 25.40 per cent of variation with maximum loading value attached to crown length (0.770).

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Received 12 May, 2016; Accepted 10 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 770-775

Manuscript Number: 2374
NAAS Rating: 4.47

Age-Gender-and Tissue-Dependent Transcriptional Responses of *cyp19a1* and *vtg* in Murray Rainbow fish *Melanotaenia fluviatilis* Exposed to17â-estradiol

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***Abstract*:** Aromatase (Cyp19a1), a key steroidogenic enzyme, which plays a key role in sex determination and differentiation. Vitellogenin (Vtg), a female specific eggprotein. However, gene is also present in juveniles and males, but normally silent; when they are exposed to estrogenic chemicals *it* will be activated. Current study investigated the effect of exogenous 17β-estradiol on the mRNA expression of *cyp19a1* and *vtg* in juveniles and adult rainbow fish with exposure to either 100 or 400 ng/L E2 for 14 days. The *cyp19a1* in the head and trunk region of juveniles, brain and gonads in both sexes of adult fish were studied using qPCR. *Cyp19a1b* was significantly elevated in the head and trunk region of juveniles at 400 ng/L E2 exposure but not at 100ng/L. *Vtg* showed concentration dependent increase in expression in the trunk regions of juveniles. In adults *cyp19a1b* significantly upregulated at 400 ng/L in brains of both sexes and in testes, but not in 100 ng/L E2. *Cyp19a1a* was not detected in tissues tested except for ovary and it decreased with increase in E2 concentration. In males, *vtg* was significantly upregulated in both concentrations of E2. Collectively, E2 at environmental concentrations can have a disruptive effect on the steroidogenic and reproductive pathways.

***Key Words*:** Murray rainbowfish, Reproductive pathway, Steroidogenic pathway, Xenoestrogen

Endocrine Disrupting Chemicals (EDCs) are those chemicals, which perturb the endocrine system of the animals (Shanthanagouda *et al.,* 2013a,b, 2014). Among the many EDCs, exogenous 17â-estradiol (E_2) is one of the most potent and ubiquitous chemicals (Shanthanagouda *et al.,* 2013 a, b), Xenoestrogens are highly potent even at nanogramconcentrations. However, endocrine changes may be particularly important at sub-lethal doses, as they constitute early responses to disturbances, preceding the onset of pathology and mortality. Estrogen, a key steroidogenichormone, synthesized mainly in reproductive organs (gonads) and minimally in non-reproductive tissues (Cui *et al.,* 2013). Its synthesis involves two different cells and hence is referred as 'two cell hypothesis' (Schulz *et al.,* 2010). Eventually, synthesized estrogen, which is converted from androgen to estrogen by aromatase, playsa key role in reproductive functions of the vertebrates (Castro *et al.,* 2005).Vitellogenin (Vtg), a female specific and key reproductive protein synthesized in the liver (Jobling *et al.,* 1996). However,*vtg* gene is also present in males and juveniles, normally it is silent. Upon exposure to estrogenic chemicals it gets activated.

The specific objective of the study was to investigate the effect ofexogenous 17â-estradiol (E2) at environmentally realistic concentrations on the expression of key steroidogenic enzyme *cyp19a1* aromatase transcripts in brain and gonads, and on reproductive gene*vtg* (in male liver only) of adult *M. fluviatilis*. In addition, study was also extended to understand the E2 effect in juveniles. The exposure experiment was designed to test if exogenous E2 at environmentally relevant concentrations wouldproduce effects consistent with their possible mode of action in their predominant expression tissues. If so, which of the isoforms of *cyp19a1,* and *vtg* at low E2 concentrations respond readily and whether these responses would be stage(juvenile or adult), concentration,tissue and or gender dependent injuveniles and adults of sexually dimorphicrainbowfish. This is the first study to test the *cyp19a1* isoforms and *vtg* mRNA expressions in juveniles (head and trunk region separately) and in both genders (in brain, gonads and liver) of adult rainbowfish exposed to E2.

MATERIAL AND METHODS

Reproductively active, adult Murray rainbow fish were purchased from a commercial aquarium fish wholesaler (Aquarium Industries, Melbourne, Australia) and held at 24±1 °C in 16 h light:8 h dark regime in flow-through aquaria with carbon filtered aerated water. Throughout the maintenance, water quality parameters including temperature, dissolved oxygen, pH and electric conductivity were monitored (TPS Ionode, Victoria, Australia). Fish were maintained in holding tanks for ~2 weeks before they were transferred to experimental tanks.

Chemicals: Molecular biology grade, 17â-estradiol [≥98%

purity] (CAS 50-28-2)used in this study was purchased from Sigma-Aldrich Pty. Ltd. Adult rainbow fish of same age and similar sized were used for exposure studies in 10 L water (in 12 L glass tanks) and to each of the treatment six individuals of single sex fish were transferred. Stock solutions and dilutions were prepared in absolute analytical grade ethanol and stored in the dark and 10 ìL (0.0001%) of the stock was added to each replicate to obtain either100 or400 ng/L E2. Analytical grade ethanol was used as a solvent to dissolve both chemicals at a concentration of 0.0001%. In this study, only the nominal concentrations were used and throughout the exposure experiment, with 100% renewal daily until the termination of the experiment for14 days of exposure. During the experiment, fish were fed frozen brine shrimp (Kyorin Co. Ltd.) once daily. A total of six individuals were sampled from each treatment after 14 days and anaesthetized using 80 ppm of AQUI-S (Iso-eugenol) (Lower Hutt, New Zealand) and decapitated.

Exposure Experiment: Reproductively active adult rainbow fish were allowed to breed in the laboratory conditions at the ratio of 3 males: 7 females. Then larvae were held for ca.1 month until they reach juvenile stage without any mortality. Juveniles of same age and similar size were chosen for the exposure experiment. Then exposure experiment was conducted with similar concentration of adult E2 exposure (100 and 400 ng/L E2) for 14days. After14 days of exposure, juveniles were anaesthetized at 40 ppm AQUI-S. Since it was difficult to collect individual organs in juveniles; fish were dissected for head and trunk regions. Then whole head and trunk regions were stored at -80°C for total RNA extraction and real-time analysis. All experimental procedures were conducted with the approval of RMIT University Animal Ethic Committee.

Water quality: During the experiment, general water quality parameters were monitored daily until the termination of the experiment. Throughout the exposure period, the water quality parameters including pH, DO_2, temperature and conductivity were consistent between treatments.

Gene Expression Analysis: Real-Time qPCR were followed as described earlier(Patil and Gunasekera, 2008; Shanthanagouda *et al.,*2012). Briefly, the cycling parameters for the q PCR were as follows: 50 °C for 2 min, 95 °C for10 min, then 40 cycles of 95°C for 15 seconds and 62°C for 1 min. A melting curve analysis was performed at the end of the amplification phase with a minimum of 30°C to a maximum of 95°C, with 0.2°C increases for every 0.02 s to test the specificity and identity of the qPCR products. Primers for qPCR for *cyp19a1a* (GU723457), *cyp19a1b* (GU723458), *vtg* (Woods 2007) and *gapdh* (Ponza, 2006) were designed using primer express (ABI) software and synthesized (Sigma-Aldrich or Gene-Works) based on the cDNA sequences obtained. The primers (Table 1) were designed at the 3' end of the cDNA sequences and amplified 229, 161, 126 and 100 bp for *cyp19a1a,cyp19a1b, vtg* and *gapdh,* respectively.

Table 1. Primers used for quantification of *cyp19a1a, cyp19a1b, vtg* and *gapdh* expression in the Murray Rainbowfish

Primer Name	Sequence (5'- 3')	Amplicon
cyp19a1aF	ACGTAAGGCAGTCCGTGCTGGAGATGG	*cyp19a1a*
cyp19a1aR	TCCACCACTGGGTGGAAGCGCAGGCATT	*cyp19a1a*
cyp19a1bF	GCGTAAAGCTCTGGAGGATGATGACATTG	*cyp19a1b*
cyp19a1bR	GAAGAAGCGATTGGGCACTGTATTG	*cyp19a1b*
vtgF	GAAAGCGGTTGTGCTTGCCCTGACTCTG	*vtg*
vtgR	GGCATTCCTCCTGGGAGGTCTGCC	*vtg*
gapdhF	ACACCCACTCCTCCATCTTT	*gapdh*
gapdhR	GTTGCTGTAGCCGAACTCAT	*gapdh*

All samples were analyzed in triplicates for each individual tissue and the data was normalized to an internal control gene, *gapdh* (Mean Normalized Expression, MNE), as *gapdh* is known to express stably between tissues tested in this and also inearlier studies (Shanthanagouda *et al.,* 2012, 2013 a, b). The MNE is the relative expression of the target gene (in this study, *cyp19a1 isoforms* and *vtg*) to that of the reference gene (in this study, *gapdh*). During each qPCR run, linearized plasmid cDNA templates were used as standards to monitor primer amplification efficiency and consistency. Real-time data was collected, compiled and the cycle threshold was calculated automatically using the CFX software package (Bio-Rad). The data was analyzed using the publicly available Q-gene excel script package (Muller *et al.,* 2002). Throughout the exposure study the efficiency values for primers varied between 0.95 and 0.98. Data from each sample was averaged and shown as Mean Normalized Expression. The data was tested for normality and subsequently analyzed by one-way analysis of variance (ANOVA) followed by post-hoc test between the treatments for each transcript expression using SPSS17.0 (SPSS Inc. 2008) and the significance was set at $P<0.05$.

RESULTS AND DISCUSSION

Expression in juveniles*:*Juvenile rainbow fish did not express *cyp19a1a* in head or trunk regions of both controls or after treatment with E2 (data not shown). The expression of *cyp19a1b* at 400 ng/L E2 significantly increased compared to control, solvent control and 100 ng/L E2 in both head and trunk regions of juveniles (Fig. 1 A,B). Meanwhile, the trunk region showed significantly increased expression of *vtg* in both 100 and 400 ng/L E2 treatments (Fig. 1C). The*vtg* expression at 400 ng/L E2 was significantly higher than 100 ng/L E2 and it was not detectable in both control (Fig. 1C).

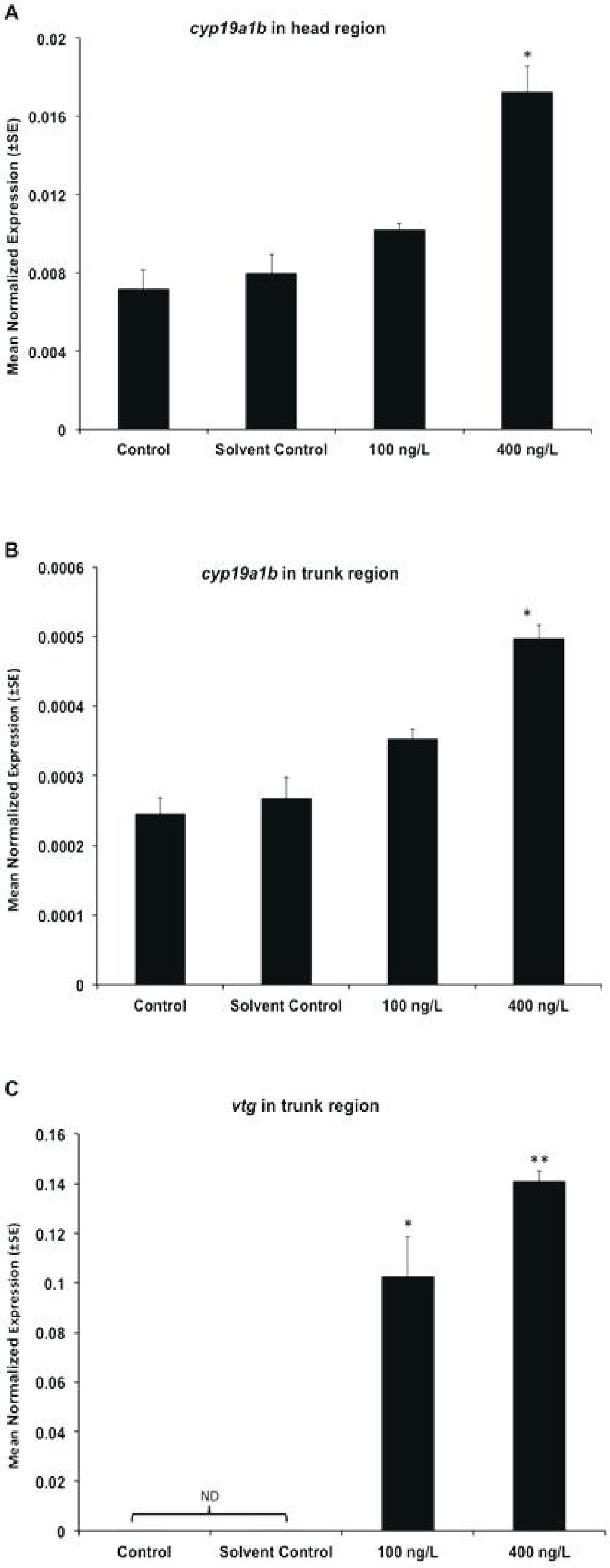

Fig. 1. Expression of *cyp19a1b* in head (A), trunk (B) region, and *vtg* (C) in trunk region of juveniles exposed to E2. (*Indicates significantly different to others)

Expression in adults: The expression of *cyp19a1b* in brains of both sexes significantly up regulated only at 400 ng/L compared to both controls and 100 ng/L E2 (Fig. 2 A,B). Whereas *cyp19a1b* showed a decreasing trend in the ovary and was significantly down regulated at 400 ng/L compared to controls and 100 ng/L E2(Fig.2 C,D). However, its expression was contrasting in testes compared to ovary, where its expression was significantly elevated at 400 ng/L E2 compared to other treatment groups. Both genders of rainbow fish did not express *cyp19a1a* in brain tissues either in controls or after treatment with E2 (data not shown). The expression of *cyp19a1a* in ovary significantly decreased in both 100 and 400 ng/L E2(Fig. 2E) and there was no expression noticed in male gonads (data not shown). Whereas *vtg* expression in male gonads significantly increased in both E2 concentrations and *vtg* at 400 ng/L was significantly higher than 100 ng/L E2(Fig. 2F).

The present study, simultaneously evaluated the responses of the key steroidogenic *cyp19a1* isoforms and reproductive *vtg* gene expressions in juveniles and both genders(sexually dimorphic) of adult *M. fluviatilis*, following exposure to E2. Consistent with studies in rainbow fish and other teleosts (Cheshenko *et al.,* 2008; Shanthanagouda *et al.,* 2013b), the E2 exposure had a measurable effect on expression of both *cyp19a1* isoforms and *vtg* in the species at environmentally realistic concentrations. More significantly, data show that *cyp19a1* isoforms and *vtg* genes are more sensitive to the impacts of E2 exposure, implying the suitability of *cyp19a1* isoforms and *vtg* as better biomarkers of exposure to xenoestrogen in rainbo wfish and their impact on steroidogenic and reproductive pathways.

Response of *cyp19a1* isoforms in adults: *cyp19a1a*: Decreased expression of *cyp19a1a* with exposure to exogenous E2 indicates that it interferes with gonadal aromatase expression. Similar observations were also observed in *M. fluviatilis* exposed to exogenous E2 at higher concentrations (Shanthanagouda *et al.,* 2013a) suggesting ovarian tissue is most sensitive to exogenous E2 irrespective of the E2 concentrations. The*cyp19a1a* did not express in any of the tissues other than ovary with or without treatment in either males or females. In the current study, *cyp19a1a* response to E2 exposure was restricted to the ovary—either partial or nearly complete inhibition of *cyp19a1a* expression in the ovary, with no measurable expression in either brain of both genders, testisor juveniles. Similar repression of *cyp19a1a* in ovarian tissue has been observed in zebrafish, *Danio rerio* exposed to E2 at 10 nM (~2.7 ìg/L) (Hinfray*et al.,* 2006). Conceivably, the E2 can supplement or replace endogenous estrogens, triggering a negative feedback loop to inhibit *cyp19a1a* transcription or they may indirectly inhibit the process of testosterone biosynthesis. Direct binding of the xenoestrogens to upstream transcription factors (promoter regions) of *cyp19a1a* gene could also regulate the expression (Cheshenko *et al.,* 2007). The inhibitory action of E2 on the expression of *cyp19a1a* in the ovarian tissues could be due to a negative feedback mechanism on GnRH. And it may be possible that other unknownmodulatory pathways are responsible for the repression of *cyp19a1a* activity observed in this study. Precise responses of *cyp19a1a* to oestrogenic compounds are known to be complex and depend on the nature of the chemical, fish species, developmental stages, tissue context, fish exposure

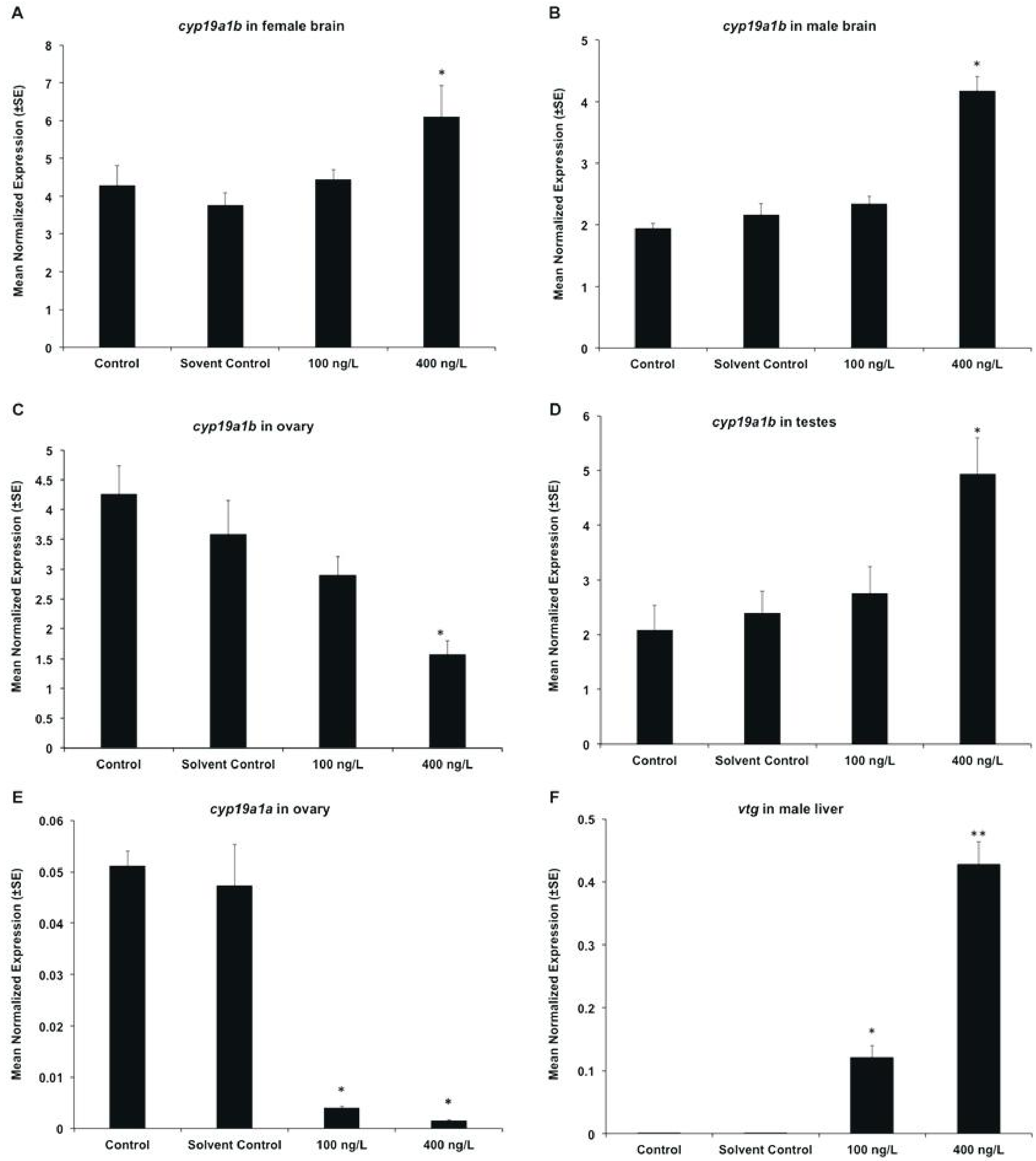

Fig. 2. Expression of *cyp19a1b* in adult rainbowfish exposed to E2 (A) Female brain, (B) Male brain, (C) Ovary and (D) Testes, E) *cyp19a1a* in ovary, and F) *vtg* in male liver. (*Indicates significantly different to others (P<0.05)

patterns (including habitat), and exposure duration (Filby*et al.,* 2006; Cheshenko *et al.,* 2008). Exposure of both juveniles and adults (both genders) of *M. fluviatilis* to E2 resulted in significantly upregulated *cyp19a1b*. Similarly, the upregulation of *cyp19a1b* in the female brain of *M. fluviatilis* exposed to both E2 was observed but at higher concentrations (Shanthanagouda *et al.,* 2013a). However, similar observations were reported in other species including medaka (Contractor *et al.,* 2004), zebrafish (Hinfray*et al.,* 2006; Kallivretaki*et al.,* 2006) and guppies (Hallgren and Olsen, 2010), in both genders following exposure to various concentrations of exogenous estrogens.The study shows that exposure to E2 tends to down-regulate the expression of *cyp19a1b* in the ovarian tissues. In contrast, upregulation of *cyp19a1b* in the ovary was observed in adult fathead minnows exposed to very low concentrations of E2 (32-320 ng/L) in a dose dependent manner (Halm *et al.,* 2002). The inhibition of *cyp19a1a* and the down regulation of *cyp19a1b* isoforms in the ovarian tissues indicate that the ovarian tissue is more sensitive to exogenous oestrogen in *M. fluviatilis* (Current study and Shanthanagouda *et al.,* 2013a). The expression of *cyp19a1b* in the testes contrasted with that in the ovary. The expression of *cyp19a1b* was significantly higher in testes with exposure to E2 in both concentrations of E2in the experiment and remained above the controls. Similar results were also observed in adult fathead minnows exposed to 32–320 ng/L E2 for 14 days (Halm *et al.,* 2002). This indicates that the activation of a positive feedback mechanism with exposure to exogenous oestrogenic chemicals in the testes.However, the contrasting upregulation of *cyp19a1b* brain and downregulation in gonads of *M. fluviatilis* at higher E2 concentration (Shanthanagouda *et al.,* 2013a) and upregulation in juveniles head region and brain tissues of both genders at environmental concentrations indicate that fish is age-, gender- and tissue- specific.

Response of *vtg* in *M. fluviatilis:* In the present study, it was difficult to dissect the gonads; hence it was not possible to identify the sex of the fish. An increase in *vtg*transcript expression was observed in trunk region of juveniles and male livers exposed to E2 in both concentrations tested. Similar results were also observed in male sheepshead minnows (Hemmer *et al.,* 2002), mosquitofish (Leusch*et al.,* 2005) and Japanese whiting exposed to E2, and medaka exposed to either E2 or EE2 (Islinger*et al.,* 2002; Yamaguchi *et al.,* 2005). As these examples indicate, expression of *vtg* is consistently induced in the livers of male teleosts in response to E2.Hence, *vtg* serves as a suitable biomarker of exposure to (xeno) estrogenic chemicals, as shown in the present study.

The results of the present study suggest that, exogenous E2 could have a disruptive effect on the steroidogenic and reproductive pathways and hence sex differentiation, sexual behavior and reproductive cycles. This study examined only the transcript expression; therefore further research is necessary on protein expression and measurement to elucidate the effects and mechanisms of the action of EDCs on development, metabolism, reproduction, and sex ratios. Altered expression of *cyp19a1* and expression of *vtg* in juveniles and male livers following exposure to E2 suggests their value as more reliable biomarkers of exposure to estrogenic compounds and may be applicable to any other species.

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Received 20 June, 2016; Accepted 09 August, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 776-779

Manuscript Number: 2375
NAAS Rating: 4.47

Rainfall Analysis and Strategies for Crop Planning at Pakur District of Jharkhand, India

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Abstract: A detailed statistical analysis of weekly and monthly rainfall data for the period of 15 years (1997-2011) of Dumka in Pakur district of Jharkhand were analyzed to know weekly, monthly, seasonal and annual rainfall variability and probabilities at different level for suitable crop planning. The overall mean annual rainfall was 1388.8 mm, with standard deviation 371.2 mm and coefficient of variation 26.7 %. The annual rainfall of 1395.9 mm with 71 rainy days and 973.1 mm rainfall and 61 rainy days may be expected with 50% and 75 % probability level, respectively. The seasonal rainfall was distributed as 1117.9 mm, 134.9 mm and 135.9 mm in *kharif*, *rabi* and *zaid* seasons, respectively. July is the wettest month (average rains 310.5 mm) with lower coefficient variation (51 %). Each standard week from 24th to 38th receives a rainfall of more than 29 mm; however maximum rain (128.5 mm) occurred in 38th SMW followed by 28th SMW (96.5 mm). The rainfall of *kharif* season is adequate for agriculture and summer season rainfall would be helpful for summer ploughing operation but *rabi* cultivation needs irrigation planning. Keeping in view the rainfall pattern and its distribution in the area, suggestions have been made to modify the microclimate with respect to crop planning to increase the quality and productivity under rainfed conditions.

***Key Words*:** Coefficient of variance, Crop planning, Pakur district, Probability, Rainfall

India's economy is mainly dependent on agriculture, which is based on monsoon rainfall and its distribution. Fluctuation in rainfall is directly governs the growth, development and yield of crops. To exploit the available rainfall effectively, crop planning and management practices must be followed based on the rainfall amount and distribution at a place. Probability and frequency analysis of rainfall data enables us to determine the expected rainfall at various chances. Rainfall at 80 per cent probability can be safely taken as assured rainfall, while 50 per cent chance can be considered as the maximum limit for taking any risk (Gupta *et al.*, 1975). The weekly, monthly and seasonal probability analysis of rainfall data for crop planning has been suggested by Ray *et al.* (1980). The early or delay in onset of monsoon, early or late withdrawal of monsoon, breaks in monsoon period, unusual heavy or no rainfall during the critical phenol-phase of crops may disturb the normal crop growth and development. The rainfall pattern decides the cultivation of crops, their varieties, adoption of cultural operations and harvesting of excess rainwater of any region (Kar, 2003).

Probability analysis is the most reliable method to predict occurrence of future rainfall events based on past behavior of rainfall (Kumar and Kumar, 1989). But average annual rainfall is not much helpful for crop planning. Kumar *et al*. (2007) suggested that analysis of weekly rainfall is more useful for prediction of proper time of sowing, cultural operations and scheduling irrigation to crops. An attempt has been made to understand the rainfall climatology by analyzing the temporal and spatial rainfall distribution and its variability on weekly, monthly, seasonal and annual basis for the last 15 years for Zonal Research Station Dumka, Pakur district in Jharkhand at India. The degradation of forest and increase in built-up area is also one reason for the emerging water scarcity in the region (Avishek *et al.*, 2008). Climatically the state falls in monsoon belt. The state has hilly terrain, steep slopes and undulating topography where most of the rainfall goes as waste as heavy run-off. Special tools and directed actions are needed to most effectively utilize scarce water resources (Hazra and Avishek, 2010). This paper uses the concept of water accounting to assess the water resources of the region.

MATERIAL AND METHODS

Daily rainfall data for 15 years (1997-2011) were collected from agro-meteorological observatory situated at Zonal Research Station (ZRS) Dumka, BAU, Pakur districtextended between 23º 40' to 25º18' N Latitude and 86º 25' to 87º 57' E Longitude with 625 m above MSL. The weekly, monthly, seasonal and annual rainfall pattern were critically examined and analyzed. The calendar year was divided into three seasons i.e., *kharif* (June to September), *rabi* (October to February), and *zaid* (March to May) based on existing agricultural practices in this region.

The rainfall and rainy days of the months of respective season has been summed up to calculated seasonal rainfall and rainy days respectively. The yearly total rainfall and rainy days was calculated simply by summing up daily rainfall and rainy days of the respective year and mean was calculated by dividing the yearly total by the total number of year. Then the weekly, monthly, seasonal and annual rainfall and rainy days were critically examined and analyzed. The standard deviation and coefficient of variation were also worked out. Weekly, monthly, seasonal and annual probability of rainfall at 90, 75, 50, 25 and 10 % confidence level was carried out using Weibull's distribution method (Chow 1964), which is

$$P=\frac{m}{n+1}x100$$

where, P is the plotting position percent chance; m is the rank number when the data are arranged in descending order and n is total number of years.

RESULTS AND DISCUSSION

Analysis of weekly rainfall variability: 15 years average weekly rainfall distribution pattern of Dumka was shown in fig. 1. The weekly probability of rainfall was worked out by using Weibull's distribution method. The weekly rainfall of 20 mm or more at 75 % probability level can be expected during 26, 28 to 31, 36 and 39th SMW, respectively (Fig. 2). It is observed that the south-west monsoon normally commenced in Pakur district during 24th (10-16th June) SMW and withdrawal 38th (16-22nd September) SMW. These rainfall accounts are sufficient for growing *kharif* crops in this region. The mean weekly rainfall during 24th to 38th SMW varied from 29.31 to 128.5 mm. The mean weekly rainfall showed that 24th to 38th SMW are considered as most stable period and total average length of growing period is 15 weeks at Pakur district. Expected 70% rainfall to the total average of annual is received during 24th to 38th SMW. Chand *et al.* (2011) also suggested that the collection of surface runoff during the excess rainfall period and it was consequent used in dry period. The probability of getting 22 mm or more rainfall exceeded 50 % level of confidence during 19th, 23th continued till 39th SMW (23-29th September).

Analysis of monthly rainfall variability: The monthly rainfall probability at 10, 25, 50, 75, and 90% confidence level was computed using Weibull's distribution method (Fig. 3). At 50% level of confidence 191.0 mm rainfall received during June while at 75% level of confidence it was only 131.8 mm. The rainfall received during last week of June in Pakur district is at least assured level which can be utilized for ploughing and land preparation for *kharif* crops. The assured rainfall or at 75% chances received during the month of July, August and September are 292.8, 254.7 and 340.3 mm, respectively (Table 1). July to September are major rainfall contributing months (65 % of the annual rainfall) and having lower variability however average rainfall received during November (2.8 mm) and in April (27.4 mm) is meager with high variability (Fig. 4).

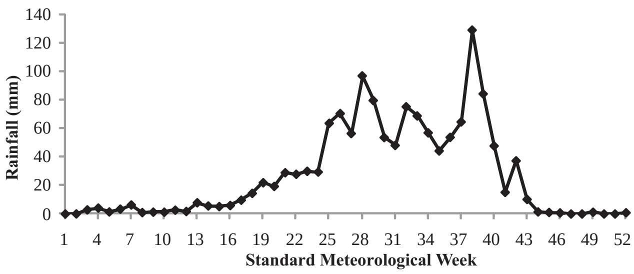

Fig. 1. Weekly rainfall distribution at Dumka, Pakur district (1997-2011)

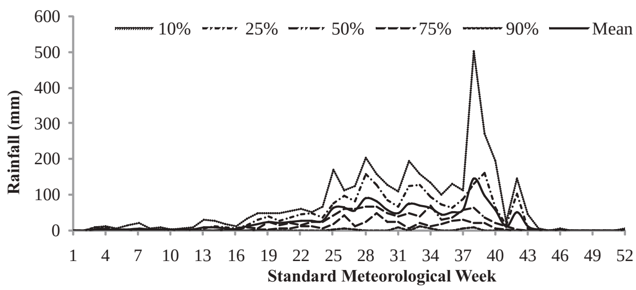

Fig. 2. Weekly rainfall probability at different levels of Dumka, Pakur district (1997-2011)

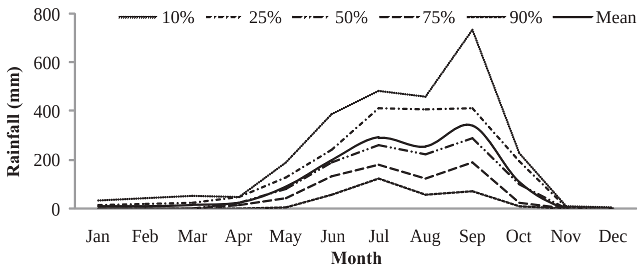

Fig. 3. Monthly rainfall probability at different levels of Pakurdistrict of Jharkhand (1997-2011)

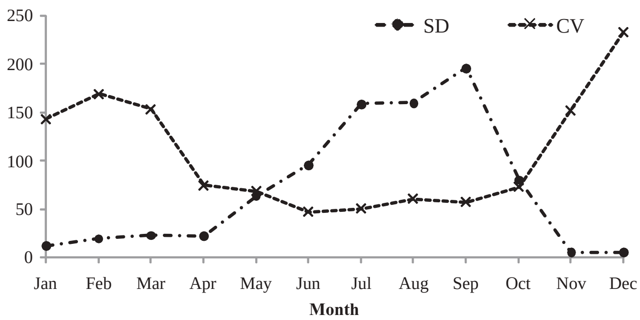

Fig. 4. Monthly rainfall variability of Dumka, Pakur district (1997-2011)

Analysis of seasonal rainfall variability: The highest rainfall was received during *kharif* season (1117.9 mm). A major part of it generally lost through runoff, which can be stored through in-situ management or ex-situ water harvesting structure and used during *kharif*, *rabi* and *zaid* seasons for growing crops like black gram, green gram, sesamum, gram, lentil, pea, mustard, linseed, barley, wheat, fodder and vegetables, etc. It can also be utilized as life saving irrigation particularly during dry periods because a dry period of one or two weeks in rainy season also adversely affects the standing *kharif* crops in the region. The mean rainfall received was 135.9 mm during *zaid* season and 134.9 mm in *rabi* season. The percentage contribution of seasonal rainfall to the total was 80.5, 9.7 and 9.8 during *kharif*, *rabi* and *zaid* season, respectively. The lower value of coefficient of variation (36.1 %) during *kharif* season depicted consistence occurrence of rainfall. However, the higher value of CV inferred that cultivation in *rabi* (53.1 %) and *zaid* (51.3%) season can be practiced by depending on soil residual moisture or irrigation due to uncertainty of rainfall. *Rabi* season (October - February) rainfall amounting to 134.9 mm would be helpful for winter ploughing operation.

Analysis of annual rainfall variability: The mean annual rainfall of Pakur district in Eastern Plateau and Hills Region of Jharkhand for the past 15 years (1997-2011) was 1388.8 mm. The minimum annual rainfall of 822.4 mm was during the 2003 and maximum of 2256.1 mm in 2006 over the study period (Fig. 5). Out of 15 years, 9 years recorded annual rainfall in excess of average or normal (1388.8 mm) while 6 years recorded below normal rainfall (Fig. 6). The average annual rainy days was 69 and standard deviation and coefficient of variation was found to be 9.3 and 13.5, respectively. The annual rainy days ranged from 55days (2009) to 86 days (1999). Therefore, its amount, time of occurrence and spatial variability controls the agricultural practices adopted in the region.

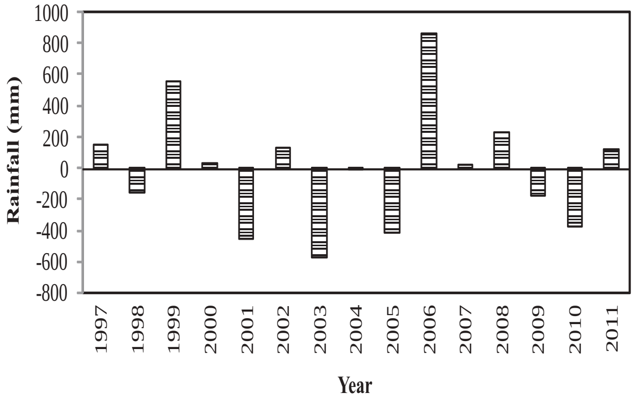

Fig. 5. Annual variability of rainfall over normal in Dumka, Pakur district (1997-2011)

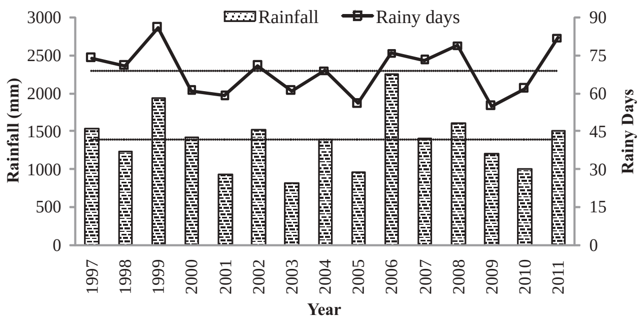

Fig. 6. Annual rainfall and rainy days during 1997-2011

Management of crop planning in *kharif* and *rabi* season: All the tillage practices and seed bed preparations should be done within the 24th to 26th week to avail the subsequent weekly rainfall. The 50 % chances of getting rainfall occurred during 26th to 27th week which can be useful for sowing of early and long duration crops like rice, maize, pigeon pea, black

Table 1. Monthly variability of rainfall of Dumka, Pakur district, Jharkhand

Months	Mean	Percent	SD	CV	Mean+SD	Mean-SD
Jan.	8.3	0.6	11.8	143.3	20.1	-135.1
Feb.	11.3	0.8	19.1	169.5	30.3	-158.3
Mar.	14.5	1.0	22.3	153.7	36.8	-139.2
Apr.	29.5	2.1	22.0	74.7	51.5	-45.2
May	92.0	6.6	63.4	68.9	155.4	23.1
Jun.	202.5	14.6	95.4	47.1	298.0	155.4
Jul.	310.5	22.4	158.2	50.9	468.6	259.5
Aug.	261.8	18.9	159.5	60.9	421.2	200.9
Sep.	343.1	24.7	195.9	57.1	539.0	286.0
Oct.	110.3	7.9	80.0	72.6	190.3	37.7
Nov.	3.0	0.2	4.6	152.4	7.6	-149.4
Dec.	2.1	0.2	4.9	233.3	7.0	-231.2
Annual	1388.8	100.0	371.2	26.7	1760.0	1362.0

Table 2. Seasonal rainfall pattern of Dumka, Pakur district (1997-2011)

Crop Season	Av. Rainfall (mm)	Per cent	S.D.	C.V.
Kharif	1117.9	80.5	403.8	36.1
Rabi	134.9	9.7	71.6	53.1
Zaid	135.9	9.8	69.7	51.3
Annual	1388.8	100.0	371.2	26.7

gram and green gram should be done immediately so that germination could take place with available moisture at root zone. After 28th week, the rainfall is more and runoff is likely to occur so there is scope to harvest excess amount of rainwater and recycling or life saving irrigation at critical stages of crop growth period. Probability of getting rainfall at 25% level between 40th to 41st weeks is only 67.1 mm, so limited chances of receiving adequate amount of moisture at the root zone level for proper germination of *rabi* season crops. Crops like wheat, maize, lentil, pea and chickpea with intercropping can also be taken up with residual moisture and with life saving irrigation during critical crop growth stages. Wheat is the major *rabi* crop growing in the region and with available assured irrigation starting from first fortnight of November.

The distribution of rainfall within the crop period is more important than the total amount of rainfall in a season. The information regarding rainfall and rainy days variability and probability of this region is very conducive for selecting timely seedling, choice of crops and variety and irrigation planning. Prediction of different factors, such as assured amount of rainfall expected at various probabilities at different stages of crop growth, probability of short dry periods within the growing season, play important role in crop planning for a region. In other words, during *kharif* season rainfall was adequate for agriculture. However, irrigation was required for *rabi* season crops. This prediction helps to optimize choice of crops and irrigation scheduling for different crops cultivation in this region.

Received 20 January, 2016; Accepted 24 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 780-784

Manuscript Number: 2376
NAAS Rating: 4.47

Effect of Pre-harvest Application of Chemicals on Shelf Life and Yield of Peach *cv.* Shan-i- Punjab

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Abstract: Ten year old plants of peach cv. Shan-i-punjab were sprayed with calcium chloride (1, 2 and 3%), potassium nitrate (1, 2 and 3%) and (2- chloro-4pyridyl) 3- phenyl urea (1.25, 2.50 and 5ppm) 25 days before harvesting. Maximum colour development, palatability rating, spoilage percentage were in fruits treated with 3% KNO_3. Minimum physiological loss in weight, colour development and maximum fruit firmness, pulp: stone ratio and yield were with (2 chloro-4pyridyl) 3-phenyl urea 5ppm. Firmness of fruits decreased with time gap.

Key Words: Chemical treatment, Peach, Physiological loss, Shelf life

Many varieties of peach *(Prunus persica* (L.) Batsch) like Florida sun, Shan-i-Punjab, Early Grande, Prince and Partap are grown successfully in Punjab, however, *cv.* Shan-i-Punjab finds favour with orchardists because of its higher economic returns, taste and good keeping quality. Peach is a perishable fruit and needs to be harvested at an appropriate stage of maturity. Harvesting at either under or over mature stage adversely effect fruit quality and results in decreased profit margin of peach growers. Peaches harvested in pre-mature stages of development showed higher fruit firmness and higher incidence of wooly breakdown as compared to peaches which are harvested at more mature stages, but these fruits showed better sensory quality (Rombaldi *et al.,* 2001). On the other hand, peach fruit left for too long on the tree became too soft to ship well because of reduced shelf life (Murray *et al.,* 1998). Progress has been made in the use of controlled atmosphere storage and research has shown the potential for post-harvest disease control using biological agents. The identification of effective natural chemical (i.e., those present in plant extracts), which may be more acceptable to consumers than those that are synthetically produced. Thus, research has been focused on extending port-harvest fruit storage life by pre or post-harvest treatments with calcium, potassium and (2 Chloro-4 pyridyl) 3-Phenyl Urea. Foliar application of certain bio-regulators and chemicals like (2 chloro-4pyridyl) 3-phenyl urea and potassium is another practice which is gaining popularity for increasing fruit size, total yield and improving the quality of fruits in temperate fruit plants. The efficiency of these chemicals for increasing the fruit size, yield and improving quality of fruits in temperate fruit plants depends on the time of application, environmental factors and tree conditions. Keeping in view these facts, the present investigation was planned to study the effect of $CaCl_2$, KNO_3, and (2 chloro-4pyridyl) 3-phenyl urea on shelf life and yield of peach cv. Shan-i-Punjab.

MATERIAL AND METHODS

The trail was conducted on 10 year old uniformly vigorous Shan-i-Punjab peach trees randomly selected for the purpose of the study at Govt. Garden and Nursery, Attari, Amritsar (31.6° N, and 74.9° E). The selected trees were given uniform cultural practices during the course of the study as recommended by PAU, Ludhiana, the pre-harvest application of chemicals was given at the end of 2nd stage of fruit development and the beginning of 3rd stage of fruit development i.e., 3 or 4 weeks before harvesting (Kaur and Singh, 2011). The fruits were harvested at the proper maturity and kept in cold storage for further studies. Healthy and uniform plants of peach cv. Shan-i-Punjab were marked and sprayed with calcium chloride (1, 2, 3%), potassium nitrate (1, 2, 3%) and (2 chloro-4pyridyl) 3-phenyl urea L-(2 chloro-4pyridyl) 3-phenyl urea at concentration as 1.25, 2.50, 5.00 ppm and control were sprayed with plain. A total of ten treatments were given comprising three replications in peach treatment and data were analyzed in Randomized Block Design in factorials as per the procedures described by Singh *et al.* (1998) and the results are summarized in tables with average of three replications. Uniform sized fruits were harvested from the treated plants with the help of secateur in the early morning hours. Harvested fruits were immediately carried to the laboratory for sorting and packaging. The bruised and diseased fruits were sorted and the healthy fruits were washed and air dried at room temperature. After drying, the fruits were packed in one kg CFB boxes in layers and subsequently placed in cold chamber (0 to 1ºC tempt and RH 90-95%). The cumulative loss in weight was calculated on fresh weight basis and the fruits were evaluated by a panel of five judges on a score card (maximum 10 points).

Firmness of Randomly selected fruits (three form each replication) was measured with the help of fruit pressure tester Penetrometer (Model FT-327, USA) about 1 square centimeter of the skin in each fruit from the shoulder end on both sides was removed with the help of peeler and firmness of pulp was recorded and expressed in terms of kg/cm^2. Pulp-stone ratio was calculated by dividing the values of weight of pulp to the corresponding weight of stone. Fruits were rated for this character by a panel of five judges on the basis of external appearance of fruits, texture, taste and flavour. A nine point 'Hedonic Scale' described by Amerine *et al.* (1965) was used for its inference.

RESULTS AND DISCUSSION

Physiological loss in weight (%) and fruit colour: The fruits given pre-harvest treatments significantly decreased the physiological loss in weight as compared to untreated fruits (Table 1). At the same time physiological loss in weight increased with the advancement of storage period. Mean minimum physiological loss in weight (0.02%) was in peach fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm, 2.50ppm and $CaCl_2$ 3%. Maximum physiological loss in weight (0.07%) was observed in fruits treated 3% KNO_3. The fruits kept for storage period of 25 days showed significant losses of weight. The minimum average physiological loss in weight (0.03%) was observed after 5 days of storage and maximum (0.06%) after 25 days of storage. After 5 days of cold storage, the maximum physiological loss in weight was in control followed by, KNO_3 3 % and $CaCl_2$ 1% and minimum physiological loss (0.01%) was examined in fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm and $CaCl_2$ 3% followed by (0.02%). Similarly after 15 days of cold storage maximum PLW was in fruits treated with KNO_3 3% and minimum in CPPPU and $CaCl_2$ 3% treated fruits. Calcium application have shown to be effective in terms of membrane functionality and integrity maintenance, with lower losses of phospholipids and proteins and reduced ion Leakage (Lester and Grusale, 1999), which could be responsible for the lower weight loss. Likewise, Moon *et al.* (2000) observed reduced fruit weight loss in “Niitaka' pear fruits with calcium treatments. Navjot (2005) in peach *cv*. Earli Grandi. Data pertaining to fruit color is presented in Table 1 and it revealed that fruit colour development increased with the advancement of storage period. Mean minimum values 5.53 were observed on the day of harvesting. The mean maximum values 8.05 were observed after 25 days of storage. After 5 days of storage fruit treated with KNO_3 3 % showed maximum values (6.10) in (2 chloro-4pyridyl) 3-phenyl urea 5ppm treated fruits. Similarly, at the end of storage period, the fruits treated with KNO_3 3 % recorded maximum 9.00 values while the fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm

Table 1. Effect of $CaCl_2$, KNO_3 and (2 chloro-4pyridyl) 3-phenyl urea on PLW (%) and colour in peach fruits

Treatments	Storage intervals (Days)										
	PLW (%)						Colour				
	05	0.06	15	20	25	Mean	0	05	15	25	Mean
$CaCl_2$ 1%	0.06	0.06	0.06	0.06	0.14	0.06	5.50	5.70	7.40	8.50	6.88
$CaCl_2$ 2%	0.05	0.06	0.05	0.06	0.06	0.04	5.69	6.00	6.50	8.00	6.49
$CaCl_2$ 3%	0.01	0.06	0.03	0.04	0.05	0.02	5.40	5.70	6.40	7.50	6.31
KNO_3 1%	0.02	0.06	0.04	0.04	0.07	0.03	5.69	6.00	6.40	7.80	6.51
KNO_3 2%	0.04	0.06	0.05	0.07	0.07	0.04	5.80	6.00	7.60	8.90	7.11
KNO_3 3%	0.06	0.06	0.07	0.07	0.18	0.07	6.10	6.20	7.80	9.00	7.36
(2 chloro-4pyridyl) 3-phenyl urea 1.25ppm	0.04	0.06	0.04	0.05	0.05	0.03	5.30	5.50	6.10	7.90	6.25
(2 chloro-4pyridyl) 3-phenyl urea 2.50ppm	0.02	0.06	0.03	0.04	0.05	0.02	5.20	5.50	5.98	7.20	5.99
(2 chloro-4pyridyl) 3-phenyl urea 5 ppm	0.01	0.06	0.02	0.04	0.05	0.02	5.10	5.44	5.90	6.97	5.90
Control	0.06	0.06	0.06	0.06	0.06	0.06	5.60	6.19	6.80	8.80	7.03
Mean	0.03	0.06	0.04	0.05	0.06		5.53	5.82	6.68	8.05	

CD (p=0.05) PLW % : Treatment: 0.003, Days interval: 0.002, Interaction: 0.008
Colour: Treatments : 0.18, Days interval : 0.14, Interaction : 0.44

registered minimum 6.97 values followed by 7.20 in (2 chloro-4pyridyl) 3-phenyl urea 2.50ppm treated fruits. The application of (2 chloro-4pyridyl) 3-phenyl urea 5ppm showed minimum average values while maximum were observed in KNO_3 3% treated fruits. The delay in colour development with calcium chloride treatments may be due to retarded rate of respiration degradation of chlorophyll and synthesis of carotenoids and anthocyanins.

Fruit firmness and pulp: stone ratio: The fruits given pre-harvest treatments of above mentioned chemicals significantly increased the firmness as compared to untreated fruits. A significant difference in fruit firmness was also observed with the progression of storage period (Table 2). The mean maximum fruit firmness was observed after 25 days of storage period. After 5 days of cold storage, the peach fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm showed the maximum fruit firmness (7.87) and it was found minimum (5.10) in KNO_3 3% treated fruits. Similarly 15 and 25 days of storage fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm registered maximum fruit firmness followed by fruits treated with $CaCl_2$ 3%, while it was recorded minimum in KNO_3 3%. The maximum average fruit firmness (7.28) was recorded in fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm, followed by $CaCl_2$ 3% treatments, whereas the minimum (4.88) fruit firmness was observed in KNO_3 3% treated fruits. Higher fruit firmness in calcium chloride treated fruits may be due to the role of calcium in farming the cross links with carboxylic group of polygalacturonase polymers present in middle lamella of cell (Mastrangelo *et al.,* 2000) and reduces the activity of polygalacuronase thus stabilizing and strengthen the cell walls (Picchioni *et al.,* 1993). Declining trend in flesh firmness with advancement of storage period by calcium chloride treatments has also been observed in plum cv. status purple (Mahajan and Dhatt, 2004). Cronje *et al.* (2009) reported higher fruit firmness of litchi cv. Maritus during cold storage by calcium treatments. Similarly, Gerasopolus and Drogaudic (2005) observed and increase in fruit firmness with calcium chloride treatments in Kiwifruit.

Present findings are also in agreement with findings of Suwatariren *et al.* (2002) in strawberry. The pulp: stone ratio was significantly higher in (2 chloro-4pyridyl) 3-phenyl urea, KNO_3 and $CaCl_2$ treated fruits than the control fruits. The pulp: stone ratio reduced with progression in storage period. The mean maximum pulp: stone ratio (9.44) was on the day of harvesting and the mean minimum was after 25 days of storage. On the day of harvesting, maximum (10.26) pulp: stone ratio was recorded in peach fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm treatments followed by KNO_3 3% treatment and minimum pulp: stone ratio (8.30) was found in $CaCl_2$ 1% fruits. At the end of storage period, the maximum pulp: stone ratio (9.76) was observed in (2 chloro-4pyridyl) 3-phenyl urea 5ppm treatment. The minimum pulp: stone ratio (6.53) was noticed in untreated fruits. Akhtar *et al.* (2010) reported the decrease in pulp: stone ratio with advancement of storage period in loquat. The decline in the pulp: stone ratio with the advancement of storage period may be due to the increase in moisture loss from peach fruits. This

Table 2. Effect of $CaCl_2$, KNO_3 and (2 chloro-4pyridyl) 3-phenyl urea on fruit firmness and pulp: stone ratio in peach fruits

Treatments	Storage intervals (Days)													
	Fruit firmness (kg cm^{-2})							Pulp: stone ratio						
	0	05	10	15	20	25	Mean	0	05	10	15	20	25	Mean
$CaCl_2$ 1%	7.52	7.42	7.30	6.19	6.06	5.96	6.74	8.30	7.98	7.82	7.59	7.44	6.82	7.66
$CaCl_2$ 2%	7.60	7.50	7.30	6.50	6.40	6.30	6.93	9.00	8.73	8.63	8.53	8.49	7.46	8.47
$CaCl_2$ 3%	7.76	7.60	7.50	6.76	6.56	6.36	7.09	9.34	9.23	8.80	8.60	8.54	7.66	8.69
KNO_3 1%	6.86	6.69	6.43	5.70	5.93	5.16	6.04	9.69	9.59	9.57	9.29	9.10	8.29	9.34
KNO_3 2%	6.70	5.43	4.96	4.93	4.85	4.80	5.27	9.79	9.71	9.73	9.46	9.29	8.76	9.45
KNO_3 3%	5.10	5.00	4.96	4.86	4.76	4.60	4.88	10.03	9.96	9.76	9.73	9.46	9.29	9.70
(2 chloro-4pyridyl) 3-phenyl urea 1.25ppm	7.63	7.46	7.13	6.23	6.20	6.13	6.79	9.52	9.43	9.29	9.28	8.83	8.40	9.12
(2 chloro-4pyridyl) 3-phenyl urea 2.50ppm	7.76	7.50	7.30	6.76	6.56	6.36	7.09	9.97	9.84	9.82	9.74	9.56	9.55	9.75
(2 chloro-4pyridyl) 3-phenyl urea 5ppm	7.87	7.86	7.71	6.93	6.73	6.60	7.28	10.26	10.13	9.96	9.88	9.86	9.76	9.98
Control	7.40	7.16	6.80	6.61	6.52	5.90		8.57	8.33	8.12	7.21	6.85	6.53	7.60
Mean	7.22	6.96	6.73	6.14	6.00	5.81		9.44	9.29	9.15	8.93	8.74	8.25	

CD (p=0.05) Fruit Firmness: Treatment: 0.06, Days interval: 0.05, Interaction: 0.16
Pulp: stone ratio: Treatments : 0.21, Days interval : 0.16, Interaction : 0.53

decline was less in calcium chloride treated fruits because of the role of calcium in maintaining cellular integrity.

Spoilage (%), palatability rating and yield (kg tree^{-1}): The $CaCl_2$ treatment significantly reduced the spoilage percentage in fruits under cold storage. Peach fruits treated with $CaCl_2$ did not show any spoilage during the cold storage period with advancement of storage spoilage percentage increase. The spoilage percentage was recorded in any treatment after 5, 10, 15 days of cold storage 0.48 per cent and 0.54 per cent mean spoilage was recorded respectively. At the end of storage 25 days maximum spoilage (1.40) was recorded in KNO_3 2% fruit followed by the fruits untreated (1.36%). The mean maximum fruit spoilage (1.20%) was observed was in (2 chloro-4pyridyl) 3-phenyl urea treated fruits, while the fruits treated with KNO_3 2 and 3% control showed the average spoilage %age at the tune 0.78, 0.54, 0.75 respectively. Calcium also increases the synthesis of phytoalcxins and phenolic compound which and it also reduces the risk of micro cracks in the cuticle which is known as the direct site of fungal infection (Elmer *et al.* 2000). Wojick and Lewandowski (2003) and Naradisron *et al.* (2006) also reported reduced spoilage %age with calcium chloride treatments in strawberry fruits. Among the treatment, the highest palatability rating (8.41) was observed in KNO_3 3% treatment followed by $CaCl_2$ 1% treatment (8.40). Minimum average palatability rating (7.49) was recorded in (2 chloro-4pyridyl) 3-phenyl urea 5ppm treated fruits. The palatability rating of fruits stored under cold storage conditions indicated increase continuously upto 20 days of storage in all the treatments and after that it declined. The average maximum (8.51) palatability rating was recorded after 20 days of storage and the minimum (7.66) palatability rating was observed at the time of harvesting. In freshly harvested fruits, the maximum palatability rating (8.20) was observed in KNO_3 3% treated fruits and minimum (7.10) was recorded in fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm and it was followed by 7.30 in control fruits. Similarly, after 5, 10, 15 and 2 days of cold storage minimum palatability rating was recorded in fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm and it was followed by control fruits and the maximum was observed in KNO_3 treated fruits. Kaundal *et al.* (2000) noticed high palatability rating in calcium chloride treated plum fruits. The higher palatability rating of calcium chloride treated fruits at the end of storage might be due to retardation of ripening and softening processes of fruit that led to the development of better juciness, texture, flavour and sweetness.

The data regarding the effect of calcium chloride, CPPU and potassium on fruit yield is presented in Table 3. The data reveal that maximum fruit yield was recorded in fruits treated with CPPU 5ppm (80.36kg tree^{-1}) fruit yield in all the CPPU treatments was significantly higher than all other treatments. Minimum fruit yield (68.50 kg tree^{-1}) was obtained from control fruits. Among KNO_3 and $CaCl_2$; KNO_3 3% recorded (77.90 kg tree^{-1}). All the treatments recorded significantly higher fruit yield than control. The significant increase in yield by CPPU treatment was due to higher mean fruit weight and less percentage of fruit drop recorded.

Table 3. Effect of $CaCl_2$, KNO_3 and (2 chloro-4pyridyl) 3-phenyl urea on in spoilage %, palatability rating and yield in peach

Treatments	Storage intervals (Days)									
	Spoilage %				Palatability rating					Yield (kg tree^{-1})
	05	15	25	Mean	0	05	15	25	Mean	Mean
$CaCl_2$ 1%	00.0	00.0	00.0	00.0	7.95	8.28	8.66	8.22	8.40	73.7
$CaCl_2$ 2%	00.0	00.0	00.0	00.0	7.50	8.23	8.43	8.14	8.22	74.8
$CaCl_2$ 3%	00.0	00.0	00.0	00.0	7.44	8.17	8.40	8.13	8.14	75.9
KNO_3 1%	00.0	00.0	00.0	00.0	8.13	8.17	8.37	7.50	8.15	75.7
KNO_3 2%	00.0	0.96	1.40	0.78	8.16	8.33	8.52	8.13	8.34	76.8
KNO_3 3%	1.63	00.0	00.0	0.54	8.20	8.34	8.54	8.16	8.41	77.9
(2 chloro-4pyridyl) 3-phenyl urea 1.25ppm	0.70	1.23	0.96	0.96	7.50	8.13	8.59	8.37	8.22	78.6
(2 chloro-4pyridyl) 3-phenyl urea 2.50ppm	0.76	0.63	1.06	0.98	7.41	8.11	8.37	8.15	8.10	79.8
(2 chloro-4pyridyl) 3-phenyl urea 5ppm	1.26	1.70	0.66	1.20	7.10	7.21	7.78	7.50	7.49	80.3
Control	0.53	0.36	1.36	0.75	7.30	7.50	8.17	7.80	7.79	68.50
Mean	0.48	0.48	0.54		7.66	8.04	8.38	8.01		

CD (p=0.05) Spoilage %: Treatments: 0.17, Days interval: 0.13, Interaction: 0.41
Palatability rating: Treatments: 0.07, Days interval: 0.05, Interaction: 0.17
Yield: Treatments: 0.21, Days interval: 0.16, Interaction: 0.53

CONCLUSION

The research has been focused on extending post-harvest fruit storage life by pre harvest treatments with calcium, potassium and (2 chloro-4pyridyl) 3-phenyl urea. From this study, it is concluded that treatment of fruits these chemicals is effective in increasing the shelf life of peach fruits as maximum colour development, palatability rating, spoilage percentage were recorded in fruits treated with 3% KNO_3. Minimum physiological loss in weight and maximum fruit firmness, pulp: stone ratio and yield were recorded in fruits treated with (2 chloro-4pyridyl) 3-phenyl urea 5ppm.

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Received 12 May, 2016; Accepted 19 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 785-788

Manuscript Number: 2377
NAAS Rating: 4.47

Economic Analysis of Factors Affecting Adoption Rate of Agroforestry Technologies in Tamil Nadu

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Abstract: A study was conducted to determine factors affecting adoption of agroforestry technologies involving 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 primary data collected from 240 randomly selected agroforestry farmers showed that the likelihood to adopt agroforestry technologies was influenced significantly by age (2.08), level of education (0.145), land size (0.213) and agroforestry income (-0.254). Adoption of agroforestry practices led to an improvement in livelihood of farmers as indicated by the disparities in livestock ownership, farm assets, crop production and incomes in practicing agroforestry.

***Key Words*:** Agroforestry, House hold-benefits, Multiple regression

India has a long tradition of agroforestry practices. The agroforestry systems in India include trees on farms, community forestry and a variety of local forest management and ethno forestry practices. In India, the practice of growing scattered trees on farmlands is quite old and has not changed much over centuries; mainly used for shade, fodder, fuel wood, fruit, vegetables and medicinal uses. The tree component introduced in an agroforestry system is a technological substitute for fuel, timber, fodders in many subsistence economics, which could improve farm household food security and nutrition. The specific objectives of the study are to estimate the factors affecting the adoption rate of agroforestry technologies and household benefits in agroforestry in Tamil Nadu.

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. Primary data was mainly cross-sectional, collected from 240 agroforestry farmers randomly selected from a list of tree growers in the following taluks: Pennagram and Morappur for the 2013-2014 production seasons. 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

Agricultural productivity makes a major contribution to their livelihoods. Agroforestry has been praised world over as a major source of livelihood among rural households. The farmers accrue several livelihood benefits from agroforestry practices in the study area. In this section, the benefits towards the farmers' livelihood have been categorized as produce from agroforestry.

In the study area, most of the produce is used at home for local consumption. In Dharmapuri district, most of the farmers produce mainly for market for cash. However, even selling a proportion of their produce in the market and the remaining portion was used for home consumption. The result revealed that the milk sale (40.83%), animal sale (93.63%), firewood (89.42%), poles (18.18%) timber sales (100%) and poultry (75.21%) were considered to be very important addition to household income. Cow was the major producers of milk for sale, while local breed produced milk for home consumption. Buffalo, goats and sheep were the animals reared for sale by the farmers.

Furthermore, livestock of agroforestry farmers had also generated additional income to the farmers. A substantial amount of money was therefore generated from the products of the different components of agroforestry, and was used by the farmers to meet their family needs. This, in turn had contributed enormously in enhancing the economy of the rural communities. It can be further observed from the table that poultry plays a very important role in the study area. Most of the households keep poultry, and in many households, children and women owned the hens. In most cases, chicken are sold and in some cases eggs supplement household income especially when there is emergence for cash.

About 91% of the respondents admitted they regularly prune trees to get fodder for their livestock for household purpose. It was evident that the pruning of trees for animal feeds is largely carried out by cattle rearer, and some local farmers, mainly during the dry season, and especially after crop harvests.

In the present study, majority of the agroforestry units are also major 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 or when there is food shortage after the previous harvest is exhausted.

Socio-cultural benefits of agroforestry: Socio-cultural beliefs play a significant role in influencing agroforestry adoption among the rural households in Dharmapuri district. The belief systems existing among the rural people may inhibit or promote the practice of agroforestry. From the Table 2, 48.33% of the respondent planted tamarind which provided shade for people and animals house, whereas 51.66% of the respondent planted teak provide ornamental shade and also used to demarcate the homestead, while 28.75% planted tamarind + sorghum were benefited for fodder purpose and remaining 31.66% of respondent planted teak + maize for food and fodder purpose.

T*eak* was the favorite tree among the respondents. Tamarind, the tree commonly found near houses and near animals grazing or feeding area for shade. This is because agroforestry practicing farmers all over the block use the tree shades for rest during all farming activities. The low level of acknowledgement again cannot be divorced from lack of understanding. Furthermore, since this benefit is not quantified, it is mostly taken for granted by farmers. Trees are hardy and tolerant to a wide range of soils and moisture stress. Apart from the fruits, the wood is considered as a premium quality construction timber. In spite of heavy bearing and higher income, tamarind has not been considered as a commercial crop because of long gestation period and non-availability of superior quality planting material.

Environmental benefits: Tables 3 indicate that 48.33% of the respondents had multipurpose benefits such as reduced soil erosion. The leaves are collected together and used to provide mulch and more and to incorporate the crop field. Whereas, 51.66% of respondents planted *teak* to increases carbon biomass, reduce water logging and enrich soil in the study area.

Factors affecting adoption rate of agroforestry technologies: The rate of adoption is calculated as the number of technologies adopted divided by the total number of technologies transferred and expressed in percentage.

Table 1. Household benefits of agroforestry

Produce from agroforestry	Use all produce at home (Number)	Use more at home than sell (Number)	Sell more than use at home (Number)	No of respondents (Total)
Milk	90 (37.50)	52 (21.66)	98 (40.83)	240
Animals	8 (5.10)	2 (1.27)	147 (93.63)	157
Firewood	3 (2.88)	8 (7.69)	93 (89.42)	104
Poles	160 (72.73)	20 (9.09)	40 (18.18)	220
Timber	0 (0.00)	0 (0.00)	240 (100.00)	240
Fodder	136 (91.89)	11 (7.43)	2 (1.35)	148
Home implements	154 (80.21)	5 (2.60)	33 (17.19)	192
Fruits	30 (25.00)	10 (8.33)	80 (66.67)	120
Raw materials	192 (96.00)	6 (3.00)	2 (1.0)	200
Poultry	20 (8.55)	38 (16.24)	176 (75.21)	234

(Figures in parentheses indicate percentage to the totals)

Table 2. Social and cultural benefits of agroforestry

Types of agroforestry	No of respondents planted (n=240)	Benefits	No of respondents benefitted (n = 240)
Tamarind	47	Shade for people, animals, house, boundary marking	116 (48.33)
Teak	48	Contain livestock, ornamental, Shade for people and animals and to demarcate the homestead	124 (51.66)
Tamarind + sorghum	69	Shade for people, animals, house, boundary marking, food purpose	69 (28.75)
Teak + maize	76	Contain livestock, ornamental, shade for people and animals and to demarcate the homestead, food and fodder	76 (31.66)
Total	240		240 (100.00)

(Figures in parentheses indicate percentage to the total)

The implicit model of the regression is as follows: Y = f(X1, X2, X3, X4, X5, X6,X7,X8, e).
Where; Y=Adoption rate of agroforestry technologies (%)
X1= Farmers age (years)
X2= Farmers educational level (years)
X3= Household size of farmers (number of persons)
X4= Farming experience of farmers (years)
X5= Farm size of farmers (hectares)
X6= Farmers income (N)
X7= Farmers access to credit (Dummy variable, Yes =1, No = 0)
X8= Farmers contact with extension agents (monthly)
e= Error

The coefficient of multiple determination (R2) has a value of 0.791 (79.10%) indicating that the independent variables (X1, X2,………. X8) jointly explained 79.1% of the variation in the dependent variable (Y). Farmers' age (X1) was negatively related to adoption of agroforestry technologies, meaning that younger farmers adopted the technologies more than the older farmers. This relationship is significant at the 5% level of probability as the t-calculated value (2.005) is greater than the t-tabulated value (1.98). Farmers' educational level (X2) has a positive relationship with adoption rate of agroforestry technologies implying that the more educated farmers adopted agroforestry technologies more than the less educated farmers. The relationship is significant at the 1% level of probability as the t-calculated value (3.206) is greater than the t-tabulated value (2.617). Farmers' household size (X3) is positively related to adoption rate of agroforestry technologies indicating that farmers having larger households adopted the technologies more than their counterparts having smaller households. The effect is however insignificant at the 10% level of probability as the t-calculated value (0.121) is less than the t-tabulated value (1.658). Farmers' experience (X4) has a positive effect on adoption rate of agroforestry technologies showing that the more experienced farmers adopted the packages more than the less experienced farmers. The effect is not significant at the 10% level of probability due to the value of t-calculated (0.427) being less than the t-tabulated value (1.658). Farm size of farmers (X5) is positively related to adoption rate of agroforestry technologies implying that as the farmers' farm sizes increase they adopt more of agroforestry technologies, and vice versa. This effect is however significant at the 5% level of probability as the t-calculated value (2.325) is greater than the t-tabulated value (1.98). Farmers' income (X6) is positively related to adoption of agroforestry technologies meaning that the richer farmers

Table 3. Environmental benefits of agroforestry

Responses	No of respondents planted (n=240)	Use	No of respondents benefitted (n = 240)
Tamarind	116	Control soil erosion and provide mulch, litter fall, waste assimilation	116 (48.33)
Teak	124	Control soil erosion, increase carbon bio mass ,reduce water logging and enriched the soil	124 (51.66)

(Figures in parentheses indicate percentage to the total)

Table 4. Multiple regression estimates of factors affecting farmers' adoption rate of agroforestry technologies

Independent Variables	Linear form		Exponential form		Double log form	
	Coefficient	t- ratio	Coefficient	t- ratio	Coefficient	t- ratio
Intercept	2.08	0.181	5.6+28	0.103	2.373	1.544
X^1 Farmers age (years) farmers	-0.179	-2.005**	-7.89E-07	-0.02	-0.294	-0.751
X^2Educational level (years)	0.145	3.265***	-1.6E+22	-0.536	-0.048	0.321
X^3 Household size of farmers (number of persons)	-0.662	0.121	-2.2E+23	-0.028	0.133	0.895
X^4 Farming experience of farmers (years)	0.07	0.427	-4.6E+08	-0.010	0.008	0.070**
X^5= Farm size of farmers (hectares)	0.213	2.325**	2.2E+28	4.374***	0.174	1.933
X^6= Agroforestry income (N)	-0.254	3.206***	0.001	0.0001	0.141	1.703*
X^7= Farmers access to credit (Dummy variable, Yes =1, No = 0)	0.561	1.968*	-7.0E+28	-0.639	0.271	1.464
X^8= Farmers contact with extension agents (monthly).	-0.159	4.250***	1.3E+28	2.781***	0.295	2.788***
R^2	0.823		0.297		0.284	
? 2	0.777		0.228		0.208	
F-Ratio	5.477^{xxx}		4.286***		3.723***	

Notes: *** significance at 1 per cent; * significance at 10 per cent; ** significance at 5 per cent ; NS=non significant adopted the technologies more than the poorer farmers. The effect is significant at the 1% level of probability as the t-calculated value (3.206) is greater than the t-tabulated value (2.617). Farmers' access to credit (X7) has a positive effect on adoption of agroforestry technologies indicating that farmers with access to credit adopted the technologies more than those without access to credit. This effect is statistically significant at the 10% level of probability as the t-calculated value (1.968) is greater than the t-tabulated value (1.658). Farmers' contact with extension agents (X8) is positively related to the adoption rate of agroforestry technologies showing that farmers with higher number of contacts with extension agents adopted the agroforestry technologies more than farmers with less contact with extension agents. This relationship is statistically significant at the 1% level of probability as the t-calculated value (4.250) is greater than the t-tabulated value (2.617).

CONCLUSIONS

It can be concluded that the level of the household's farm production and net income is greater among farmers practicing agroforestry than those who were not practicing, implying that, agroforestry is significantly contributing to increased yields and income and thus income poverty reduction at household level. The trees and crops into such systems produce both food for subsistence and cash, fodder for the livestock, and reduce the problem of soil degradation and water quality and quantity while solving the problem of energy crisis. The livestock are mostly stall-fed and contribute to the household's nutrition and income through sale of their products like milk, eggs and meat. In order to improve productivity and sustainability of the Agroforestry systems in Dharmapuri District and contribute to income poverty reduction, there is need for the government to promote efficient use of the farm inputs and labour along with policies, which harness market incentives is a prerequisite. Improvement of the market opportunities and extension services will also motivate farmers to invest in crop production and thus improve the management and production at large (Chauhan *et al.,* 2009). The present findings on poverty reduction were only based on the household's level of production and income from the agroforestry systems.

Received 20 May, 2016; Accepted 10 August, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 789-792

Manuscript Number: 2378
NAAS Rating: 4.47

Constraint Analysis of Tuna Fisheries in Lakshadweep

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***Abstract*:** The current study was conducted in four major tuna landing islands of Lakshadweep i.e., Agatti, Minicoy, Androth and Kavaratti. The constraint analysis is conducted through Rank Based Quotient method. The constraints were divided into three core constraints such as production, marketing and government policy constraints with different set of parameters. The findings of the study revealed that the most important constraint in production is escalating of fuel cost (RBQ: 98.32) and the high input cost (RBQ: 93.52). Lack of cold storage facilities (RBQ: 94.61) and poor facilities (RBQ: 88.28) in marketing and lack of cooperation/support from fisheries officers (RBQ: 97.64) and lack of infrastructure for landing (RBQ: 94.07) from government side were other major constraints in Lakshadweep. Collectively, though tuna fisheries in Lakshadweep is fast catching up and developing, still concerted efforts are needed to mitigate the constraints that are unique to island fisheries.

***Key Words*:** Input cost, Pole and line and tuna fishery, RBQ

Tunas are among the *largest* and most specialized and commercially important of all fishes (Collete and Nauen, 1983). They are the fourth major internationally traded fish commodity and contribute 8% of the international fish trade in value terms (SOFIA, 2014). Indian Ocean contributes 19% of the world tuna catch (ISSF, 2013). Principal markets for tuna are Japan, USA and the European Union countries. Major commodities traded are sashimi, canned, chilled, frozen and smoked products. The export of tuna and tuna products has shown remarkable growth from 1230 tonnes in the year 2001-02 to an all time high level of 37302 tonnes in the year 2007-08 (John and Pillai, 2009). Three major species of tropical tuna caught in the Indian Ocean are skipjack, yellow fin and big eye. Potential tuna catch of the Indian EEZ is estimated at 2.78 lakh tonnes (Pillai and Jyothi, 2007). Total tuna landing in India is 85291 tonnes, which is 2.25% of total marine fish landings (CMFRI, 2013-14). In India 29.9% of Skipjack tuna is contributed by Lakshadweep fishery (Koya*et al*., 2012).

The common species of tuna in the Lakshadweep water are: skipjack (*Katsuwonus pelamis*), Yellow fin (*Thunnus albacore*), Frigate tuna (*Auxis thazard*), Little tuna (*Euthynnus affinis*) (Modayil, 2006).Tuna landings in Lakshadweep is 13505 tonnes, they account 15.83% of Indian total tuna landings and 86.5% of the fish production of Lakshadweep islands (DFL, 2015).The main fishing method practiced in Lakshadweep islands is pole and line except Androth (Pillai *et al*., 2006).Pole and line for tuna using live bait is the most important gear for tuna fishery with a contribution of 92.8% followed by troll line, drift gill net and handline, contributing 3.3%, 2.1% and 1.9%. In Androth, troll line is the major fishing method (CMFRI, 2010-11). As per the basic statistics (2012-13) there are about 2017 fishing boats in Lakshadweep. Non-mechanized boats forms about 52% of the fleets, followed by mechanized boats (28.11%) and motorized boats (19.8%) (Anonymous, 2013). It is estimated that about 13% of the total population of Union territory of Lakshadweep are active, full time fishermen and fisheries sector provide livelihood for about 60% of the people of Lakshadweep . It is estimated that the exploitable potential of Tuna from the Union territory of Lakshadweep waters is 150000 tonnes. The total fishable potential of non-Tuna resources of Union territory of Lakshadweep waters is 100000 tonnes, provided, there is significant development in the introduction and use of non-traditional fishing techniques like Trolling, Long Lining, Perch Traps, etc.

Tuna is one of the most economically underutilized fisheries in Indian waters and more than half of the potential tuna stock is located around the Lakshadweep waters. Indian tuna fishery is not well developed leading to a big gap between potential and actual catch. A systematic study targeting the constraints and possible solutions is required to understand tuna fisheries in totality from a socio-economic perspective and device strategies for mitigation of existing shortcomings. Significant developments can be made possible by technological progress and policy changes.Considering the above mentioned potential of tuna fisheries in Lakshadweep and need to improve it on scientific lines, an exploration of constraints in tuna fishery is carried out and suitable measures are proposed.

MATERIAL AND METHODS

The four islands Minicoy, Androth, Agatti and Kavaratti, which have maximum catch, were considered for the present study. The primary data was collected between the first week of October andthird week of November 2014, spanning over 45 days. In each of these four islands, around ten days were fixed for data collection. During the study, the number of boat owners/ fishers was fixed as at least 30 in each island. Likewise, 63, 41, 54 and 46 fishers who were predominantly boat owners from Agatti, Androth, Minicoy and Kavaratti respectively were interviewed for the purpose of performing constraint analysis.To identify the constraints in tuna fishery and suggest suitable measures for improvement, Rank Based Quotient (RBQ) was used to quantify the data collected by preferential ranking technique for ranking the parameters (Sabarathnam and Vennila, 1996).

$$RBQ_j \sum_{i=1}^{r} \frac{fi\ (n+1-i)}{(N)} *100$$

Where,

f_i= Number of fishers reporting a particular constraint under i^{th} rank

N = Total number of fishers

n = Number of constraints identified

r = Number of ranks

i = i^{th}rank (i= 1,2,…,r)

j = j^{th} constraint (j= 1,2,…,n)

RESULTS AND DISCUSSION

Constraints faced by respondents from the four islands of Lakshadweep including Kavaratti, Agatti, Minicoy and Androth, were divided into three core constraints each having a different set of parameters by giving equal weightage based on severity of the observed constraints.The rationale for collecting such data was to delineate the constraints faced by the respondents that hamper the productivity and suggest possible policy interventions. The five point scales was adopted while calculating RBQ for each set of parameters and were ranked on the basis of their RBQ score. RBQ scores are presented in table (Tables 1, 2 and 3).

Production constraints: In relation to production constraints, majority of the respondents from all the islands reported escalating fuel cost as the major constraint followed by high cost of other inputs. Intrusion of foreign vessel was reported as the third major constraint in Kavaratti, Agatti and Androth while the same was ranked sixth for Minicoy. The uncertainty of good volume of catch was reported as the fourth major constraint for three islands namely Kavaratti, Agatti and Androth while the same was ranked third for Minicoy. Although lack of skilled man power was reported as the least constraint for Agatti (13^{th}), Androth (13^{th}) and Kavaratti (12^{th}) the same was reported as the major constraints for Minicoy (4^{th}). Stringent terms and conditions for leasing a boat were ranked least by all the respondents from all the islands.

In general, escalating fuel costs remains major constraint (RBQ: 98.32) faced by the respondents among all the islands under study. Rise in the price of diesel from Rs.30 in 2006 to Rs.61 in 2014 is observed. This throws light on the escalating fuel cost which interferes with the small scale fishing activity of the island. Despite fishery being allied sector of Agriculture, there is hardly any subsidy provided for fuel by the Government. Fuel being the major and costly operating input for fishing, which forms a obvious major constraint. It was followed by high inputcost like bait net, bait hold, mechanical spraying device and food expenses together forming the second major constraint (RBQ: 93.52).

Table 1. Production constraints for tuna fishery in Lakshadweep

Islands	Lakshadweep		Kavaratti		Agatti		Minicoy		Androth	
Constraints	RBQ	Rank	RBQ	Rank	RBQ	Rank	RBQ	Rank	RBQ	Rank
Escalating fuel cost	98.32	1	99.22	1	99.43	1	96.3	1	98.26	1
High inputcost	93.52	2	94.88	2	96.49	2	87.83	2	94.95	2
Uncertainty about good volume of catch	89.18	3	90.84	4	90.59	4	86.11	3	89.2	4
Intrusion of foreign vessel	89.18	3	91.77	3	92.63	3	82.67	6	89.55	3
Lack of meteorological information	86.38	4	87.27	5	88.89	5	82.14	7	87.11	5
Weather disturbances	84.31	5	82.45	10	86.62	6	81.35	8	86.76	6
Lack of mechanization	84.24	6	84.78	7	84.47	9	84.39	5	83.1	9
Poor economic condition	83.09	7	81.99	11	85.03	8	79.76	9	85.71	7
Poor quality management of catch	82.91	8	85.56	6	85.15	7	76.72	10	84.67	8
Lack of skilled manpower	81.65	9	81.21	12	79.59	13	85.05	4	80.84	13
Timely availability of credit	80.57	10	83.23	8	82.31	12	75.26	12	81.88	11
Non-availability of credit	80.46	11	82.61	9	82.43	11	75.4	11	81.71	12
Small size fishing	80.29	12	81.06	13	83.9	10	73.94	13	82.23	10
Stringent terms and conditions for leasing a boat	71.81	13	71.43	14	71.54	14	72.75	14	71.43	14

The third major constraint was observed for uncertainty about good volume of catch (RBQ: 89.18). It is attributed to the behavioral biology of the tuna species which is mostly migratory in nature which add uncertainty to the landed volume of catch that brings about uncertainty to the landed volume of catch. The catch of small size fishes during fishing were reported as the second least constraint as 90 % catch of tuna leads to the production of *masmin* (smoked and dried product).

In view of ever increasing price of fuel and small scale nature of fisheries of these islands, a government support in the form of subsidized fuel and government fuel outlays matching the fuel demand of fisheries could possibly effectively tackle escalating fuel cost, a major constraint. Continuous upgradation and replacement of old engines with more efficient new models would also prevent fuel cost from becoming a major constraint. Government outlays or fisheries department providing other inputs like bait net and tank at reasonable price which is currently purchased from main land could reduce the impact of high cost of input which is second major constraint in production. Continuous monitoring of meteorological data along with its relationship with fish stock abundance, resource mapping and fisheries advisory services like Potential fishing zone (PFZ) could help us to reduce the uncertainty associated with fish catches. Strengthening of monitoring control and surveillance (MCS) system along the chain of islands would rectify the issue of intrusion of foreign vessels.

Marketing constraints: Majority of respondents ranked lack of cold storage facilities (RBQ: 94.61) as major constraint from all the sampled islands of Lakshadweep. It was followed by poor marketing facilities (RBQ: 88.28) as the second major constraint in Kavaratti and Minicoy while the same was reported as the third major constraint for Agatti and Androth. The third major constraint in Kavaratti was observed for lack of supply chain facilities and low demand in local market was reported as fourth marketing constraints in Kavaratti, Agatti and Androth while the same was observed as the third major constraint for Minicoy. Distress sale to the owner and lack of avenue for self marketing was reported as the least favoured marketing constraint.

As a whole, lack of cold storage facilities (95%) was analysed as the major marketing constraint after taking into account the constraints faced by the respondents from all the sampled islands of Lakshadweep. Poor marketing facilities was also observed as one of the major constraints (second) followed by lack of supply chain facilities (third) and inability to sell major portion of landing in local market (fourth). Distress sale to owners and lack of avenue for self marketing were analysed as the least major constraints after taking into consideration the favoured constraint reported by the respondents from all the sampled islands.

Though in recent years several cold storage facilities came into existence, the numbers are still far less than the required number. There is a need to establish more number of these facilities in different island to support the emerging tuna fisheries in Lakshadweep. Establishment of retail and wholesale outlets for local fish marketing will strengthen and develop organized local fish marketing system in these islands. Inability to sell the bulk of catch as fresh fish in local market has led to its conversion into economically less favorable *masmin*. Lack of well-developed supply chain facilities is the major hurdle in diverting bulk production to mainland markets. A network of cold chain and adequate numbers of fish transport vessel is prerequisite for a successful supply chain system channeling surplus catch to the main land having better price realization.

Policy constraints: The lack of co-operation and support of fisheries officers was reported as the major constraint by all the islanders under study. With regard to the second major

Table 2. Marketing constraints for tuna fishery in Lakshadweep

Islands	Lakshadweep		Kavaratti		Agatti		Minicoy		Androth	
Constraints	RBQ	Rank	RBQ	Rank	RBQ	Rank	RBQ	Rank	RBQ	Rank
Lack of cold storage facilities	94.61	1	95.87	1	96.51	1	91.11	1	94.88	1
Poor marketing facilities	88.28	2	88.26	2	90.32	3	87.78	2	85.85	3
Lack of supply chain facilities	85.88	3	81.3	3	90.63	2	83.15	4	87.32	2
Inability to sell major portion of landing in local market	83.68	4	80.22	4	86.35	4	83.52	3	83.66	4
Non-remunerative price	75.29	5	71.96	5	82.7	5	67.22	7	78.29	5
Limited Market intelligence (actual price range of fish)	72.01	6	68.48	6	74.76	6	70.37	5	73.9	6
Predominance of intermediaries	65.69	7	64.35	7	62.86	7	70.19	6	65.61	7
Species preference by auctioneer	61.91	8	61.74	9	62.22	8	61.48	9	62.2	8
Distress sale to the owner	61.52	9	60.22	10	61.11	10	62.96	8	61.71	9
Lack of avenue for self-marketing	61.08	10	62.17	8	61.43	9	60.19	10	60.49	10

Table 3. Constraints in government policies for tuna fishery in Lakshadweep

Islands	Lakshadweep		Kavaratti		Agatti		Minicoy		Androth	
Constraints	RBQ	Rank	RBQ	Rank	RBQ	Rank	RBQ	Rank	RBQ	Rank
Lack of cooperation/support from fisheries officers	97.64	1	97.23	1	97.3	1	98.65	1	96.9	1
Lack of infrastructure for landing	94.07	2	96.84	2	94.29	3	91.92	6	92.68	4
Lack of marketing infrastructure	93.18	3	92.89	4	93.49	4	92.59	5	92.9	3
[1]Poor transportation facility	93.14	4	89.33	7	94.92	2	93.43	4	93.57	2
[2]Lack of government control and involvement in fish marketing	92.07	5	93.48	3	90.48	6	93.77	3	89.36	6
Lack of guidance and support from government	91.67	6	90.12	6	92.22	5	91.08	7	92.24	5
Lack of alternative livelihood during ban season	90.86	7	92.09	5	87.62	7	94.11	2	88.47	7
Non-awareness of governmental schemes	82.17	8	76.88	9	84.13	9	80.81	8	84.7	8
Lack of trade promotion	80.12	9	79.45	8	85.24	8	70.2	9	84.04	9
Lack of Public investment	75.94	10	73.52	11	77.94	10	69.7	10	80.71	10
Exorbitant licensing cost of craft and gear	70.63	11	76.09	10	64.6	11	70.2	9	69.4	11

[1] Poor transportation facility is in terms of connectivity between island and mainland
[2] Government control to avoid conflict between fishery from different islands and active involvement in fish marketing (like minimum support price to avoid distress sale)

constraint faced by the islanders, the results were quite intriguing. Poor transportation facility was reported as the second major constraint in Agatti and Androth attributed to the inefficacy in marketing of fresh tuna at nominal prices resulting in the alternative approach of producing *masmin* which has lower returns in comparison to sale of fresh tuna, while lack of infrastructure for landing was reported as the second major constraint in Kavaratti. Lack of public investment and exorbitant licensing of craft and gear were analyzed as least constraints in all the islands.

Involvement of fishers in local level fisheries policy framing by fisheries department officials and regular interaction among fishers and officials could bridge the gap between them which will smoothen the functioning of fisheries. Development of infrastructural facilities related to fish landing, marketing and transportation will help the sector. Active involvement of government in fish marketing through measures like minimum support price system and government owned fish transport vessels to avoid distress selling and stabilize the price are among the possible steps which could strengthen the fishery and allied sectors in these islands.

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Received 18 April, 2016; Accepted 12 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 793-796

Manuscript Number: 2379
NAAS Rating: 4.47

Indian Seafood Export: Trends, Forecast and Market Stability Analysis

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Abstract: In India, the seafood export gradually increased from a mere earning of Rs. 3.98 crores in 1961-62 to Rs. 30213.26 crores in 2013-14 and in terms of quantity the export increased from mere 15732 tonnes to staggering 9.83 lakh tonnes in the same period. Three-year moving average for export and production shows increasing trend with a correlation coefficient of 0.87 between them. Lowest CGR was observed for the decade 1981-1990 (2.50% for quantity and 4.76% for value) whereas for the rest of the decades the figures were higher than 3.0 % for quantity and 5.0% for value. Using Markov chain approachit was observed that Japan was the most stable market among the major importers of Indian Seafood as reflected by the probability of retention at 86.36 % and the most unstable markets was the Middle East with the 40 % retention.The forecast for the marine product export for 2020 was found to be 13.82 lakh tonnes using Holt method.

Key Words: Compound growth rate (CGR), Holt method, Markov chain approach, Seafood export

India's exports of marine products had its beginning as early as 1938-39. The exports included dried, salted or smoked fish, aquatic animal oils, fish meal& fertilizers and miscellaneous marine animals and plant products. Most of the dried fish were exported to East Asian countries such as Hong Kong, Singapore, Myanmar (Burma) and Sri Lanka (TNAU, 2015). The landmark in Indian Seafood export was created when the first shipment of 13 tonnes frozen shrimp (worth Rs. 70,000) was sent to the United States in 1953 from Cochin (SEAI, 2015). There was a significant drop in the quantity exported by 1960-61 but with a higher value. The drop was for the reason that canned shrimp exports came down owing to the prohibitive cost of cans. From then onwards there was a steady growth (TNAU, 2015). The important factors which has contributed to the expansion of foreign seafood trade are favorable price offers in foreign market for frozen shrimp and lobster, increase in fishing effort by introduction of deep sea fishing vessels (charter policies), rise in USD price in international market which meant more rupees realization per US dollar, emphasis of government on export promotion and massive centrally sponsored schemes to provide infrastructure at fishing harbors and landing centers to improve fresh fish handling and provide sanitation and other assistance required for quality processing of fisheries produce. Indian seafood industry has undergone several changes over the years in terms of quantity exported, the composition of item exported and even destination of export. Hence, a deeper insight in seafood export trends, dynamics and market shifts is required to predict the future prospects of the sector. The current study, based on secondary information, was an attempt to explore the seafood export industry of India.

MATERIAL AND METHODS

The current study is based on time series data on quantity and value of marine products exports from India obtained from secondary sources (DAHDF, 2013-14; Sathiadhas *et al*., 2012). Double Exponential Smoothing (Holt) method has been employed to allow for forecasting non-seasonal time series data of seafood exports with trends. The forecast for Holt's linear exponential smoothing is found by having two equations to deal with – One for level and one for trend. The forecast is found using two smoothing constants, and (with values between 0 and 1), and three equations:

Level: $l_t = \acute{a}\, y_t + (1-\acute{a})(l_{t-1} + b_{t-1})$,

Trend: $b_t = \hat{a}(l_t - l_{t-1}) + (1-\hat{a}) b_{t-1}$,

Forecast: $y_t(h) = l_t + b_t h$.

Here l_t denotes the level of the series at time t and b_t denotes the trend (additive) of the series at time t. The optimal combination of smoothing parameters and should be chosen by minimizing the MSE over observations of the model data set.

The decadal compound growth rate was calculated to ascertain the growth in exports of marine products from Indiawhich was estimated by following method used by Prajneshu and Chandran (Prajneshu and Chandran, 2005). If yt is the study variable at time period t, then the mathematical expression employed for computation of compound growth rate (CGR) r is conventionally given by

$y_t = y_0 (1 + r)^t$

In general, after a multiplicative error å is assumed in the above equation, logarithmic transformation is done throughout to make it a linear statistical model. That is,

$\log y_t = \log y_0 + t \log(1+r) + \log$?

The above model can be rewritten as

$\text{Log} y_t = A + B\ t +$?'

Where,

$A = \log y_0$; $B = \log(1 + r)$ and ?' = log ?

Then the unknown parameter constants A and B are estimated by the method of ordinary least squares. Thus, once B is estimated, the CGR r is given by

$r = \exp(B) - 1$

Markov chain approach was used to get insight into structural change and change in the direction of seafood export of India. Annual export data for period 1991-92 to 2013-14 were used to analyze the direction of trade and changing pattern of Indian marine products exports. In the present study, the dynamism of seafood export trade in terms of gains and losses in import quantity of Indian marine products by the major importing countries was examined using the Markov chain model employed by Kusuma and Basavaraja (2014).

RESULTS AND DISCUSSION

In terms of quantity, the Indian seafood export increased from 15732 tonnes in 1961-62 to 3.43 lakh tonnes in 1999-2000 and the figure crossed 9.83 lakh tonnes in the year 2013-14. A similar rise in the value of seafood export was also evident with earnings rising from Rs. 3.98 crores in 1961-62 to Rs. 5116.67 crores in 1999-2000. The year of 2009-10 saw a landmark in seafood export with the value of export crossing Rs. 10000 crores. The export value reached a staggering figure of 30123.26 crores by the year 2013-14 (DAHDF, 2013-14).

Marine fish production has seen a rapid increase from 1988-89 to 2013-14. A relatively steeper increase in the quantity of seafood export was observed during 1989-90 to 1997-98 and from 2007-08 till now. A slower growth rate in export was realized from 1999-2000 to 2006-07 (Fig.1). An apparent overlap between the phases of steep increase in production and export was observed which can be further emphasized by the high correlation coefficient of 0.87 between marine fish production and quantity exported. The value of seafood export depends on the composition of the export basket from India. Though countries like Japan, USA and EU have lesser share in the quantity of exported Indian Seafood, they accounted for a major share in the earned foreign exchange because of shrimp exports. From 1991 till 2001, Japan was the major source of foreign currency earnings for Indiathrough seafood export. In the year 2002 and 2003, USA out-figured Japan in percentage value share (Table 1) owing to decline in quantity exported to Japan and decreased per unit price realization of Indian seafood in Japan. On the other hand, both higher unit price and an increase in quantity exported to USA have made it a leading Indian seafood importer in value. The share of shrimp, which command higher price in an export basket to USA, has recorded increase both in terms of total quantity and unit price during 2002-2003 (Raghuram and Asopa, 2008). From 2004-05 till 2008-09, EU was the major market for Indian seafood in value terms (Table 1).

The shift from USA to EU could possibly be due to prevailing deterrent in the form of an anti-dumping duty imposed by USA along with the deposit (10% value of export) which USA government can hold up to three years (Sathiadhas *et al*., 2012). Since 2009, S.E. Asian countries (including China) are leading importers of Indian seafood in value because of relaxed sanitary standards prevailing in these countries which attract huge seafood export from India.

Table 1. Shift in value share (%) of seafood export (to the total seafood exports) from India

Years	Japan	USA	E.U	S.E Asia including China	Middle east	Others
1991-92	47.92	11.86	27.18	8.50	1.93	2.60
1992-93	44.43	10.49	29.87	10.14	2.70	2.36
1993-94	45.47	11.95	27.56	10.71	1.37	2.93
1994-95	46.49	13.70	21.17	15.86	1.31	1.47
1995-96	46.6	10.28	25.21	13.72	2.54	1.65
1996-97	46.73	19.25	10.88	1.53	19.22	2.39
1997-98	48.52	11.17	12.41	2.12	23.97	1.81
1998-99	50.42	12.91	12.90	3.87	17.48	2.41
1999-00	45.8	17.40	14.23	2.14	17.97	2.45
2000-01	41.03	15.71	18.34	2.68	19.22	3.02
2001-02	35.13	22.62	18.44	19.96	3.42	0.43
2002-03	22.79	28.78	20.48	20.90	2.98	4.09
2003-04	19.26	27.01	24.35	20.23	3.34	5.82
2004-05	18.09	23.41	27.37	19.89	3.68	7.56
2005-04	15.96	22.62	29.46	19.81	4.25	7.91
2006-07	16.19	16.11	33.00	21.21	4.44	9.05
2007-08	16.11	13.34	34.96	20.78	5.17	9.64
2008-09	14.34	11.87	32.53	25.20	5.53	10.54
2009-10	12.83	10.08	29.99	32.55	5.51	9.05
2010-11	13.05	15.43	26.81	31.72	5.19	7.80
2011-12	12.90	17.94	22.96	32.85	5.39	7.96
2012-13	10.60	21.35	22.15	30.77	5.90	9.22
2013-14	8.15	25.63	20.29	32.48	5.29	8.15

Thus higher contribution in value terms is directly related to enormous quantity exported to these countries. From 1996 till 2000, Middle East countries were among the major importers of Indian seafood in quantity (Table 2). The major factor determining the diversion of seafood exports towards S.E Asia and the Middle East was less strict quality standards in these countries compared to USA and EU (Sathiadhas *et al*., 2012).

Table 2. Shift in quantity share (%) of seafood export (to the total seafood exports) from India

Years	Japan	USA	E.U	S.E Asia including China	Middle east	Others
1991-92	24.62	12.85	31.88	23.25	4.03	3.38
1992-93	20.01	9.77	32.34	29.16	3.91	4.82
1993-94	18.16	10.47	31.19	32.13	3.14	4.91
1994-95	17.94	10.95	24.88	41.20	2.65	2.37
1995-96	17.23	8.56	28.10	39.86	3.44	2.81
1996-97	18.29	20.42	8.30	2.53	46.68	3.77
1997-98	18.03	11.34	8.23	3.27	56.30	2.83
1998-99	20.91	14.98	11.35	6.24	42.53	3.98
1999-00	19.93	19.22	10.45	3.92	42.83	3.65
2000-01	16.88	15.78	10.07	3.86	49.45	3.96
2001-02	16.10	10.79	19.86	43.74	4.64	4.87
2002-03	11.34	12.64	23.16	41.37	4.58	4.46
2003-04	12.14	12.90	23.37	42.33	3.57	5.69
2004-05	12.54	10.85	25.52	40.90	3.60	6.59
2005-04	11.67	10.90	26.72	38.51	4.35	7.86
2006-07	11.01	7.14	24.45	44.26	3.85	9.29
2007-08	12.44	6.76	27.58	37.59	4.75	10.89
2008-09	9.50	6.12	25.15	39.19	4.51	15.54
2009-10	9.24	4.93	24.29	43.28	5.15	13.11
2010-11	8.70	6.16	21.03	48.35	5.41	10.36
2011-12	9.95	7.93	17.89	49.71	4.43	10.09
2012-13	8.26	9.96	17.06	46.19	4.46	14.07
2013-14	7.27	11.27	17.76	46.34	5.90	11.47

Computed decadal compound growth rate (CGR) for seafood export quantity reveals a maximum growth during 1961-1970, whereas, the least was recorded during 1981-1990. An increase in CGR (quantity) from 1981-1990 to 1991-2000 could be attributed to the rapid increase in frozen fish export from India owing to the increased marine fish production and emerging seafood export facility in the country. The speedy motorization of traditional fishing crafts during the 1980s was instrumental in augmenting marine fish production during late 1980s and early 1990s (Srinivas Gopal and Leela, 2013). A CGR maxima and minima for seafood export value were recorded for 1961-1970 (12.63%) and 1981-1990 (4.76%) respectively (Table 3). A significantly higher CGR for export value has been registered for 1991-2000 when compared to previous and later decades that could be attributed to higher per unit price realization of exported shrimps.

Table 3. Compound growth rate of seafood export quantity and value

Decade (PR)	Quantity (CGR %)	Value (CGR %)
1960-2014	3.59	7.20
1961-1970	4.53	12.63
1971-1980	4.25	9.10
1981-1990	2.50	4.76
1991-2000	3.73	6.90
2001-2014	3.24	5.29

Using annual seafood export (quantity) data from 1960-61 to 2013-14 as input in the employed model, a forecast for the marine product export is done using Holt method for 2020, which is estimated to be 13.82 lakh tonnes (Fig. 2). The projected seafood export shows increasing trend which is a positive sign for our growing seafood export industry.

Transitional probability matrix using Markov chain approach (Table 4) shows the dynamic changes in the seafood markets of India. The matrix indicates the changes in the direction of seafood export traffic for 1991-91 to 2013-14. The row elements in the matrix indicate the loss in trade of

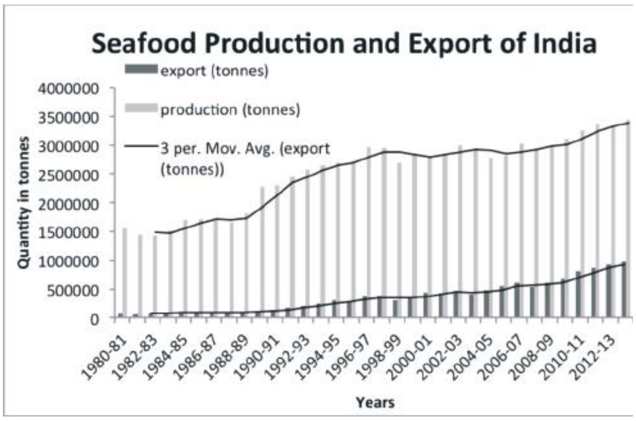

Fig. 1. Indian seafood production and export trend from 1960-61 to 2013-14

Fig. 2. Indian Seafood export (Quantity) forecast using Holt method

Table 4. Transitional Probability Matrix of Markov Chain approach for Indian Sea food Export (1991-92 to 2013-14)

Country	Japan	USA	EU	SE Asia including China	ME	Others
Japan	0.8636	0.0455	0.0000	0.0000	0.0000	0.0909
USA	0.0526	0.7368	0.1579	0.0526	0.0000	0.0000
EU	0.0000	0.2000	0.6400	0.1600	0.0000	0.0000
SE Asia including China	0.0000	0.0909	0.1364	0.6364	0.1364	0.0000
ME	0.0400	0.0000	0.0000	0.1200	0.4000	0.4400
Others	0.0526	0.0000	0.0000	0.0000	0.4737	0.4737

importing countries to other competing nations whereas the column elements represent the probability of gain in trade. The diagonal elements of the matrix represent the probability of retention of the quantity traded by the respective countries. It is evident from the matrix that Japan was the most stable market for Indian seafood with a retention probability of 86.36%. Middle East countries were found to be the least stable market with only 40% retention probability while USA and EU were found to have retained of 73% and 64% of Indian Seafood export.

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Received 12 March, 2016; Accepted 15 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 797-801

Manuscript Number: 2380
NAAS Rating: 4.47

Women Awareness and Their Perception Towards Environmental Degradation

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Abstract: This study was conducted to create awareness among women towards environment degradationand their perception finding causes towards envornmental degradatio. The study was undertaken in two districts of Haryana state namely, Hisar, Kaithal, and a total no. of one hundred twenty working people (women) were selected and interviewed with the help of well-structured schedule. The study revealed that majority of the women were of middle age group (36-50 years), educated up to higher education, belonged to nuclear family with 4 members, performed government, private jobs and self employment.The findings further revealed that women awareness towards environment degradation (86.66%) and about types of pollution (48.33%) were found fully aware about the environment degradationand . The study also shows that major causes of environment degradation were bursting of crackers and burning of garbage in open, exhaustive pumping up of ground water for irrigation (2.91), high use of synthetic fertilizers/chemicals (2.90), waste disposal (2.88), industrial activities (2.60) and automobiles (2.51) with their weighted mean scores.

Key Words: Awareness, Climate Change, Causes, Healthy environment, Women empowerment

In rural areas, a woman's life is very dependent on nature, as she has to carry on her family through managing and using natural resources. Women are primary providers of household food, fuel and water for cooking, heating, drinking and washing. As users, women have direct contact with the natural environment as they collect essential items like fruits, vegetables, medicinal herbs, fuel wood, fodder, water etc. for their every day needs and women are responsible for collecting water and for controlling its use. Mostly rural families depend on nature for their livelihood and women are the key persons in using, managing and protecting the natural resources hence, there is a close linkage between women and natural environment.

The mean gain in knowledge was highest in rural sanitation followed by green leafy vegetables, biodiversity, control in household pests, rain water harvesting, recycle, reuse plastic, increase in global warming, Indoor air pollution and water borne diseases (Gouri *et al.* 2014). As a farmer woman they produce foods and agricultural products. Their tasks in agriculture and animal husbandry as well as in the household make them daily managers of the living environment. Women, particularly, rural and indigenous women play a major role in managing natural resources - soil, water, forests and energy- as they have profound knowledge of the plants, animals and ecological processes around them. The present study was undertaken to assess their awareness and analyzing their perception responsible for the environment degradation.

MATERIAL AND METHODS

The present study was conducted in Haryana state and two districts Hisar and Kaithal were selected, purposively. From each district, three blocks were selected randomly. Further, two villages were selected from each block making 12 villages. From each village, ten women were selected randomly, making a total sample of 120 women. Hence, one hundred twenty women were interviewed for the study about the awareness and causes of environment degradation from agriculture and public sector. For assessing the objectives of the study the data was collected by conducting personal interview with the respondent at their home/working center. The interview of every individual was taken separately so that the others did not influence the answers. The information collected through the responses of the respondents, were suitably coded, tabulated and analyzed to draw meaningful inferences by using statistical tools such as frequency distribution, percentages, weighted mean scores and rank order.

RESULTS AND DISCUSSION

Awareness towards environment degradation: It was observed from the Table 1 that majority of the women (95.83%) had awareness about the environment degradation and air pollution (90.83%).

The level of awareness among hill women about health information was negligible with regard to indoor air pollution in Bhaluti village of Nainital district of Uttrakhand (Yadav and Bhardwaj, 2010). Majority of the respondents about soil and water pollution were fully aware (88.33%). Similar trend was observed about the environment degradation.

It was observed that 48.33 per cent were fully aware whereas, 35.0 per cent were aware and 16.66 per cent of the respondents were not aware about types of environment degradation by air, water, soil and noise pollution.

All respondent were fully aware about 'dust in air'. Majority of the women were fully aware about 'Congested areas, slum', 'Poor ventilation inside the house', 'Large amount of straw burning' and 'Road transportation'. It was observed that about 2/3 of the total respondent were fully aware about 'Electricity generation'.

The study revealed that much awareness on plastic and plastic related products is being made, yet the uses of plastic bags are increasing day by day (Rangarajan, 2011).

In the Table 2, it was found that 48.33 per cent, 45.83 per cent and 32.50 per cent women were fully aware about combustion of coil gases, oil, etc., and decomposition of organic matter and burning of firewood and biomass, respectively. It was revealed from the study that 49.16 per cent women were not aware about green house effect. The study found that more and more Indians are becoming aware of the hazards of drinking impure water and the demand for effective water purifiers is growing rapidly (Nazia and Santosh, 2012).

It was found from Table 3 that majority of the respondents (> 80 per cent) were fully aware and below 20 per cent respondents were aware about fertilizers and pesticides residual leaching, improper sewage disposal, human and animal wastes, immersion of ashes of dead and immersion of god's idols in water.

It was found that majority of the respondents 66.66 per cent were fully aware, 'Chemicals, industrial effluents percolation', 32.50 per cent and 33.33 per cent were fully aware about leaching of minerals from rocks and decaying of organic matter, respectively.

It is clear from Table 4 that 100 per cent of the women were fully aware about the climate change from the information resources' and 'Losses of biodiversity'. It was depicted that about 90-92 per cent and 5-10 respondents were fully aware and aware about deforestation /cleaning of forest, soil wastes like plastics, clothes, glass, metal, throwing of garbage in open and pattern of weather is generally changing.

The study reveals that 87.5 per cent were fully aware, 12.5 per cent of the respondents were aware while, there was not even a single respondent who was not aware

Table 1. Women's awareness towards environment degradation (n=120)

Statements	Awareness level*			WMS
	Fully aware	Aware	Not aware	
Do you know how pollution affects your health?	115 (95.83)	5 (4.16)	-	2.95
Do you know air pollution?	109 (90.83)	11 (09.16)	-	2.90
Soil pollution	106 (88.33)	14 (11.66)	-	2.88
Water pollution	106 (88.33)	14 (11.66)	-	2.88
Do you know about environment degradation?	104 (86.66)	16 (13.33)	-	2.86
Types of environment degradation	58 (48.33)	42 (35.00)	20(16.66)	2.31

*Figures in parentheses in column 3 indicate percentages; column 4 indicate weighted mean scores

Table 2. Women's awareness about air pollution

Statements	Awareness level*			WMS
	Fully aware (%)	Aware (%)	Not aware (%)	
Dust in air	120(100)	--	-	3.00
Congested areas, slums	107(89.16)	13(10.83)	-	2.89
Poor ventilation inside the house	105(87.50)	15(12.50)	-	2.87
Large amount of straw burning	97(80.83)	21(17.50)	2(1.66)	2.79
Road transportation	87(72.50)	30(25.00)	3(2.50)	2.70
Electricity generation	79(65.83)	39(32.50)	2(1.66)	2.64
Decomposition of organic matter	55(45.83)	32(26.66)	33(27.50)	2.18
Combustion of coal gases, oil etc.	58(48.33)	27(22.50)	35(29.16)	2.19
Burning of firewood and biomass	39(32.50)	38(31.66)	43(35.83)	1.96
Green house gases effect	31(25.83)	30(25.00)	59(49.16)	1.76

*Figures in parentheses in column 3 indicate percentages; column 4 indicate weighted mean scores about 'sewage, sewage sludge, building debris, generated from household'.

The study found that range between 77.50-87.5 per cent and 8.66-20 per cent respondents were fully aware and aware about sewage, fertilizers and pesticides residue acid rain and dry deposition of pollutants, polluted water polluted soil and majority of world population suffering from water and air borne diseases, respectively.

The study reveals that 42.5 per cent and 54.16 per cent were fully aware and 60.83 per cent and 45.83 per cent respondent were aware about fly ash, iron and steel slag and medical and industrial waste disposed off, respectively. It was depicted that 95 per cent of respondents were not aware about any meeting/workshop/training regarding environment degradation.

Causes of environment degradation: This study found that the factors causing fuel wood demand in urban areas include, rural-urban migration, urbanization, poverty, hikes in prices of kerosene and cooking gas amongst others **(**Babanyara and Saleh, 2010). The data from the Table 5 revealed that highest mean scores for environmental degradation was found similar and highest in air pollution, water pollution and cutting forest (2.96) followed by soil pollution and noise pollution. It was depicted that similar and highest mean score (2.91) for air pollution due to bursting of crackers and garbage in open whereas, mean scores 2.85, 2.80 and 2.77 were recorded for pesticide, insecticides used in agricultural operations, air conditionings and tobacco smoking etc., respectively.

The data also revealed that the cause 'Construction

Table 3. Women's awareness about water pollution

Statements	Awareness level*			WMS
	Fully aware (%)	Aware (%)	Not aware (%)	
Fertilizers and pesticides residual leaching	103(85.83)	17(14.16)	-	2.85
Improper sewage disposal	103(85.83)	17(14.16)	-	2.85
Human and animals wastes	101(84.16)	19(15.83)	-	2.84
Bathing, washing clothes, excreting in water	100(83.33)	20(16.66)	-	2.83
Immersion of ashes of dead	97(80.83)	23(19.16)	-	2.81
Immersion of god's idols in water	100(83.33)	16(13.33)	4(3.33)	2.80
Chemicals, industrial effluents percolation	80(66.66)	40(33.33)	-	2.66
Leaching of minerals from rocks	39(32.50)	49(40.83)	32(26.66)	2.05
Decaying of organic matter	40(33.33)	42(35.00)	38(31.66)	2.01

*Figures in parentheses in column 3 indicate percentages; column 4 indicate weighted mean scores

Table 4. Women's Awareness about soil pollution

Statements	Awareness level*			WMS
	Fully aware (%)	Aware (%)	Not aware (%)	
Have you heard about climate change from the information resources	120 (100)	00 (0.00)	-	3.00
Losses of biodiversity	120 (100)	00 (0.00)	-	3.00
Deforestation/cleaning of forest	111 (92.50)	9 (7.50)	-	2.95
Solid waste like plastics, cloth, glass, metal	108 (90.0)	12 (10.00)	-	2.90
Throwing of garbage in open	109 (90.83)	11 (9.16)	-	2.90
Pattern of weather is generally changing	110 (91.64)	6 (5.00)	4(3.33)	2.88
Sewage, sewage sludge, building debris, generated from households	105 (87.50)	15 (12.50)	-	2.87
Fertilizers and pesticides residues	102 (85.00)	18 (15.00)	-	2.85
Acid rain and dry deposition of pollutants	104 (86.66)	10 (8.66)	6 5.00)	2.81
Polluted water pollutes soil.	99 (82.5)	15 (12.50)	6 (5.00)	2.77
Majority of world population suffering from water, air borne diseases	93 (77.50)	24 (20.00)	3 (2.50)	2.75
Fly ash, iron and steel slag	51 (42.50)	73 (60.83	6 (5.00)	2.54
Medical and industrial wastes disposed-off	65 (54.16)	55 (45.83)	-	2.54
Have you attended any meeting/workshop/training regarding environment degradation?	6 (5.00)	00 (0.00)	114 (95.00)	1.00

*Figures in parentheses in column 3 indicate percentages; column 4 indicate weighted mean scores

Table 5. Causes of environment degradation

Causes	Weighted mean	Rank
Environment degradation due to		
Air pollution	2.96	I
Water pollution	2.96	I
Cutting forest	2.96	I
Soil pollution	2.94	II
Noise pollution	2.79	III
Causes of air pollution		
Bursting of crackers	2.91	I
Burning of garbage in open	2.91	I
Pesticides, insecticides uses in agricultural operations	2.85	II
Air conditioning	2.80	III
Tobacco smoke, combustion of solid fuel for cooking and heating	2.77	IV
Construction material, furniture, carpeting and home cleaning agent	2.71	V
Burning of straw in field after harvesting	2.68	VI
Cottage industries, chemicals incidents and spills.	2.58	VII
Accidental fires and forest fires	2.39	VIII
Trade and tariff that gives of dust, fumes, vapour and gases	2.36	IX
Diesel operated tube well/Machines	2.35	X
Threshing operation	2.26	XI
Grain dust of large scale due to harvester, combines	2.26	XI
Natural processes eg. Thunder storm, volcanoes.	2.17	XII
Causes of water pollution		
Exhaustive pumping up of underground water for irrigation	2.91	I
Waste disposal	2.88	II
Hydropower generation	2.82	III
Agricultural chemical residues percolation	2.80	IV
Inadequate sewage systems	2.78	V
Industrial effluents	2.56	VI
Large-scale dams	2.53	VII
Navigation canals cut across the major rivers	2.48	VIII
Intensive irrigation system	2.47	IX
Causes of soil pollution		
High use of synthetic fertilizers/chemicals	2.90	I
Early assimilation/leach down of fertilizers in soil	2.85	II
Acid rain	2.65	III
Large number of industrial chemicals, dyes, acids, etc.	2.59	IV
Soil erosion	2.55	V
Metallic and nuclear wastes also degrade soil	2.50	VI
Fly ash and chemical residues	2.45	VII
Causes of noise pollution		
Industrial activities	2.60	I
Automobiles	2.51	II
Indoor pollution by radio, television	2.46	III
Generators, electric fans, air coolers, air conditioners	2.41	IV
Indiscriminate use of loudspeakers	2.40	V
Rail traffic	2.38	VI
Urbanization and modern civilization	2.22	VII
Use of fire crackers during festivals, marriage and many other occasions	2.13	VIII
Different home appliances, Family Conflict	2.08	IX
Aeroplanes	2.04	X
Unsustainable Activities at market place, religious, social, and cultural functions, sports and political rallies.	1.89	XI
Farm machines, pump sets operation	1.84	XII

(Figures in columns 3 and 4 indicate weighted mean scores and rank order) material, furniture, carpeting and home cleaning agent' was mean score 2.71, 'Burning of straw in field after harvesting' as per mean score 2.68, 'Cottage industries, chemicals incidents and spills.' and 'Accidental fires & forest fires' were causing environment degradation with mean score 2.58 and 2.39, respectively. The data also revealed that minimum mean score (2.17) for causing air pollution was natural processes.

The results indicated that the physical and biological quality of the lake water is greatly degraded due to the sewage water entering in it mostly from the food supplying shops located in the south of the lake and runoff generated from populated area in the north and western boundary of the lake (Khan *et al.,* 2011). It was found that the main causes for water pollution were exhaustive pumping up of underground water for irrigation (2.91), waste disposal (2.88), hydropower generation (2.82) and agro-chemicals residue percolation (2.80).

The data also revealed that water pollution caused by 'Inadequate sewage systems' and Industrial effluents' with mean score 2.78 and 2.56, respectively.

It was revealed from that 'High use of synthetic fertilizers/chemicals' accounted mean score 2.90, 'Early assimilation/leach down of fertilizers in soil' (2.85) was found serious causes of soil pollution. The data also revealed that mean score for 'Soil erosion' was 2.55, 'Metallic and nuclear wastes degrade soil' was having mean score 2.50, 'Fly ash and chemical residues' was their mean score 2.45.

It is apparent from Table that 'Industrial activities' and 'Automobiles' was found serious cause of noise pollution having mean score 2.60 and 2.51, respectively. While 'Indoor pollution by radio and television' mean score 2.46, and 'Generators, electric fans, air coolers, air conditioners' was with mean score 2.41. The data also revealed that noise pollution caused by 'Indiscriminate use of loudspeakers' obtained mean score 2.40, 'Rail traffic', 'Urbanization and modern civilization' and 'Use of fire crackers during festivals, marriage and many other occasions' were counted as major causes. The data also revealed that 'different home appliances, family conflict' caused noise pollution with mean score 2.08.

The data also revealed that 'Aeroplanes', 'Unsustainable Activities at market place, religious, social, and cultural functions, sports and political rallies' was found one of the serious causes regarding environment degradation with mean score 2.04, 1.89, respectively. 'Farm machines, pump sets operation' was found least serious cause with mean score 1.84.

Received 24 April, 2016; Accepted 10 May, 2016

CONCLUSION

The findings revealed that women awareness towards environment degradation and about types of pollution were found fully aware as per women responses. The study shows that women dust in air, loss of biodiversity; fertilizers and pesticides residual leaching were agreed about these statements. Major causes of environment degradation were bursting of crackers and burning of garbage in open, exhaustive pumping up of ground water for irrigation, high use of synthetic fertilizers/chemicals, waste disposal, industrial activities and automobiles with their weighted mean scores.

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 802-805

Manuscript Number: 2381
NAAS Rating: 4.47

Impact of Training on Entrepreneurial Behavior of Dairy Farmers in Punjab

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Abstract: A study was conducted in the Malwa region comprising of Bathinda, Mansa and Muktsar districts of Punjab to study entrepreneurial behavior of dairy farmers. A sample comprising 60 trained dairy farmers who got training from Krishi Vigyan Kendras (KVKs) of study area was selected to study the impact of training. For control 60 dairy farmers not trained under these KVKs were selected. Ex post facto research design was employed to determine impact. The entrepreneurial index was calculated to see the extent of entrepreneurial level of the trained and control group dairy farmers. The analysis revealed that the entrepreneurial behaviour index (EBI) was maximum in achievement motivation in the farmers of both categories. The overall EBI of the trained and control dairy farmers was found to be 73.35 and 54.67 respectively. The comparative analysis indicated that there was significant difference in the entrepreneurial behaviour level at 0.01 level of probability of trained and untrained dairy farmers.

***Key Words*:** Entrepreneurial behaviour, Entrepreneurial index, Trained and untrained dairy farmers

The entrepreneurs can play an important role in increasing agricultural production and in turn contribute for economic development of the country (Pandeti, 2005). In the present context, entrepreneurial competencies are becoming increasingly important for farmers due to external and internal changes. The concept of competencies can provide insights into the entrepreneurial behaviour of farmers, and gives a means to evaluate an intervention programme aimed at developing entrepreneurial competencies. According to Amarnath and Samvel (2008) the emergence of entrepreneurs in a society depends upon closely interlinked social, religious, cultural, psychological and economic factors. The development of entrepreneurship ensures optimal utilization of resources and facilities and value addition to product and services. Thus, the dairy farming has become a commercial enterprise and it is a boon to many families to improve their economic condition (Gautam *et al.,* 2007). Thus, entrepreneurship development as an approach does not confine itself in setting up enterprises but surpasses this limit in creating conducive climate for optimum utilization of limited and scattered resources and making people functional in all walks of life (Mishra, 2005). Training in entrepreneurship provides an impetus to the potential and budding entrepreneurs to acquire a new identity. This is an approach towards transforming people for making people aware about their own identity, help them accept a new identity and finally establish such identity for entrepreneurial pursuit (Mishra, 2005). The development of entrepreneurship is crucial in harnessing vast untapped human resources of a country like India and this also hold true in the field of dairy where available potential is still to be realized. Today when there is growing concern for greater attention to our rural economy, the dairy sector offers big opportunity to transform our economy by bringing prosperity to the rural sector. The supporting income from animal husbandry and dairying is farmer's cash insurance against any distress caused by the crop failures (Sah *et al.,* 2005). Entrepreneurship and dairy enterprise is a suitable combination for economic amelioration and developing human resources to meet challenges of present scenario. To ascertain the impact of trainings conducted by three KVKs on entrepreneurial behavior of dairy farmers of Punjab a study was conducted in Bathinda, Mansa and Muktsar districts of Punjab.

MATERIAL AND METHODS

The study was conducted in three districts namely Bathinda, Muktsar and Mansa of Malwa region of Punjab state. Considering the adaptability of the design, *ex post facto* design was chosen as the phenomenon had already occurred. A list of farmers who acquired specialized training on dairy farming from the Krishi Vigyan Kendras (KVKs) from three selected district from 2011-2013 was procured. Out of the list procured from KVKs, which had 220, 180 and 175 dairy farmers who acquired training from Bathinda, Muktsar and Mansa KVKs respectively, 20 trained farmers were selected randomly from each KVK. An equal matching sample of 20 control dairy farmers from each of three districts. Hence, 60 trained and 60 control group dairy farmers constituted the total sample of 120 farmers for the present study. The dairy farmers who possessed minimum three dairy animals such as cows/buffaloes or both were considered for the study. Entrepreneurial behaviour was measured in terms of the extent to which dairy farmers have the traits responsible for entrepreneurial behavior by self assessment scale (Technonet Asia, 1981) with minor modifications and was operationalized as the function of ten psychological attributes namely risk taking, hope of success, per suability, manageability, knowledge ability, self confidence, persistence, feedback usage, innovativeness and achievement motivation to measure level of entrepreneurial behaviour of trained and untrained dairy farmers. These traits are considered specific attributes for measuring the entrepreneurial behaviour of dairy farmers.

Entrepreneurial behaviour index (EBI) : Entrepreneurial behaviour index (EBI) is a number on the basis of which the respondents can be said to have more or less entrepreneurial attributes by virtue of which the chance of success or failure in dairy entrepreneurship can be predicted. It was measured as percentage of obtained score to maximum possible score.

RESULTS AND DISCUSSION

Socio economic characteristics of the respondents: The findings revealed that majority of the trained and untrained dairy farmers belonged to young and middle age group and were matriculates whereas majority of the untrained farmers were educated up to middle. Almost hundred per cent of farmers of both categories were engaged in dairy farming and agriculture. Majority of the trained dairy and untrained dairy farmers belonged to nuclear and joint family respectively and both hailed from medium size family. The trained dairy farmers owned medium (4-10 ha) land holdings whereas majority of untrained dairy possessed semi-medium (2-4 ha) land holdings. Average annual income of the trained and untrained dairy farmers was Rs. 382333 and Rs. 140916, respectively. They both trained and untrained dairy farmers had up to 11 years of experience in dairying.

Entrepreneurial behaviour index of respondents: Entrepreneurial behaviour index (EBI) is a number on the basis of which the respondents can be said to have more or less entrepreneurial attributes by virtue of which the chance of success or failure in dairy entrepreneurship can be predicted. The highest entrepreneurial behaviour index (85.69) was in achievement motivation of entrepreneurial behaviour and was ranked first whereas, the lowest (65.69) in case of the persuability attribute and ranked last (Table 2). Other attributes such as innovativeness, manageability, use of feedback and persistence, knowledge ability, hope of success, risk taking and self confidence were ranked II, III, IV, V, VI, VII, VIII and IX with their calculated entrepreneurial behaviour index were 78.06, 77.78, 75.00 74.17, 73.89, 68.33, 67.50 and 67.36 respectively.

Table 1. Distribution of respondents according to their socio-economic characteristics

Characteristics	Trainees (60)	Non-trainees (60)
Average age (No. of years)	34.6	37.4
Average number of formal schooling years	11	9
Average family size	5	7
Family type (%)		
Nuclear	34	17
Joint	26	43
Average land holding (ha)	4.42	3.04
Occupation (%)		
Dairy + Agriculture	100	98
Dairy + Agriculture + Other	0	2
Average annual income (Rs)	382333	140916

Table 2. Extent of entrepreneurial behaviour attributes possessed by trained dairy farmers

Attributes	Mean Score	EBI	Ranks
Achievement motivation	10.28	85.69	I
Innovativeness	9.37	78.06	II
Manageability	9.33	77.78	III
Use of feedback	9.00	75.00	IV
Persistence	8.90	74.17	V
Knowledge ability	8.87	73.89	VI
Hope of success	8.20	68.33	VII
Risk Taking	8.10	67.50	VIII
Self confidence	8.08	67.36	IX
Persuability	7.88	65.69	X
Overall entrepreneurial behaviour	88.02	73.35	

It is encouraging to note that highest index was found in case of achievement motivation and was ranked first. This indicates that the respondents had comparatively high amount of inner urge to improve themselves and excel into dairy enterprise. The overall entrepreneurial behaviour index i.e., 73.35 can be termed as moderate to high. This shows the effectiveness of training programme.

Entrepreneurial behaviour attributes of untrained dairy farmers: The achievement motivation also emerged at first rank with an entrepreneurial behaviour index value 65, whereas the risk taking among the other attributes recorded as he last rank with the entrepreneurial behaviour index 47.78 (Table 2). Other attributes such as manageability, persistence, hope of success, knowledge ability, innovativeness, use of feedback and persuability ranked at II, III, IV, V, VI, VII, VIII, IX with the entrepreneurial behaviour index was 61.39, 56.94, 56.67, 53.89, 53.33, 50.97, 50.42 and 50.28, respectively (Table 3).

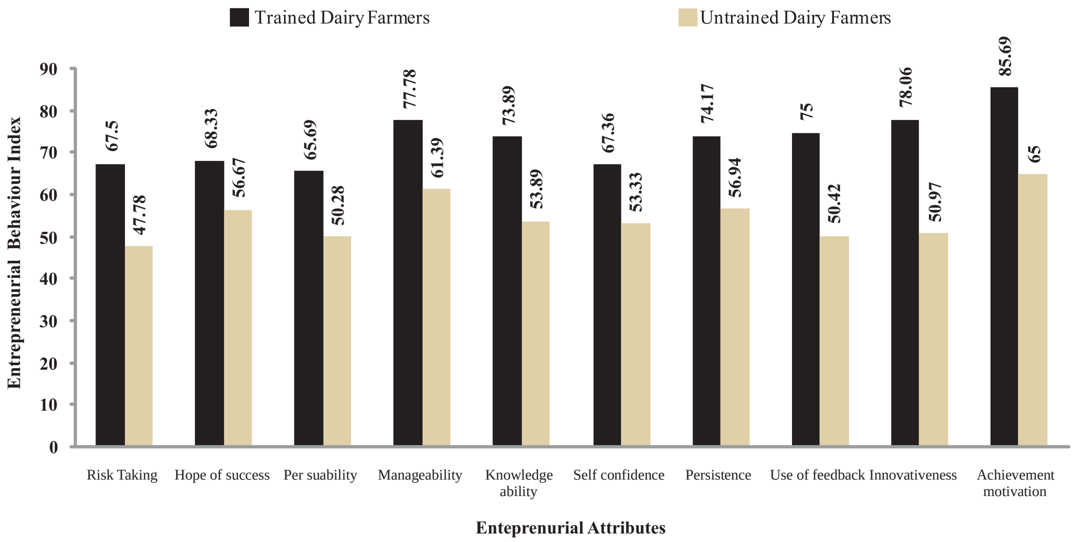

Fig. 1. Distribution of respondents according to entrepreneurial attributes

Table 3. Extent of entrepreneurial behaviour attributes possessed by untrained dairy farmers

Attributes	Mean Score	EBI	Ranks
Achievement motivation	7.80	65.00	I
Manageability	7.37	61.39	II
Persistence	6.83	56.94	III
Hope of success	6.80	56.67	IV
Knowledge ability	6.47	53.89	V
Self confidence	6.40	53.33	VI
Innovativeness	6.12	50.97	VII
Use of feedback	6.05	50.42	VIII
Persuability	6.03	50.28	IX
Risk taking	5.73	47.78	X
Overall entrepreneurial behaviour	65.60	54.67	

The achievement motivation had highest entrepreneurial behaviour index in control group dairy farmers also. The reason might be the same as the inner urge to improve themselves in economic terms. It was also noted that lowest entrepreneurial behaviour was in case of risk taking. It is due the fact that untrained dairy farmers were small and medium dairy entrepreneurs with limited herd size and inadequate financial status. This forced them to concentrate only on to secure what they have. The overall entrepreneurial behaviour index of untrained farmers was found to be 54.67. This can be termed as moderate and average. So, there must be entrepreneurship development training programme to be organized for untrained dairy farmers.

Comparative analysis of entrepreneurial behaviour of dairy farmers : The mean score of overall entrepreneurial behaviour of trained farmers (88.02±12.04) was highly significant as compared to mean score of untrained farmers (65.60±5.84).

The higher mean score of the trained farmers does not show any superiority of trained farmers over untrained dairy farmers. The Z test value was 8.39, which was significant at 0.01 level of probability. It could be comprehended that there exists a significant difference between the entrepreneurial behaviour of the trained and untrained farmers. It can be inferred that better educational, higher land holdings, higher scientific orientation might have influenced the entrepreneurial behaviour. This might be possible reason for observed significance difference.

CONCLUSION

It can be concluded that majority of the trained dairy farmers had moderate to high entrepreneurial behavior, whereas majority of untrained dairy farmers had an average entrepreneurial behaviour index. This shows that average entrepreneurial behaviour was possessed by the untrained dairy farmers. There is possibility to enhance these traits among them. Entrepreneurship training programmes should be implemented with the objective to enhance the entrepreneurial activities of the dairy entrepreneurs. The untrained dairy farmers should be given training various aspects of feeding, health care, breeding and value addition to make milk and milk products to promote scientific dairy farming on commercial basis.

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Received 12 March, 2016; Accepted 25 June, 2015

Indian Journal of Ecology (2016) 43 (Special Issue-2): 806-810

Manuscript Number: 2382
NAAS Rating: 4.47

Farmers' Perception in context of Impact of Agrochemicals on Environment

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***Abstract*:** The study was conducted in Haryana in districts of Karnal and Sirsa. Result concerned with personal profile shows that most of the farmers were of middle age, educated up to middle school, and performed only farming. Most of the farmers perceived it correct that agrochemicals can cause variety of adverse effects on environment. Regarding negative effects almost all the farmers observed surface & ground water contamination, eutrophication & sedimentation, damage to aquatic life, killing of non target species, reduced population of birds and animals and loss of biodiversity. Due to these adverse effects of agrochemicals on birds, animals and environment other farming practices must be adopted that could be most effective alternatives to present farming system such as organic farming, integrated pest management, integrated farming system, vertical farming, protected cultivation, cowpathy and homeofarming should be promoted for sustainable development.

Key Words: Agrochemicals, Environment, Impact, Perception

Environment is often exposed to chemical contaminations; these chemical contaminations are mainly from the use of agrochemicals for the prevention of crop damaging pests, fungus, weeds etc. About 33% of crop loss is caused by weeds followed by 26 by diseases and insects and 15 by rodents and others but the market share in term of value is 65% of insecticides followed by herbicides (16%), fungicides (15%) and others (4%), (Industry Reports, Analysis by Tata strategic, 2015). The present study deals with the perception of farmers regarding the adverse effect of agrochemicals on environment and various impacts observed by them on their environment.

MATERIAL AND METHODS

The study was conducted in Haryana state which is geographically located at 30.73° N and 76.78° E. The study was conducted in two districts namely Karnal and Sirsa, these two districts were selected purposively as they consumed highest amount of agrochemicals in entire state. From each districts seven villages were selected. From Karnal Pabana Hassanpur (Gharaunda), Padhana (Nilokhedi), shamgarh (Nilokhedi), Gangar (Nilokhedi), Chapra Kheda Rasoolpur (Karnal), Phoosgardh (Karnal), Sohana (Karnal) were selected. From Sirsa district Rupana Khurd (Chopta), Bakriyawali (Chopta), Panihari (Sirsa), Kheja Kheda (Sirsa), Shahpur begu (Sirsa), Farwain khurd (Sirsa), Bajekan (Sirsa) were selected. From each village ten farmers were selected randomly. Thus a total number of fourteen villages and one hundred forty farmers were selected for the study.

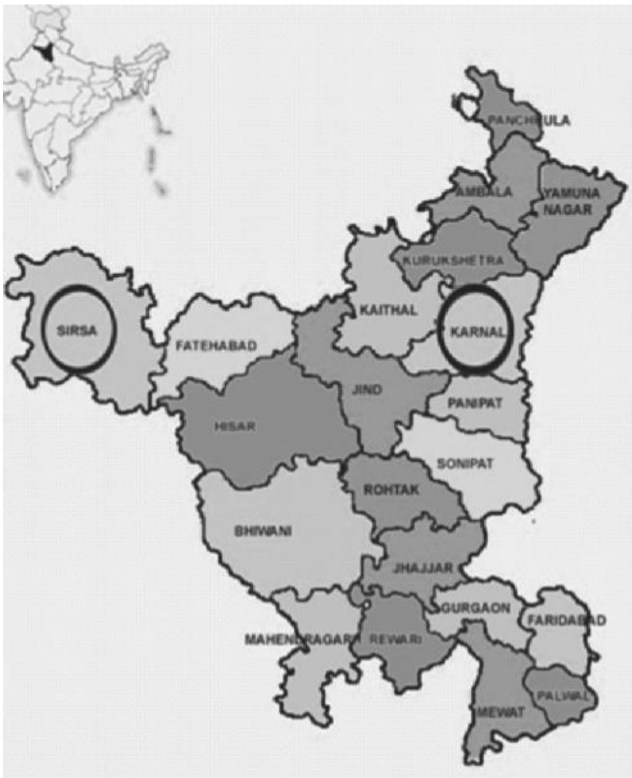

Fig. 1. Locale of study

RESULTS AND DISCUSSION

Personal profile of the respondents: Only 12.14% of the farmers' belonged to young age group, 53.57% of farmers belonged to middle age group and 34.28% of farmers to old age group. About 27% of the farmers were educated up to middle school and none of the farmers were post graduate.

Occupation of farmers was also studied and it was seen that 83.57 percent of farmers were engaged only in farming and 16.42 percent were doing job/business along with farming.

Table 1. Personal profile of respondents

Age	F	%
Young	17	12.14
Middle	75	53.57
Old	48	34.28
Education		
Llliterate	24	17.14
Primary	6	4.28
Middle	38	27.14
Matriculation	42	30
Higher secondary	18	12.85
Graduate	12	8.57
Post graduate	0	0
Occupation		
Only farming	117	83.57
Business/job and farming	23	16.42

Perception of farmers about the harmful effect of agrochemicals on birds and animals: All the farmers perceived that the agrochemicals can lead to reduced reproduction and hatching, contaminated water can adversely affect birds and animals (Nath *et al*., 2013), there is reduced life span, fertility risks and the cattle dipping in rivers and ponds can be poisonous. Various studies have revealed the presence of different types of agrochemicals in water bodies like Glyphosate, Methyl parathion, Endosulphan, DDT, Organochloride and Organophosphorous pesticide. A very high percentage of farmers i.e. 90.71 per cent perceived that agrochemicals can cause poisoning in birds and animals; and animal grazing on chemically treated land can become sick.

The result also show that 84.28 per cent of farmers perceived that insecticides can be used to kill ticks and fleas in animal. In India, the use of pesticides remains the cornerstone of controlling ticks, lice and other ecto-parasites from the livestock animals. In the absence of an effective alternative method of control, reliance on chemicals is bound to increase, which exerts selection pressure on the target organism resulting into the development of resistance. 70 percent of farmers perceived that chemical residues are found in meat, milk and eggs. Chemical persists in animal body causing diseases was perceived by 68.57 per cent of farmers and chemicals have carcinogenic effect in birds and animals was perceived by 52.85 percent of farmers.

It was perceived by 42.14 per cent of farmers that pesticides can reduce the milch quantity in animals, 30.71 per cent of farmers perceived that it can cause still birth,

Table 2. Perception of farmers about the harmful effect of agrochemicals on birds and animals

Statement	F	%
Reduced reproduction and hatching, Contaminated water adversely affect birds and animals, etc.	140	100
Cause poisoning in birds and animals	127	90.71
Using insecticides to kill ticks and fleas in animals is harmful	118	84.28
Chemical residues in meat, milk and eggs	98	70
Chemical persists in animal body causing diseases	96	68.57
Carcinogenic effect in birds and animals	74	52.85
Low milch	59	42.14
Stillbirth	43	30.71
Thinning of egg shells in birds	25	17.85
Increased body temperature	19	13.57
Physiological disorders	19	13.57

17.85 per cent of farmers perceived that chemicals can cause thinning of egg shells in birds. Only 13.57 per cent of farmers perceived that chemicals have the tendency to increase body temperature and cause physical disorders in animals. None of the farmers had the perception that chemicals residues can also turn male frog into hermaphrodite and cause muscle tremors in animals.

Environmental risks of agrochemicals perceived by farmers: Hundred percent of farmers perceived that agrochemicals can cause soil salination, soil contamination, decrease in enzyme activity, killing of beneficial insects and loss of biodiversity. All the farmers perceived that there is reduced population of birds, Loss of biological control, chemically contaminated air, contaminated water of hand pumps, rivers and ponds, release of nitrate and nitrite in water and resistance against chemicals in insects and pests. Perception of farmers about release of heavy metals in air was 79.28 per cent. Pesticides have contaminated almost every part of our environment and pesticide residues are found in soil, air and in surface and groundwater. Pesticide contamination poses significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms to insects, plants, fish and birds.

Positive impact of agrichemicals as observed by farmers: Hundred percent of the farmers mentioned that the agrochemicals are useful in controlling population of insects and pest, it is well known that pesticides have been an integral part of crop production as it reduces loss from the weeds, diseases and insect pests that can markedly reduce the amount of harvestable produce.

A very high percentage of farmers i.e. 82.85 per cent said that agrochemicals are helpful in reducing deforestation as we can produce more on small piece of land with the help of agrochemicals, 80.71 per cent of farmers mentioned that there will be less amount of sediment runoff, reduced soil erosion, more space available for birds and animals to flourish if we use agrochemicals in agriculture and 64.28 percent of farmers said that agrochemicals can also be helpful in controlling insect born diseases such as malaria.

Negative impact of agrochemicals as observed by farmers: Regarding the negative impact 100 per cent of the farmers said that agrochemicals can cause surface water contamination, eutrophication and sedimentation, kills aquatic life, ground water contamination and killing of non target vegetation and 80.71 percent of farmers said that chemicals have also lead to reduced population of birds and animals and loss of biodiversity.

Most of the farmers in both the districts perceived that agrochemicals could reduce reproduction (Hamlin and Guillette, 2010) and hatching (Fry, 1995) in animals and birds; contaminated water could adversely affect birds and animals (Nath *et al*., 2013); they could also lower life span of various birds and animals; cattle dipping in rivers and ponds led to poisoning, caused fertility risks, poisoning in birds and animals and animals grazing on chemically treated land could become sick. Farmers perceived that it was acceptable to use insecticides to kill ticks and fleas in animals. In India, the use of pesticides remains the cornerstone of controlling ticks, lice and other ecto-parasites from the livestock animals. In the absence of an effective alternative method of control, reliance on chemicals is bound to increase, which exerts selection pressure on the target organism resulting in the development of resistance.

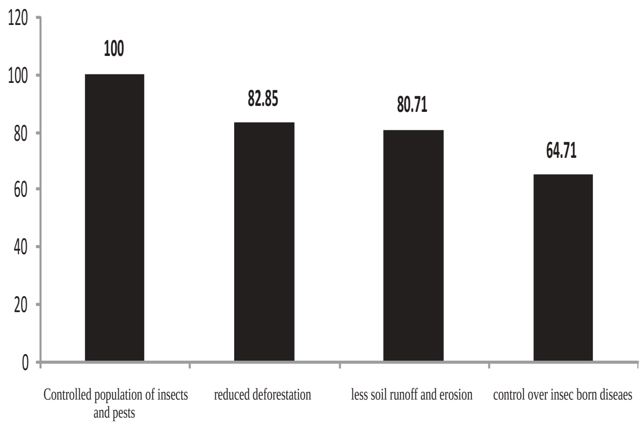

Fig. 2. Positive impact of agrochemicals observed by farmers

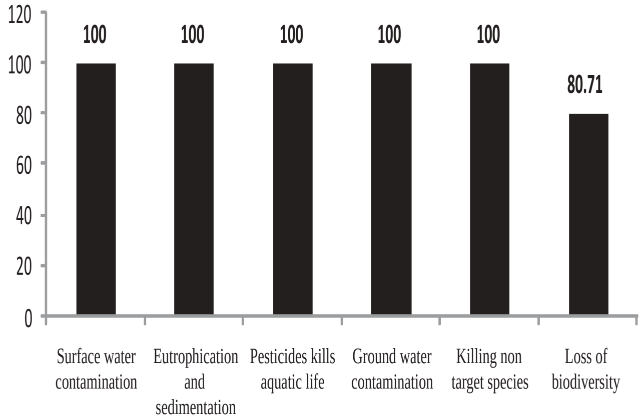

Fig. 3. Negative impact of agrochemicals observed by farmers

Farmers perceived that chemical residues were present in meat (Rutherford *et al*., 2000), milk (Fagnani *et al*., 2011; Iftikhar *et al*., 2014) and eggs (Kan, 2005). Chemicals present in these food items are persistent in nature and lead to their accumulation in animal tissues and subsequently cause human dietary exposure through consumption of animal products viz., meat, milk, eggs and sea foods (Kumar *et al*., 2013). A study conducted by Wang *et al*. (2007) show that among the total number of suspected samples for pesticides, 175 (46.1%) cases were found positive to contain pesticides of various kinds which were Carbamate insecticides, Rodenticides anticoagulants, Organophosphate insecticides, molluscicides, herbicides, etc. besides totally 225 animals, 123 animals were found positive for pesticide intoxication; among them 47.2% were dogs, 34.1% were cats 9.8% of other species and 8.9% of unspecified animal samples.

Less than half of the farmers also perceived that agrochemicals had carcinogenic effect in birds and animals was supported by Dich *et al*. (1997). Twenty five per cent believed that they lowered milch in cattle and merely 5% believed that agrochemicals could also cause thinning of egg shells in birds (Bennette, 1990). It was also observed that none of the farmers believed that agrochemicals could cause physiological disorders, muscle tremors, still birth and increased body temperature. None of the farmers in both the districts believed that atrazine could turn male frog into hermaphrodite but this very commonly used herbicide was moderately toxic but highly persistent and systemic herbicide. Atrazine could turn male frogs into females that are successfully able to reproduce. Previously conducted researches showed that atrazine could cause sexual abnormalities in frogs, such as hermaphroditism (having both male and female sex organs). The results also suggested that atrazine, which is a weed killer used primarily on corn crops, could have potentially harmful effects on populations of amphibians, animals that are already experiencing a global decline.

All the farmers in both the districts perceived that agrochemicals could cause soil salination, soil contamination, decrease in enzyme activity, killing of beneficial insects and loss of biodiversity. Recent studies have indicated that our environment is chronically polluted by pesticides and levels of biocidal contamination have increased tremendously. The environmental deterioration due to pesticides is endangering the situation of future (Sitaramaraju *et al*., 2014). The findings of the study also revealed that farmers perceived reduced population of birds, loss of biological control, chemically contaminated air, surface water contamination (Agarwal *et al*., 2010), ground water contamination (Sunitha *et al*., 2012), water contamination in rivers and ponds as an impact of agrochemicals, release of nitrate and nitrite in water and resistance in insects against chemicals. Various studies have revealed the presence of different types of agrochemicals in water bodies like glyphosate (Toledo *et al*., 2014) can also reduces the growth and activity of free-living nitrogen-fixing bacteria in the soil (Santos and Flores, 1995). 2,4-D reduces nitrogen fixation by bacteria that live on the roots of bean plant (Fabra *et al*., 1997). Methyl parathion, endosulphan, DDT, organochloride and organophosphorous pesticide residues were also found in water bodies (Singh *et al*., 2012).

In India pests cause crop loss of more than Rs 6000 crores annually, of which 33 per cent are by weeds, 26 per cent by diseases, 20 per cent by insects, 10 per cent by birds and rodents and the remaining (11 per cent) is due to other reasons (Rajendrea, 2003). More than sixty percent of the farmers perceived that agrochemicals can also be helpful in controlling insect born diseases such as malaria. A report Citizens Campaign for the Environment and Citizens Environmental Research Institute August, 2002 on The Health Effects of Pesticides Used for Mosquito Control makes it very clear that Scourge, Anvil, Permithrin and Malathion are commonly used chemicals for mosquito control.

Regarding the negative impact cent percent of the farmers said that agrochemicals can cause surface water contamination (Agarwal *et al*., 2010), eutrophication and sedimentation, kills aquatic life, ground water contamination (Sunitha *et al*., 2012) and killing of non target vegetation. Significant percentage of farmers also perceived that chemicals have also lead to reduced population of birds and animals and loss of biodiversity (Pesticide News 88, June 2010)

CONCLUSION

From the present study it is evident that most of the farmers perceived it correct that agrochemicals can cause various problems in birds and animals along with other environmental hazards. Agrochemicals can have both positive as well as negative impact and as there was significant adverse effect of agrochemicals observed by the farmers on environment it is required to reduce the use of agrochemicals and divert towards organic fertilizers and pesticides. It is certainly required to explore various other fields like Biodynamic agriculture, Cowpathy, Homeofarming and many others which can help to perform agriculture in a more environmental friendly way.

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 811-815

Manuscript Number: 2383
NAAS Rating: 4.47

Adoption Status of Recommended Silkworm Rearing Practices by the Rearers in Jammu Division of Jammu and Kashmir

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***Abstract*:** The study was conducted to know the extent of adoption of different recommended improved silk worm rearing practices by rearers of Jammu division. Only 25 per cent respondents adopted improved variety of mulberry, whereas, only 2 per cent and 1 per cent respondents adopted control measures in insect pest infestation and disease control in mulberry plants. Education level of respondent farmers and trainings attended by them had significant impact on adoption of different recommended silk-worm rearing practices.

***Key Words*:** Adoption, Mulberry, Rearing, Silk, Silk-worm

India is the second largest producer of silk in the world with an annual silk of around 18500 tonnes and has distinction of being the only country producing all four kinds of silk viz., mulberry, Tasar, Eri and Muga (Giridhar *et al.,* 2010). However mulberry silk contributes more than 87 percent of the country's silk production. Due to favorable climatic conditions, mulberry is cultivated mainly in five states of India namely, Karnataka, Andhra Pradesh, Tamil Nadu, West Bengal and Jammu & Kashmir. These five states collectively account for 97 per cent of the total area under mulberry cultivation and 95 per cent of raw silk production in the country. Sericulture plays a vital role in the rural development in Jammu and Kashmir, as it integrates well with the farming systems and has potential to generate attractive income. It is remarkable for its low investment, quick and high returns that fits well into socio-economic conditions of India in general and Jammu and Kashmir in particular (Qadri, 2010). Sericulture is a subsidiary occupation for about 25000 rural families in the state. Most of these families belong to economically backward section of the society. Annually about 850 MTs of cocoons are produced generating an income of about Rs 1100 lakhs for these silkworm rearers coupled with annual employment generation to the tune of 6 lakhs man days (Department of Sericulture report 2010-11). In Jammu division, three fourth of land area is rain fed supporting minor crops, horticulture trees and other agro forestry species including mulberry. Major crop in this area is maize. Land holding is small and fragmented. Farmers distribution are landless or marginal, who are unable to meet their all needs from land. These people generally resort to daily labour work during off season spread for about six months and some have taken up subsidiary occupation including silkworm rearing (Koul, 2009). Keeping in view the importance of silkworm enterprise the present study was conducted to study the status of adoption of various recommended improved silkworm rearing practices and factors affecting the adoption in Jammu division.

MATERIAL AND METHODS

The present study was conducted in three districts of Jammu of Jammu and Kashmir State. On the basis of number of silkworm rearers in each districts, the districts were categorized into three categories with i) Less than 500 rearers ii) 500-1000 rearers iii) Above 1000 rearers. From each of these categories, one district having highest number of silkworm rearers was selected. In this way, three districts namely Poonch, Reasi and Rajouri were selected from these categories for the purpose of study. Based on the number of silkworm rearers in a block, two blocks having maximum silk worm rearers from each district was selected purposively. Thus a total of six blocks was selected for the purpose of study. From each selected block four villages having maximum number of silkworm rearers were selected purposively. Thus, twenty four villages were selected for the purpose of study. The descriptive cum diagnostic research design was employed for conducting the study. The respondents were selected by proportionate random sampling with a sample size of 240 respondents. Data were collected from the selected respondents with the help of semi- structured interview schedule by using the personal interview method. The respondents were interviewed either at their home, at community places or at their farms and their responses were recorded on the spot. Appropriate statistical tests were applied for logical interpretation of data. The recommended silkworm rearing practices were taken into account for analyzing the deviations from adoption of different recommended improved silkworm rearing practices.

RESULTS AND DISCUSSION

The data presented pertaining to socio-economic status is presented in Table 1, which summarizes landholding, literacy, occupation, silk rearing skills, etc.

Adoption of different sericulture practices: Adoption commonly refers to the decision to use a technology or practice by economic units on a regular basis (Rogers, 2003).

Table 1. Descriptive statistics of the sampled farmers (Mean±S.D)

Particulars	Districts			Overall Percentage (n=240)
	Rajouri (n=170)	Poonch (n=36)	Reasi (n=34)	
Age (% farmers)				
i. (21-40) years	32	17	24	25
ii. (40-56) years	51	58	56	53
iii. (56-81) years	17	25	21	19
Average age (years)	46±11.44	48±11.73	49±11.07	47±11.42
Education (% farmers)				
i. Illiterate	24	25	26	25
ii. Primary	18	20	35	23
iii. Middle	41	42	32	40
iv. Matric	11	11	03	10
v. 10+2	6	3	03	3
Average education	6±3.68	5±3.43	6±3.74	6±3.65
Size of family (% farmers)				
i. 1-5 Members	39	08.33	08.82	30.00
ii. 5-7 Members	52	69.45	64.71	56.67
iii. 7-13 Members	09	22.22	26.47	13.33
Average	5 ±1.23	6±1.61	6±2.16	5±1.52
Occupation (% farmers)				
i. Agriculture+Sericulture	41	61	50	45
ii. Agri+Sericulture+Labour	40	25	33	37
iii. Agri+ Sericulture+Service	14	8	6	12
iv. Agri +Sericulture+Business	6	6	9	6
Average land holding (% farmers)				
Land less silkworm rearers	1	0.00	0.00	0.42
i. <1ha (marginal)	67	92	53	68
ii. 1-2ha (small)	26	8	32	27
iii. 2-4ha (semi-medium)	6	0	15	5
Average	0.84±.67	0.50±0.77	1.10±0.20	0.83±0.65
Number of mulberry trees (%farmers)				
i 0-162 trees	82	92	82	83
ii 162-291 trees	11	08	9	10
ii 291-750 trees	7	00.00	9	6
Average	89±122.70	55±56.94	92±96.08	85±112.03
Experience in sericulture (% farmers)				
i 1-17 years	41	56	41	43
ii. 17-32 years	45	39	50	45
iii. 32-65 years	14	6	9	12
Average experience (years)	20.72±10.39	20.80±10.65	17.11±11.06	20.19±10.56
Average distance from nearest sericulture market(kms)	10.95±4.03	20.42±15.28	32.91±6.78	15.48±10.65
Average distance from home to sericulture office (kms)	4.13±3.67	4.36±4.46	2.06±4.11	3.87±3.92
Extension Contact (% farmers)				
i. Low (2- 5)	19	28	12	20
ii. Medium (5 to 7)	42	47	53	45
ii. High (7-10)	38	25	35	36
Average	6.47±1.93.	6.16±1.96	6.55±1.82	6.44±1.91
Training attended (% farmers)	6	8	9	7

The overall 57 per cent of respondents planted trees on waste and degraded land followed by 40 per cent planted on bunds and only 5 per cent respondents planted trees on main field and 8 per cent respondents had tested their soil for mulberry cultivation (Table 2). This is because of the fact that majority of farmer possessed marginal and small holdings, so their first priority is for the cultivation of the cereal crops for their own consumption resultantly the mulberry plantation is done on field bunds and waste and degraded lands. Only 8 per cent farmers tested the soil for soil health.

Table 2. Selection of land for mulberry plantation and soil testing

Practice	District wise percentage of respondents			Overall Percentage
	Rajouri	Poonch	Reasi	
Selection of land				
a. On fields	6	3	00	5
b. On bunds	38	47	41	40
c. On waste and degraded land	58	50	59	57
Soil testing	8	3	12	8

Adoption of planting material: The 25 per cent respondents adopted improved variety of mulberry followed by 21 per cent respondent adopt number of healthy buds in mulberry cutting and none of the respondents adopt treatment of mulberry cuttings with chemical (Table 3). The study envisages that the maximum number of farmers is lacking in adoption of improved planting material due to its non-availability and moreover mulberry is grown wild in these areas, farmers are reluctant to uproot old plantation and to go for a new plantation. This may be because of their lack in technical knowhow regarding sericulture production technology.

Adoption of trainings and pruning of mulberry plants: The 92 per cent respondents adopted single pruning followed by only 7 per cent respondents who adopted double pruning in mulberry and 81 per cent respondents adopted training in mulberry plants.

Adoption of fertilizer and manures: The 33 per cent respondents applied farmyard manure to the mulberry plants and 5 per cent respondents adopted nitrogenous and potash fertilizer, respectively and none of them adopted phosphatic fertilizer (Table 4). This may be one of the reason that farm yard manure is locally available but not in plenty, also because of their poor purchasing power and considering mulberry as subsidiary crop. The study of Mallikarjuna *et al*. (2008) supports the present study.

Table 4. Adoption of trainings and pruning of mulberry plants by the silkworm rearers

Practices	District wise percentage of respondents			Overall Percentage
	Rajouri	Poonch	Reasi	
Training of mulberry plants	78	97	79	81
Pruning				
Single pruning	92	92	91	92
Double pruning	6	8	9	7

Adoption of plant protection measures: The data presented in the table 5 reveals that overall, from all the three districts 62 per cent respondents observed insect pest infestation in mulberry plants followed by 17 per cent respondents observed disease in mulberry plants and only 2 per cent and 0.84 per cent respondents adopted control measures in insect pest infestation and disease control in mulberry plants. It may be due to the fact that the damage caused by the insect pest might have not crossed the economic thresh hold level. This may be also because of the reason of their unawareness regarding the use of pesticides. Moreover, non-availability of pesticides may be one of the factors affecting adoption. There is no significant variation in the adoption of control measures of diseases and insect pest infestation.

Adoption of hygiene conditions during the rearing: In Rajouri district, 94 per cent respondents adopted hygienic conditions followed by Pooch district 86 per cent and in Reasi district 74 per cent. Overall from three districts 90 per cent respondents had maintained hygienic conditions during rearing.

Temperature and humidity management practices adopted: 48 and 35 per cent respondents adopted temperature and humidity during the rearing. Moreover, it

Table 3. Adoption of planting material by silkworm rearers

Practices	District wise percentage of respondents			Overall
	Rajouri	Poonch	Reasi	
Improved variety	26	22	21	25
Age of cuttings	6	17	18	9
Length of mulberry cuttings.	9	28	24	14
Thickness of cuttings for propagation.	10	22	18	13
Number of healthy buds in one cuttings	14	35	39	21
Treatment of mulberry cutting with chemicals	0	0	0	0

Table 5. Adoption of fertilizer and Manures by the silkworm rearers

Practices	District wise percentage of respondents			Overall percentage
	Rajouri	Poonch	Reasi	
Nitrogenous fertilizer	4	6	9	5
Potash fertilizer	4	6	9	5
Phosphatic fertilizer	00	00	00	0
Farmyard manure	37	47	26	33

Table 6. Adoption of plant protection measures by the silk worm rearers

Practices	District wise percentage of respondents			Overall percent
	Rajouri	Poonch	Reasi	
Incidence of diseases observed	19	17	6	17
Control measure adopted	1	0	0	1
Insect/pest infestation observed	59	75	62	62
Control measure adopted	2	0	3	2

was evident from the study that silkworm rearers from the district Rajouri had better adopted the temperature and humidity management practices as compared to silkworm rearers from Poonch and Reasi district. However regarding temperature maintenance there is no considerable variation between Poonch and Reasi district, however regarding humidity maintenance silkworm rearers from Reasi district were better adopters than Poonch district.

Factors affecting the adoption of various silkworm rearing practices: Binary logistic model was used to find out the affect of independent variables on the decision to adopt various practices of silkworm rearing. Enter method was employed to eliminate the collinarity. For the validation of the model, chi square value was taken into account. The Nagelkerlie's R^2 was used as measure of determination of variation caused by the predictors. Out of all the independent variables taken, the variables viz. experience, distance from home to sericulture market and knowledge significantly affected the farmer decision to adopt a variety, whereas, age and land holding was significantly affecting the farmer decision for soil testing. Age, trees owned and type of rearing house significantly affected the farmer decision to adopt fertilizer and manures. From all the independent variables education, distance of sericulture office, rearing equipments, mass media exposure and land holding significantly affect the farmer decision to control the insect pest. Out of all the independent variables distance from home to sericulture market and sericulture material possessed significantly affect on the farmer decision to maintain hygienic conditions during rearing. These variables favour the adoption of hygienic conditions during rearing. It is evident from the study that overall education level of respondent farmer and training attended by them had significant impact in adoption of different recommended sericulture practice. The findings of Adeogun *et al.* (2008) support the present study.

Table 7. Variables affecting the adoption of different silkworm rearing practices

Practices	Factors affecting the adoption	Coefficient (B)	S.E	Wald	Prob	Remarks
Variety	Experience	-.058	.029	3.84	.050	^{2}=52.15
	Distance of village from (sericulture market)	.055	.020	7.17	.007	Nagelkerlie's R^2=.359
	Knowledge	.470	.125	14.07	.000	P=.000
Soil testing	Age	-1.605	.746	4.632	.031	^{2}= 39.097
	Land holding	.969	.371	6.826	.009	Nagelkerlie's R^2=.354 P=.006
Manures and Fertilizer	Age	.084	.448	4.833	.028	^{2}= 31.60
	Trees owned	.003	.002	3.229	.072	Nagelkerlie's
	Type of rearing house	1.137	.554	4.216	.040	R^2=.168 P=.048
Insect/Pest observed	Education	-1.03	.57	3.28	.070	^{2}= 37.46
	Distance (Sericulture office)	-0.74	.039	3.57	.059	Nagelkerlie's
	Rearing equipments	.109	.044	6.03	.014	R^2= .197
	Mass media	-.229	.100	5.06	.024	P=.010
	Land holding	.547	.293	3.48	.062	
Diseases observed in Mulberry plants	Age	-	-	4.94	.085	^{2}= 26.26
	Knowledge	0.158	0.092	2.96	0.086	Nagelkerlie's
	Annual Income	0.000	0.000	4.67	0.031	R^2= .175
	Mass media	-0.292	0.139	4.420	0.036	P=.14
Hygienic conditions in rearing	Distance from home to market	-0.044	0.014	9.461	0.002	^{2}= 34.071
	Sericulture Material possession	-0.078	0.045	2.9666	0.085	Nagelkerlie's R^2=.182 P=.026

CONCLUSION

Only one fourth of respondents had adopted improved variety of mulberry. More than half of the respondents had planted the mulberry plants on waste and degraded land. More than one third of the respondents had planted mulberry plants on bunds. A meager per cent of respondents had applied the fertilizer and manures in mulberry plantation. Very less percentage of respondents had adopted any control measure to check insect pest and disease infestation. Majority of respondents were not trained and seek information from family and friends.

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Received 21 March, 2016; Accepted 21 August, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 816-819

Manuscript Number: 2384
NAAS Rating: 4.47

Evaluation of Bee-keeping Training Programmes Conducted by Krishi Vigyan Kendra-Sri Muktsar Sahib

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***Abstract*:** The study was undertaken to evaluate the beekeeping vocational training programmes in KVK, Sri Muktsar Sahib District of Punjab. One group pre and post evaluation design was employed for conducting formative (outcome) evaluation of beekeeping training programme. The knowledge tests were administered to 22 beekeeping trainees, before and after in one of the training programme organized in 2014. There was significant gain in knowledge in all aspect of bee-keeping enterprise. A separate sample of 120 trainees who got training on beekeeping prior to 2012 were selected for summative (impact) evaluation of beekeeping training programmes with respect to adoption status namely, adopters, discontinued and non adopters) and economic benefits. Ex-post-facto one-shot case study design was applied for this impact analysis. The vocational training programmes resulted in continued-adoption of beekeeping by 23% trained farmers. The average return per box was Rs. 1620 in small unit and Rs 4260 in large unit (more than 50 boxes). Similarly, average return per box over period of time increased from Rs 2606 in first year to Rs. 3360 in fifth years. These training programmes have the potential of enhancing the income of farming community.

***Key Words*:** Bee-keeping, Economic benefits, Krishi Vigyan Kendra, Taining

Krishi Vigyan Kendras (KVKs) is a noble concept developed by Indian Council of Agricultural Research to impart trainings and education with a view to raise the level of knowledge, attitudinal changes and testing and transferring of recommended improved farm technologies so as to bridge the gap between production and productivity and also to increase self employment opportunities among the farming community (Dash and Misra, 2004). Training to farmers encompasses all the roles of a farmer instead of looking at him only as a producer. Efforts have also been concentrated to empower the youth by giving them vocational trainings. Beekeeping is one of such enterprise, which has the potential to enhance the income of poor farmers and even the landless labour. It provides scope for self employment among the rural youth. There are various other products in beekeeping that can add to income of beekeepers such as beewax, propolis, pollen and royal jelly. Similarly, sale of bee colonies can also be source of additional income. The distinctive feature of beekeeping is the small capital investment as compared to other allied agricultural vocation. Due to low expenditure requirement and high income, beekeeping enterprise can be adopted by small, marginal and landless farmers (Sharma and Dhaliwal, 2014). It puts no pressure on land and can practiced young people, women farmers and old persons.

India is basically an agricultural country and copious amount of plant resources available for commercial beekeeping and quality honey production (Sivaram and Anita, 2000). In this regard, KVK, Sri Muktsar Sahib of Punjab State conducted several training programmes both on-campus and off-campus every year for farmers, farm women and rural youth. KVK Sri Muktsar Sahib also conducted vocational training on beekeeping for rural people to improve the social, economical, psychological and health status of their family. However there is need to know the success of these trainings to identify the constraints and impacts (Anonymous 2002). For this reason, a study was conducted which would help to evaluate the impact of the bee keeping trainings programmes in term of formative (gain in knowledge) and summative evaluation (adoption status and economic impact)

MATERIAL AND METHODS

The study was conducted in Sri Muktsar Sahib District of Punjab (lie between 30° 69' and 29° 87' latitude and 74° 21' and 74° 86' longitude 184 m above mean sea level). One group pre-post evaluation design was employed to study the reactions and gain in knowledge of the trainees who were attending the beekeeping training programme during 2014. Ex-post-facto, one shot case study design was employed for conducting impact evaluation to study adoption status and economic return from beekeeping enterprise. Two separate samples were drawn for conducting formative and summative evaluation. For formative evaluation a sample of all the 22 trainees who attended the beekeeping course organized in 2014 at KVK Sri Muktsar Sahib was taken to study the reaction and gain in knowledge of the trainees. A total of 140 trainees who imparted training in beekeeping prior to 2012 formed the population. Out of 140 trainees, the efforts were made to get the response from them through telephone or mail whether they had set up the enterprise or had discontinued the enterprise. The response of 120 trainees was received in this regard.

The practices of scientific beekeeping recommended by Punjab Agricultural University, Ludhiana were selected to form knowledge test. The knowledge test was pre-tested with 22 non sampled trainees and split half reliability method was applied for estimating the reliability coefficient. The reliability coefficient (r) was 0.893 for knowledge test. The final knowledge test of beekeeping consisted of 60 items. Gain in knowledge was measured in terms of the difference between knowledge scores of the trainees before and after training. The correct responses given by the trainees by way of recall on a knowledge test administered to them before and after the organization of vocational training course were given score 1 and incorrect responses were given score 0. Similarly, for evaluating long term impact of the training programmes to study the adoption and economic benefits from these vocational training programmes conducted by KVKs prior to 2013. The adoption status was measured in terms of percentage of past trainees setting up their enterprise (continuance/discontinuance) with the enterprise, and non-adoption of the enterprise. Economic benefits measured in terms of economic returns of the respondents who were continued-adopters of bee-keeping units in terms of generation of additional income per unit per year. The data regarding the adoption status, reasons for non-adoption/discontinuance and economic impact of the enterprises were collected by personal interview method using semi-structured interview schedule. This research instrument was pre-tested with 22 non-sampled trainees before its final use.

The data were analyzed by paired t-test to find out the statistical significance of the observed difference between pre-test and post-test training knowledge scores for selected bee-keeping practices. The effect of independent variables on the dependent variable was studied with the help of correlation coefficient.

RESULTS AND DISCUSSION

The socio-economic characteristics of the respondents shows that the majority of the respondents were young who attended the vocational training programmes on beekeeping i.e., 20 to 40 years of age and all of them were educated. The trainees were belonged to joint families with rural family background and having agriculture as their main occupation. Majority of the respondents belonged to small land holding category (1-2 ha) and medium land holding category (4-10 ha). Above 80 per cent of respondents had their family income from Rs. 1 lakh to Rs. 2 lakhs per annum.

Gain in Knowledge of the trainees in beekeeping training programme: The t-values of difference between pre-post training mean knowledge score of all the practices of beekeeping were significant (Table 1). The pre-training mean knowledge score on different practices of beekeeping ranged between 0.33 (in case of breeding of honey bee) and 6.66 (in case of management of boxes). The post training mean knowledge scores on different practices of beekeeping ranged between 3.73 and 15.66. In case overall knowledge gain, the pre-training mean knowledge score of the trainees of beekeeping was 16.30 which has increased to 46.85 after the training which is significant at the level $p<0.01$. This is in conformity with the study of Singh et al (2010) wherein they found that the t-values of difference between pre- and post-training mean knowledge scores of all the practices of beekeeping were significant.

Status of past trainees, present status and overall status with respect to adoption of bee-keeping enterprise: Only 23.33 per cent of the trainees adopted bee-keeping enterprise after getting training from the KVK (Table 2). The reasons for adopting bee-keeping as enterprise could be that it is related to trainees' main occupation and quality of training imparted to them during training programme in the KVK. The present

Table 1. Gain in knowledge of trainees about different aspects bee-keeping practices

Practice	Maximum knowledge Score	Mean knowledge score of trainees		t-value
		Pre-training	Post-training	
General information about bee-keeping	13	6.16	10.16	15.43*
Breeding of honey bees	6	0.33	5.16	9.77*
Bee flora	5	1.66	3.73	5.07*
Diseases and pest	6	0.83	4.48	12.18*
Management practices	20	6.66	15.66	14.29*
Production of honey	10	0.66	7.66	12.03*
Overall	60	16.30 ±8.86	46.85± 6.56	15.07*

* Significant at $p < 0.01$

Table 2. Status of past trainees with respect to adoption of bee-keeping enterprise

Adoption status		Total
Adopter	Non-adopter	
28(23.33)	92(76.67)	120
Present status		
Continued adopter	Discontinued adopter	
24 (85.71)	4 (14.29)	28
Status of overall adoption of bee-keeping enterprise (number of past trainees are 120)		
Continued adopter	Non-adopter	Discontinued adopter
24(20.00)	92(76.67)	4(3.33)

status means that after adopting the enterprise whether one is continuing with the enterprise or has discontinued the enterprise after a period of time. The 85.71 per cent of adopter respondents continued their be-keeping enterprise and only 14.29 per cent had discontinued their bee-keeping enterprise after some time. This shows that the continued adoption over a period of time was very good. This may be due to reason that the respondents migrate their boxes during off season to the neighbouring states like Haryana and Rajasthan. Overall adoption means how many trainees have set up their unit after obtaining training, continuing with the unit or discontinued the units after the period of time. The overall adoption of bee-keeping enterprise after getting the training from the KVK; twenty per cent of the trainees are continuing the bee-keeping enterprise and only 14.29 per cent had discontinued the bee-keeping enterprise after its adoption, whereas 76.67 per cent had not adopted the bee-keeping enterprise after getting training. This may be due to the reason that bee-keeping enterprise is a somewhat specialized enterprise and need full involvement and migrating the boxes when there is scarcity of bee flora.

Reasons for non-adoption and continuing of bee-keeping enterprise by past trainees:. The time consuming enterprise (86.96%), financial constraints (78.26%) and lack of family cooperation (70.65%) were the main reasons for non-adoption of be keeping enterprise by past trainees, whereas 45.65 per cent and 54.34 per cent respectively reported that there was lack of bee flora in their area and risk of loss involved in this enterprise (Table 3). Similarly, equal percentage of trainees (21.74%) had not adopted bee-keeping enterprise due difficult occupation and lack of proper guidance. Only, 10.87 per cent of them did not adopt the enterprise due to lack of space. The financial constraints, lack of proper guidance, shortage of time and problem of bee flora were the main reasons for discontinuation of bee keeping enterprise. Some of the adopter faced marketing problem, insecticide poisoning. Some of them also faced problem of theft of the boxes.

Table 3. Reasons for non adoption of bee-keeping enterprise as expressed by non-adopters

Reasons	Number of non-adopters	
	f*	% age
Lack of proper guidance	20	21.74
Lack of family cooperation	65	70.65
Lack of space	10	10.87
Financial constraints	72	78.26
Lack of flora	42	45.65
Difficult occupation	20	21.74
Time consuming enterprise	80	86.96
Risk of loss	50	54.34

*multiple response

Economic impact of beekeeping training programmes: The economic returns/benefits in of bee-keeping increase as the size of the unit increases and profits increase over the period of time (Table 4). The small units (upto 10 boxes) to start with, net income per box was Rs 1620 and it was Rs. 3600 in case of large units (above 50 boxes). It shows a gradual increase in net income per box from a unit of 10 boxes to a unit of more than 50 boxes. Kumar (2012) also observed that return from bee-keeping increases with increase in number of colonies. The returns also show a positive trend over a period of time. The average return per boxes irrespective of the size of the unit increased from Rs. 2606 during first year of setting of the unit to Rs. 2938 in second years to 3.64 in third years to Rs. 3210 in fourth years and 3360 during fifth years. The marketing of honey was either directly to the consumers or to large beekeepers. The price of the honey ranged between Rs. 80 to Rs. 100 for the study period.

CONCLUSION

The finding that vocational training programmes on bee-keeping achieved its objectives in term of desired outcome and impacts. The majority of the trainees were in young age group, it is good sign for generating self

Table 4. Net income of bee-keeping enterprise over a period of time

Number of boxes	1st Year		2nd Year		3rd Year		4th Year		5th Year	
	Number of beekeepers	Income per box (Rs)	Number of beekeepers	Income per box (Rs)	Number of beekeepers	Income per box (Rs)	Number of beekeepers	Income per box (Rs)	Number of beekeepers	Income per box (Rs)
Up to 10	8	1620	6	1720	4	1815	2	2060	1	2100
10-20	5	2020	4	2240	2	2360	3	2480	2	2800
20-30	4	2520	4	2850	6	3020	6	3200	7	3350
30-40	4	2730	3	3360	2	3415	3	3520	4	3650
40-50	6	3150	7	3620	6	3760	5	3850	3	4000
Above 50	1	3600	2	3840	4	4015	5	4150	7	4260
Average net income		2606		2938		3064		3210		3360

employment for rural employment for rural youth. There was considerable increase in the knowledge level of the trainees after the training programme on bee-keeping. The Ex-trainee Samelan (follow up of the trainings) organized by the KVK of Muktsar Sahib provided needful guidance to the trainees and avoid discontinuance of the enterprise. The continued adopter of bee-keeping enterprise also helped them to increase their family income that was generated from this enterprise. There is a urgent requirement to evaluate training programme organized by the different KVK and evaluation should be part and parcel of all extension activities.

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Received 16 April, 2016; Accepted 10 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 820-825

Manuscript Number: 2385
NAAS Rating: 4.47

Discrimination of Species of Genera *Grammoplites* and *Cociella* (Family: Platycephalidae) Occurring in Indian Waters, Based on Multi-variate Analysis

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***Abstract*:** A taxonomic study on *Grammoplites scaber* (rough flathead), *G. suppositus* (spotfin flathead) and *Cociella crocodilus* (crocodile flathead) belonging to family Platycephalidae (Flathead fishes) was conducted to discriminate them using multivariate analysis. A total of thirty-one morphometric and meristic characters were compared, including various body proportions. The factor analysis and discriminant analysis indicated that these species can be differentiated based on morphological features. Among ten meristic characters, six did not show any difference. However, four characters *viz*. number of gillrakers, black spot on 1st dorsal fin, increasing size of backwardly directed lateral line spines towards posterior end and preopercular spine revealed variations. SDFA gives correct classification in 98.461% cases, with only 1 misclassification. Squared Mahalanobis distance shows relative distinctness of *C. crocodiles* from the other two species of the genus *Grammoplites*. The scatter plot of the canonical scores of all the specimens for Root 1 and Root 2 shows clear demarcation between the selected species in the form of separate clusters. The study revealed that the ambiguous species of flathead can be differentiated based on certain morphological characters.

Key Words: *Cociella crocodilus, Grammoplites suppositus, G. scaber,* Morphometric, Platycephalidae

Taxonomic ambiguity exists in several genera of family Platycephalidae and accurate discrimination is imperative for sustainable utilization, management and trade (Murty and Manikyam, 2007). The identification of fishes are traditionally based on morphological characters. However, due to morphological plasticity in many cases it is a challenge to identify fishes and their developmental stages by using morphological characteristics alone (Zhang and Hanner 2012; Victor *et al*., 2009). The species of family Platycephalidae (flatheads) are widely distributed in tropical and sub-tropical regions of marine water (George, 1968**;** Mastrototaro *et al*., 2007; Melody *et al.,* 2013)**.** Worldwide family includes about 70 valid species (Murty and Manikyam, 2007) under 17 genera (Imamura, 1996). In Indian waters, about 13 species of flatheads have been reported (Day, 1878). Apart from edible values, some flatheads have important medicinal uses (IUCN, 2015). The flatheads are characterized by an elongated body with spiny depressed head. Usually, superior mouth is present (Imamura and Mc Grouther, 2008). These fishes are frequently found on sandy and muddy bottoms and in seagrass upto 300 m depth (Mastrototaro *et al.,* 2007, Knapp, 1999; Phinrub *et al*., 2013, Wikit *et al*., 2014; Froese and Pauly, 2015). The differences in the structure of lateral line scales are useful as generic character in *Platycephalus, Rogadius, Cociella* and *Onigocia* (Matsubara and Ochiai, 1995),other comprehensive morphological features (opening of canals) are pored scales (Hughes, 1981, 1985). Some species like Rough flathead (*Grammoplites scaber*), Spotfin flathead (*Grammoplites suppositus*) and Crocodile flathead (*Cociella crocodilus*) are very similar in external appearance and hence difficult to separate them. Despite several dedicated efforts in flathead taxonomy, ambiguity still exists in their identification. Hence the present study was taken up to resolve the confusions in identification of flathead species from West coast of India.

MATERIAL AND METHODS

Fish samples were collected from the trawl landings centers of maritime states of India (Munambam - Kerala, Newferry wharf, Sasoon dock, Versova - Maharashtra, Veraval and Porbandar - Gujarat). As per the record (Murty and Manikyam, 2007) these species are restricted in a specific geographical area. Fishes were identified up to species level using available keys and original descriptions. Terminology for head spines follows that of Knapp (1983). A total of twenty eight meristic and morphometric characters for three species namely *G. scaber* (rough flathead), *G. suppositus* (spotfin flathead) and *C. corocodilus* (crocodile flathead) were measured in fresh condition. The morphometric characters were measured by using a digital vernier calipers to the nearest 0.1 mm by following Murty (1975), and meristic characters like gill rackers and lateral line scales were counted on the left side of fish body by using a magnoscope.

Factor analysis was carried out for log transformed morphometric traits on 0.75 factor loading, variables shows more than 0.75 (accounting more to overall variance) were selected for Stepwise Discriminant Function Analysis (SDFA). A total of eight selected morphometric ratios were subjected to SDFA.

RESULTS AND DISCUSSIONS

Species Descriptions

Grammoplites scaber (Linnaeus, 1758), Common name: rough flathead. (Fig. 1a); Specimens examined:25

First dorsal fin with nine spine and second dorsal fin with twelve soft rays; pectoral fin rays 19 to 22 and anal fin rays 12. The number of gillrakers on the first-gillarch 7; total preopercular spines 3; the lower 2 smaller, the upper preopercular spine longest and not reaching to rim of the opercular membrane (Fig. 1b). The lateral line with 52 to 55 pored scales, with single opening to the exterior. All lateral line scales with large backward directed spine (Fig. 1c) till caudal peduncle; suborbital ridge with 3 or 4 strong spines. All pored lateral line scales bear a large spine and continue increasing in size towards posterior end of the body. Pre-orbital spine present.

The dorsal surface of the body brownish and ventral side whitish; body has 5 or 6 cross bands, caudal and first dorsal fin dusky, second dorsal fin with a dark spot on the margin.

Remark: Spines of lateral line scales are strong and increase in size anterior to posterior of the body while in *G. suppositus* spines are moderate and equal in size.

Grammoplites suppositus (Troschel, 1840), Synonyms: *Platycephalus maculipinna* Regan, 1905; common name: spotfin flathead; Specimens examined: 31

First dorsal fin with 9 spine, second dorsal fin with 12 soft rays; anal fin usually 13 rays and pectoral fin 21 to 23 rays. The number of gillrakers on the first gill arch 9; preopercular spines 3, the lower 2 small, the upper preopercular spine reaching beyond the rim of the opercular membrane (Fig. 2c). Lateral line with 52 to 54 pored scales (Fig. 2b), all bearing spine. Dorsal side of the body pale brownish and ventral silvery whitish. 1st dorsal fin has a large black blotch at the posterior base (Fig. 2a) and dark spots on the pectoral, upper lobe of caudal and second dorsal fins.

Remark: The 1st dorsal fin have large black blotch on posterior base.

Fig. 1a. *G. scaber* (Linnaeus, 1758)
Fig.1b. Preopercular spine reaching beyond the opercular membrane
Fig. 1c. Spine of pored scale on lateral line reaching beyond the posterior margin

Cociella crocodilus (Cuvier, 1829), Synonyms: *Platycephalus crocodiles;* common name Crocodile flathead; Specimens examined: 31

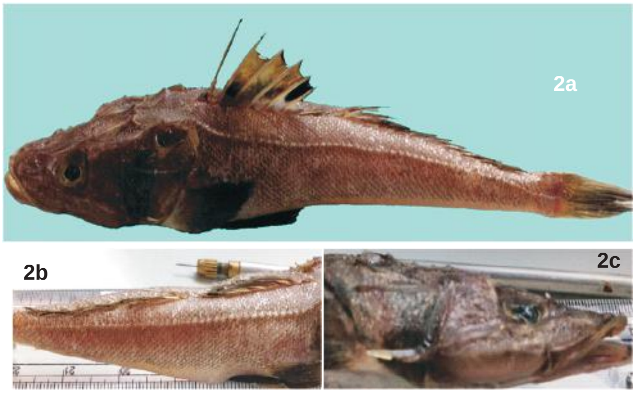

Fig. 2a. *G. suppositus* (Troschel, 1840)
Fig. 2b. The spine of pored scale on lateral line not reaching beyond the posterior margin
Fig. 2c. Preopercular spine reaching beyond the opercular membrane

Body elongate with vigorously flattened head. The head bears strong spine and bony ridges. Body width small doted spots and with 4 or 5 cross band (Fig. 3a); 1stdorsal fin dusky. Sub orbital ridge bears 3 spine, 1st spine in front of eye, 2nd at the middle of eye and 3rd at posterior margin of the eye (Fig. 3b). Body color dark. The upper caudal rays longer than lower.

The 1st dorsal fin with nine spines, pectoral fin 19 to 22, 2nd dorsal and anal fins with 11 soft rays; number of gillrakers on the 1st gillarch 6; preopercular spines usually 3; the lower two smaller than upper one; lateral line with 52 to 54 pored scales.

Remark: A small black spot on the body, number of anal fin rays 11 while *G. scaber* and *G. suppositus* have 12 and 13, respectively.

Morpho-meristic differentiation

Traditional flathead taxonomy has been dependent on the gross morphological features and meristic characters with varying degree of success. The major meristic

Fig. 3a. *Cociella crocodiles* (Cuvier, 1829)
Fig. 3b. Head part, spines on sub orbital ridge

characters used for species differentiation were either spines present on different parts or the count of fin rays. The major morphological features of taxonomic importance are bands on body and blotch on fins (Cuvier and Valenciennes, 1829; Troschel, 1840; Murty and Manikyam, 2007).

In present study, ten meristic characters for the 3 species of family Platycephalidae were examined and compared (Table 1). Several characters were found to be similar within species. Number of first dorsal fin rays (DSFR) and gillrakers on upper limb (GLRU) were also found to be consistent in all the three considered species. Most of the meristic features showed differentiating counts between the two genera namely *Cociella* and *Grammoplite.* Barring anal fin rays (ANFR), none of the characters alone were able to distinguish among all the three species. ANFR for *C. crocodiles*, *G. scaber* and *G. supposites* were 11, 12 and 13, respectively, that separates the three species, narrowly. The ranges for meristic characters were found in concurrent with the description of Troschel (1840), Day (1878), Knapp (1999) and Fisher and Bianchi (1984).

Morphometric features have not been intensively used for species differentiation by the earlier workers. Few researchers have incorporated morphometric variables scaled either to head length or standard length but unlike meristic characters, they rarely are used them for comparison between species (Day 1878; Murty and Manikyam, 2007). In present study, proportions of nine morphometric variables scaled to head length and 8 morphometric variables scaled to standard length revealed difference in mean values among the three species. An analysis of variance (ANOVA) carried out for the morphometric ratios indicated significant difference in means except for pre anal length with standard length (PAL/SL), preorbital length with head length (POL/HL) and maximum eye diameter with head length (MED/HL), where difference in mean were insignificant at 95% level (Table 2). F-value for length of upper pre-opercular spine (LPrOSU) was significantly higher than others, emphasizing on the considerable difference in mean values within the species. Length of the spine in *G. supposites* was found to be more than the remaining two species (2-3 times longer). Similar observations were also quoted by George (1968) while comparing *G. supposites* and *G. scaber*. Anal fin base length (ABL/SL) showed difference among the three species and could find application in species discrimination either alone or in combination with other traits. Pre-orbital length (PrOL/HL) in *G. scaber* was found to be shorter than the rest of the two species. Pre-orbital length (POL), along with head length (HL) and spines lengths, were among the key morphometric variables catalogued by the Day (1878) and Murty and Manikyam (2007).

After factor analysis eight morphometric ratios sorted were subjected to Stepwise Discriminant Function

Table 1. Descriptive statistics of different meristic characters of three species of family Platycephalidae occurring along west coast of India

	G. suppositus (N = 31)		*G. scaber* (N = 25)		*C. crocodiles* (N = 9)	
Variables	Median	CV	Median	CV	Median	CV
SCABLL	52	3.731	53	1.210	66	5.741
DSFS	9	0.000	9	0.000	9	0.000
DSFR	12	0.000	12	0.000	11	0.000
ANFR	13	0.000	12	0.000	11	0.000
PCFR	20	3.750	19	2.464	20	2.500
PLvFR	6	0.000	6	0.000	6	5.455
GLRU	1	0.000	1	0.000	1	0.000
GLRL	8	7.433	6	3.356	5	0.000
LLSC	52	3.881	53	1.286	64	4.081
PLLSC	52	4.542	53	1.286	54	1.537

Analysis (SDFA) to extract more relevant morphometric characters for their classification or discrimination power. The Stepwise Discriminant Function Analysis incorporated six out of eight fed variables in the model. The relative importance of these incorporated characters in the model is expressed by their loading on functions (roots). Highest factor loadings of anal fin base length with standard length (ABL/SL) on both the roots stresses upon its higher distinguishing power compared to other variables. Rest of the incorporated variables reveal more or less equal contribution in species differentiation (Table 3).

SDFA has formed a classification matrix showing correct classification in 98.46% cases, with only one misclassification (Table 4). One case of *G. supposites* is predicted as *G. scaber* by classification matrix. An instance of misclassification between *G. scaber* and *G. supposites* indicated toward the morphometric similarity of these species which is further affirmed by the lower squared Mahalanobis distance (22.136) between the two species. *G. scaber* was found to be most distant to *C. crocodiles* in morphometric terms as the value of squared Mahalanobis recorded was maximum for the pair (Table 5).

Scatterplot of canonical scores where different cases of the same species were grouped and clearly separated from the clusters of the other species (Fig. 4). Several variables included in the model had also featured in past literatures (Day, 1878; George, 1968; Murty and Manikyam, 2007).

In *G. scaber,* all lateral line scales bear a robust spine of continuously increasing size from anterior to posterior end of body, no black blotch on first dorsal fin, cross bands visible on the body. These characters were also

Table 2. Descriptive statistics of different morphometric variables of three species of family Platycephalidae occurring along west coast of India

Species	*C. crocodilus*			*G. suppositus*			*G. scaber*			ANOVA Results	
Variables	N	Mean	CV	N	Mean	CV	N	Mean	CV	F-value	Sig.
HL/SL	9	0.356	3.691	31	0.362	9.920	25	0.316	7.347	17.476	0.000
PDL/SL	9	0.369	2.326	31	0.355	10.337	25	0.315	6.884	18.136	0.000
PPvL/SL	9	0.393	2.802	31	0.382	9.497	25	0.345	6.867	14.093	0.000
PAL/SL	9	0.612	2.345	31	0.581	13.683	25	0.553	2.832	3.999	0.023
PPL/SL	9	0.300	3.082	31	0.299	9.385	25	0.268	7.028	14.298	0.000
DBL1/SL	9	0.200	2.647	31	0.219	17.496	25	0.176	10.930	14.847	0.000
DBL2/SL	9	0.267	2.741	31	0.313	9.467	25	0.328	4.647	23.433	0.000
ABL/SL	9	0.287	3.754	31	0.354	12.284	25	0.327	8.879	13.323	0.000
DBwULJ/HL	9	0.042	10.813	31	0.047	7.728	25	0.040	14.224	16.366	0.000
LPrOSU/HL	9	0.060	13.086	31	0.217	10.739	25	0.083	12.607	510.826	0.000
LPrOSL/HL	9	0.026	25.180	31	0.050	27.618	25	0.053	11.820	22.041	0.000
PrOL/HL	9	0.320	1.076	31	0.314	4.611	25	0.277	10.552	26.160	0.000
POL/HL	9	0.504	2.362	31	0.521	2.373	25	0.515	5.793	2.198	0.120
SnL/HL	9	0.305	2.590	31	0.297	6.237	25	0.261	12.944	19.111	0.000
MED/HL	9	0.179	4.504	31	0.184	11.853	25	0.168	23.700	2.000	0.144
MLSDS/HL	9	0.421	7.290	31	0.091	20.859	25	0.067	22.338	27.204	0.000
MLSDR/HL	9	0.359	7.391	31	0.376	12.611	25	0.348	8.965	11.796	0.000

Note: Variable with sig. value of <0.05 shows significant difference in mean across the species at 95% level of confidence

(Note: SL: Standard length, HL: Head length, SnL: Snout length, MED: Maximum eye diameter, POL: Post orbital head length, PDL: Pre dorsal length, DBL 1: First dorsal fin base, DBL 2: Second dorsal fin base length, ABL: Length of anal finbase,MLSDR: Maxi. L. of 2nd dorsal ray, PPL: Pre Pectoral length, PPvL: Pre-pelvic Length, PrOL: Pre-orbital length, IOW: Inter orbital width, MLFDS: Maxi. L. of first dorsal spine, MLSDS: Maxi. L. of 2nd dorsal spine, PAL: Pre anal fin length, AFBL: Anal fin base length, DBwULJ: Diff. b/w U and L jaw, LPrOSU: Length of preopercular spine upper, LPrOSL: Length of preopercular spine lower, DSFS: Number of spines on the first dorsal fin, DSFR: Number of rays on the second dorsal fin, PLvFR: Number of rays on the pelvic fin, PCFR: Number of rays on the pectoral fin, ANFR: Number of rays on the anal fin, GLRU: Gill rakers on the upper limb of first gill arch, GLRL: Gill rakers on the lower limb of first gill arch, TOTGILLRAK: Total gill rakers on the gill arch, LLSC: Number of scales on the lateral line, LATLINEPS: Number of pored scales with lateral line on the lateral line, NUBSCSPN: Number of scales with spine on lateral line, SCABLL: Number of scales above the lateral line lateral line)

Table 3. Factor structure matrix for the three species of Platycephalidae occurring along west coast of India (pooled within group correlations)

Variables	Root 1	Root 2
PrOL/HL	-0.27842	-0.26408
DBL2/SL	0.273168	-0.20242
PDL/SL	-0.24058	-0.17656
HL/SL	-0.20208	-0.30325
ABL/SL	0.062476	-0.42777
PPvL/SL	-0.21112	-0.16095

Table 4. Classification matrix generated by SDFA model for three species of family Platycephalidae occurring along west coast of India

Clasiifcation matrix generated by SDFA				
Species	Per cent	*G. scaber*	*G. suppositus*	*C. crocodilus*
G. scaber	100	25	0	0
G. suppositus	96.774	1	30	0
C. crocodilus	100	0	0	9
Total	98.461	26	30	9

Table 5. Squared Mahalanobis distance between three species of family Platycephalidae occurring along west coast of India

Squared Mahalanobis distance			
Species	*G. scaber*	*G. suppositus*	*C. crocodilus*
G. scaber	0.000	22.316	77.956
G. suppositus	22.316	0.000	35.519
C. crocodilus	77.956	35.519	0.000

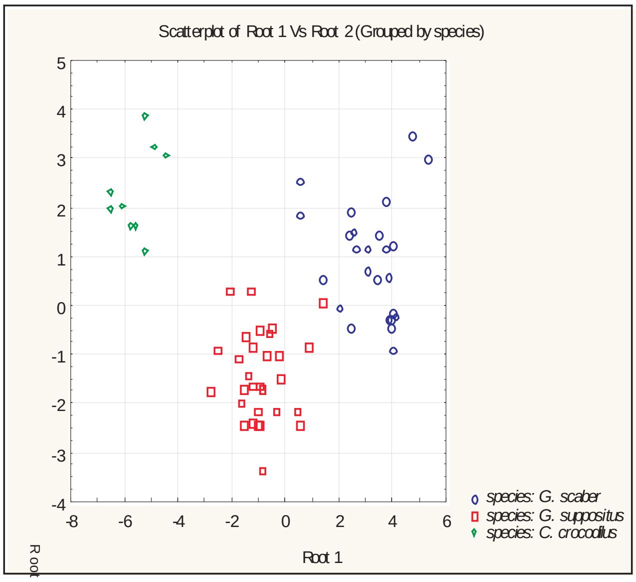

Fig. 4. Scatter plots of canonical scores for Root 1 and Root 2 of the morphometric variables of three species of Platycephalidae occurring along the west coast of India

reported by Mohammadikia and Kamarani (2012), Shao and Chen (1987), George (1968) and Carpenter *et al.* (1997). The range of lateral line scales in *G. suppositus* was found to be 49 to 56. Same feature were also reported by Murty and Manikyam (2007), Murty (1975),while Mohammadikia and Kamarani (2012) reported 47 to 56. First dorsal fin spine 9, second dorsal fin rays 11and anal fin ray 11 and cross bands 4-6 were recorded in *C. crocodiles,* which shows similarity with finding of (Knapp, 1986).

CONCLUSIONS

The taxonomic ambiguity in selected species of family Platycephalidae has been resolved in the present study.

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Received 26 April, 2016; Accepted 04 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 826-828

Manuscript Number: 2386
NAAS Rating: 4.47

Growth and Yield Attributes of Wheat and Paddy Under (*Populus deltoides*) Based Agrisilviculture System

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***Abstract*:** The performance of three wheat varieties (NW-1067, NW-1014 and HD-2643) and three paddy varieties (Sarjoo-52, NDR-359 and Swarna) were assessed under six year old *Populus deltoides* plantation at different distances from tree base (0.5m, 1.0m, 1.5m and 2.5m) and control (open condition). Under this study plant height was found better for wheat variety HD-2643 (Plant height 90.90cm) and paddy variety NDR-359 (plant height 96.34cm), when the crop was grown at 0.5m away from the tree base. However, maximum number of grain per ear/ panicle, grain yield (t ha^{-1}) were recorded in case of wheat variety NW-1014 (2.32 t ha^{-1}) and paddy variety NDR -359 (2.31 t ha^{-1}), When the crop was grown in control. Amongst different varieties, wheat variety NW-1014 and paddy variety NDR-359 were found most suitable for under this study.

***Key Words*:** Grain yield, Panicle, *Populous deltoides*, Sarjoo-52, Varieties

Poplar is the very prominent taxonomic group of tree species in plantation forestry as well as in natural forests northwestern state of India. Its natural population is small and found only in the mountains with six indigenous species. As an exotic species *(Populous deltoids*), it acquire great role afforestation/reforestation programmes, agro-forestry and conservation activities. According to India country report on poplar and willow (Anonymous 2012), area under poplar outside the forest in India is estimated to be 312,000 ha. The annual return from poplar at current market rates are estimated to be around one Rs. 60-80,000 rupees $acre^{-1}$ $year^{-1}$, which is much higher than any other on-farm intervention (Dhiman, 2012). Poplar is normally planted and grown under wide spacing accommodating 400 to 500 tree ha^{-1}. Its stand density permits enough sunlight and air circulation and therefore gives better crops yields (Tewari, 2002). In many locations, farmers now plant more trees per unit area than recommended number of 400-500 trees ha^{-1} with the hope to get increased returns. This study was therefore, planned to study the effect of different distances from tree base on wheat and paddy performance in *Populus deltoides* based agri-silvicultural system.Poplar based agroforestry systems are economically viable and more profitable than many other crop rotations (Jain and Singh, 2000; Chauhan and Mangat, 2006). It is usually managed in 6-8 years rotation cycle under agroforestry system. Owing of 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 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. Cropping with tree species is an ancient practice and very important tools 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). Growth of the poplar depends upon various factors such as clone, quality of planting stock, spacing of the trees, intercrops, site quality, climate and management practices (Tewari, 1995;Chauhan *et al*., 2012a,2015a).Its popularity with the farmer 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*., 2012b, 2015b). It benefits the farmers both economically and from soil physical fertility point of view.

The present study was conducted during 2011-2012 in already established 6 years poplar plantation spaced at 5 m x 4 m at N. D. University of Agriculture and Technology, Kumarganj, Faizabad (26^{0}27' N latitude and 82^{0} 12' E longitudes at an elevation of 113 m above mean sea level). The annual rainfall during 2011-2012 was 874.4 mm. The mean monthly maximum temperature ranged from 20.4^{0}C (January) to 41.6^{0}C (June) and mean monthly minimum temperature varied from 7.8^{0}C (December) to 28.0^{0}C (June) during the study period. The soil of experimental site is partially improved salt affected with pH=8.5. It is medium in available nutrients (NPK) and organic matter. There was no tree in control (only crop). The trees at random on in 5 m x 4 m spacing was measured for their top height and girth at breast height (GBH). The height was measured from ground to top of the trees.

The seeds of three varieties of wheat (NW-1067, NW-1014 and HD-2643) were sown during the 15th November, 2011. 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 the phosphorus was applied at the time of sowing and remaining N was applied (top-dress) to wheat crop under 5 m x 4 m spacing of poplar plantation and in control (open condition) after the first irrigation. However, seedlings of the three paddy varieties (Sarjoo-52, NDR-359 and Swarna) were raised in well prepared nursery bed during 30th May to 29th June 2012, and transplanted on 30th June at the distance of 20 cm from row to row and 10 cm from hill to hill. Before transplanting of seedlings, half dose of nitrogen and full dose of phosphorus and potash were applied. Remaining N was used twice *i.e.* after 30 and 60 days of transplanting. Wheat and paddy crop was estimated in terms of growth and yield parameters (plant height, grains per ear/panicle and grain yield) by quadrate method at time of harvest. Five quadrates of 1 m^2 were selected per replication between rows of poplar. The yield of produce (grain) was extrapolated to be expressed in t ha^{-1}.

The experiment was laid out in Factorial Randomized Block design with five replications. All cultural practices were adopted as per recommended for cultivation of wheat and paddy.

The variations in growth characters were significant in different wheat varieties. Wheat variety HD-2643 grown 0.5m away from tree base produced plant height (90.90cm), which was significantly higher than other varieties of wheat followed by NW-1067 (88.56 cm) (Table 1). However, significant higher number of grains per ear (32.34) was found in NW-1067 followed by HD-2643 (30.32), when the crop was grown in control. Similar results have also been reported by Gandhi (2008) and Dhillon *et al* (2016). Significant higher plant height (96.34cm) was recorded for paddy variety NDR-359, which was significantly higher than all other paddy varieties followed by Swarna (92.01 cm), when the crop was grown at 0.5m away from tree base. However, significant higher number of grains per panicle (204.45) was found in NDR-359 followed by Sarjoo-52 (194.33), when the crop was grown in control. It may be due to the fact that direct light intensity favours number of shoots. The variation in height of different varieties at varies distance from tree base might be due to differential competition for light, soil moisture and nutrients.

The grain yield was significantly influenced by variety and distance and the interaction between variety and treatment. Significantly higher grain yield (2.32 tha^{-1}) was recorded with wheat variety NW-1014, which was closely

Table 1. Plant growth for wheat and paddy varieties under *Populus deltoides* based agri-silvicultural system

Distance from	Wheat varieties			Mean	Distance from tree base (m)	Paddy varieties			Mean
	NW-1067	NW-1014	HD-2643			Sarjoo-52	NDR-359	Swarna	
	Plant height (cm)					Plant height (cm)			
0.5	88.56	87.56	90.90	89.00	0.5	79.01	96.34	92.01	89.12
1.0	86.90	86.56	88.67	87.38	1.0	76.34	93.34	90.32	86.66
1.5	86.20	85.23	87.24	86.23	1.5	76.01	91.01	88.34	85.12
2.5	83.90	83.56	86.23	84.56	2.5	70.34	91.34	88.67	83.45
Control	80.23	78.90	82.32	80.48	Control	65.67	85.34	82.67	77.89
Mean	85.16	84.36	87.07		Mean	73.47	91.47	88.41	
	Variety (V)	Distance(D)	V × D			Variety (V)	Distance (D)	V × D	
CD (p=0.05)	0.32**	0.41**	0.71**		CD (p=0.05)	1.06**	1.37**	2.37**	
	Number of grains (grains ear^{-1})					Number of grains ($panicle^{-1}$)			
0.5	25.01	24.67	24.01	24.56	0.5	179.23	184.00	171.23	178.15
1.0	26.67	25.65	25.01	25.78	1.0	180.12	185.33	172.22	179.22
1.5	29.01	26.32	26.34	27.22	1.5	182.34	186.68	173.67	180.89
2.5	30.01	27.67	27.67	28.45	2.5	182.67	188.34	174.34	181.78
Control	32.34	28.99	30.32	30.55	Control	194.33	204.45	186.54	195.11
Mean	28.61	26.66	26.67		Mean	183.74	189.76	175.60	
	Variety (V)	Distance (D)	V × D			Variety (V)	Distance (D)	V × D	
CD (p=0.05)	0.53**	0.68**	1.18**		CD (p=0.05)	0.98**	1.27**	2.19**	

** Significant at 1% level

Table 2. Grain yield of three wheat and paddy varieties under *Populus deltoides* based agri-silviculture system

Distance from	Wheat varieties			Mean	Distance from tree base (m)	Paddy varieties			Mean
	NW-1067	NW-1014	HD-2643			Sarjoo-52	NDR-359	Swarna	
	Grain yield (tha^{-1})					Grain yield (tha^{-1})			
0.5	1.14	1.15	1.14	1.14	0.5	1.56	1.58	1.33	1.49
1.0	1.44	1.32	1.28	1.35	1.0	1.71	1.69	1.54	1.65
1.5	1.99	1.46	1.37	1.61	1.5	1.87	1.79	1.64	1.77
2.5	2.27	1.74	1.82	1.95	2.5	1.90	1.99	1.74	1.87
Control	2.30	2.32	2.25	2.29	Control	2.21	2.31	2.18	2.23
Mean	1.83	1.60	1.57		Mean	1.85	1.87	1.69	
	Variety (V)	Distance (D)	V × D			Variety (V)	Distance (D)	V × D	
CD (p=0.05)	0.59**	0.76**	1.31**		CD (p=0.05)	0.43**	0.55**	0.96**	

** Significant at 1% level

followed by NW-1067(2.30 tha^{-1}) in control (Table 2). The variation in yield of different varieties at varies distance from tree base might be due to differential competition for light, soil moisture and nutrients. Similar results have also been reported by Singh *et al* (2014). The variety and distance was significantly affected the yield of paddy crop. Among all the three varieties of paddy crop significantly higher grain yield (2.31tha^{-1}) was recorded in NDR-359, which was closely followed by Sarjoo-52 (2.21 tha^{-1}) variety in control. The reduction in the grain yield under tree canopies may be due to the fact that shade negatively affects grain yield. Similar results have also been reported by Sirohi *et al* (2012) and Chauhan *et al.* (2012c).

The perennial plant (*Populus deltoides*) have significant effect on the performance of annual crops i.e. wheat and paddy. The number of grain per ear/ panicle and grain yield was found to be significantly higher in control. Whereas, the plant height was significantly higher when crops were grown in 0.5 m from tree base. On the basis of the yield potential, it may be concluded that wheat variety NW-1014 was found to be the best variety of wheat under agri-silviculture system. In case of paddy, NDR-359 is a suitable variety in comparison to the other.

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Received 16 April, 2016; Accepted 14 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 829-831

Manuscript Number: 2387
NAAS Rating: 4.47

Chemical Properties of Soils in Relation to Different Forest Vegetation Covers of Achanakmar Chhattisgarh, India

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Abstract: The present study was carried out under soils of different forest vegetation covers to assess the chemical properties of soils in relation to different vegetation covers viz. *Tectona grandis*, *Bambusa arundinaceae*, *Shorea robusta,* mixed, open and scrub. The organic carbon, total nitrogen, soil organic matter, were analyzed for three different soil depths viz. 0-20, 20-50 and 50-100 cm. The per centage values of soil organic carbon, total nitrogen, soil organic matter and C:N ratio were found highest under the soils of mixed vegetation cover followed by *Tectona grandis*, *Bambusa arundinaceae*, *Shorea robusta* and least under open and scrub vegetation covers. Organic carbon and total nitrogen showed a positive relationship with soil organic matter. Both organic carbon and total nitrogen contents decreased with the increasing depths of soil.

***Key Words*:** Achanakmar, C:N ratio, Forest vegetation covers, Soil organic matter, Soil organic carbon, Soil total nitrogen

The growth and reproduction of forest cannot be understood without the knowledge of soil. The soil and vegetation have a complex interrelation because they develop together over a long period of time. The vegetation influences the chemical properties of soil to a great extent. Moreover, different tree species can differ significantly in their influence on soil properties as well as soil fertility (Augusto *et al.,* 2002). The properties of the soil are the important factor for the growth of the plants. Among them, the most important factor is soil fertility i.e. the essential nutrients available in the soil, for the growth of plants. The adequate theoretical and practical knowledge of various forest soils and the complex relationship between the life of various trees and other plants of the forest is therefore necessary to study.

The soil organic carbon (SOC) and soil total nitrogen (STN) are some of the soil properties that are used as basic indicators in assessing soil property and soil quality. The SOM and STN are the major determinants and indicators of soil quality and fertility and are closely related to soil productivity (Al-Kaisi *et al.*, 2005). The reduction of SOC and STN will lead to a decrease in soil fertility, soil nutrient supply and porosity (Gray and Morant, 2003).

The carbon: nitrogen ratio indicates the availability of carbon and nitrogen (C/N) in the soil (Miller, 2001). The C and N cycles in the soil are linked through processes of N assimilation, N mineralization, denitrification and organic matter decomposition (Yano *et al.,* 2000). Apart from the importance of C and N separately, the relation between them is interesting in ecological terms. The C:N ratio is widely used, when researching on the ecology of the forest. This ratio indicates the availability of N in floor material, rate of decay of the forest floor (Fisher and Binkley, 2000) and the quality of the organic matter under the canopy (Cote *et al.*, 2000) which can also be linked to the soil microbial biomass (Hogberg, 2004). Very limited studies are available related to the chemical properties of soils in Central Tropical India, the present study was thus carried out to assess the various chemical properties of soils with respect to different vegetation covers to know the ecological relationship of different vegetation covers on nutrient storage and fertility status of soils.

The present study was carried out in Achanakmar Chhattisgarh, lies between east longitudes 81° 51' 76'' E and north latitudes 22° 24' 56'' N**.** The annual temperature varies from 9.2°C to 42.1°C. The hottest months are May and June and the minimum temperature is in December and January. The July and August are the heaviest rainfall months and nearly 95 per cent of the annual rainfall is received during June to September. The rainfall is unevenly distributed and also the amount of rainfall varies from year to year and experiences a hot and semi-humid climate. The average rainfall is 130.04 cm. The relative humidity is higher during the South West monsoon season, being generally over 75%. After monsoon Season, humidity decreases and during the winter season, air is fairly dry.

Soil sampling was carried out randomly in under different vegetation covers viz. sal, teak, bamboo, mixed, open and scrub vegetation covers. A total of 60 (4 replicates x 3 soil depths x 5 vegetation covers) soil samples were collected. It was ensured that sampling sites typically represent the whole study area. The soil samples were collected from three different depths viz., ''upper'' (0–20 cm),

Table 1. Geographical location and soil organic carbon (%)* at various depths in the soils of different forest vegetation

Vegetation	Latitude	Longitude	Soil organic carbon (%)			
			0-20 cm	20-50 cm	50-100 cm	Average
Sal	N 22° 33.71"	E 81° 44.61"	1.36 (2.35)	0.77 (1.32)	0.35 (0.60)	0.82 (1.42)
Teak	N 22° 31.72"	E 81° 45.44"	1.63 (2.81)	0.91 (1.56)	0.31 (0.53)	0.94 (1.62)
Bamboo	N 22° 27.96"	E 81° 46.86"	1.45 (2.50)	0.76 (1.31)	0.28 (0.48)	0.83 (1.43)
Mixed	N 22° 23.25"	E 81° 53.09"	2.52 (4.43)	1.18 (2.03)	0.51 (0.87)	1.40 (2.41)
Open and Scrub	N 22° 27.96"	E 81° 46.86"	0.86 (1.48)	0.53 (0.91)	0.25 (0.43)	0.54 (0.93)

* Soil organic matter in parentheses

"middle" (20-50 cm) and "lower" (50-100 cm). The soil tests were conducted at the forestry, wildlife and environmental sciences, Guru Ghasidas Vishaviayalaya, Bilaspur, Chhattisgarh. Walkley and Black's rapid titration method as modified by Walkley (1947) was adopted for organic carbon estimation. The factor of 1.724 was used to convert the values of organic carbon into soil organic matter. Total nitrogen was estimated by the Kjeldhal method.

The organic C was found higher under soils of mixed vegetation followed by *Tectona grandis*, *Bambusa arundinaceae*, *Shorea robusta* and open and scrub vegetation. Organic C (%) was also comparatively higher in the soils of upper horizons followed by middle horizons and least was observed in lower horizons among all the five vegetation covers (Table 1). The organic C content decreased with the depth of the soil among all five vegetation covers which may be due to the fact that humus formation and decomposition of organic matter takes place in the upper layers. The average values of SOM varied from 0.93 to 2.4 per cent under different vegetation covers. The decrease in SOM with increasing depth was observed among all the vegetation covers (Table 1).

The average values of total N also varied significantly in different vegetation covers being maximum in soils of mixed vegetation cover and lower in open and scrub. The trend of decreasing total N per cent was observed with increasing soil depth among all vegetation soils (Table 2). Cote *et al.* (2000) and Singh *et al.* (2016) concluded that both organic C and total N were significantly affected by species composition. In the present study, soil organic matter, soil organic carbon and total N under different vegetation covers were having a close relationship as the values of different soil chemical properties were found higher in mixed vegetation cover followed by teak, bamboo, sal and lower in open and scrub vegetation cover. The high amount of organic matter in the forest types in the upper layers may also be the reason for richness of organic C and total N in the upper layers as compared to lower layers. This finding was also supported by Gupta and Sharma (2008) who also recorded that all these attributes were intimately linked with soil

Table 2. Soil total nitrogen (%) and C:N ratio* at various depths in the soils of different forest vegetation

Vegetation	Soil total nitrogen (%)			
	0-20 cm	20-50 cm	50-100 cm	Average
Sal	0.229 (5.94)	0.114 (6.76)	0.008 (3.98)	0.144 (5.77)
Teak	0.288 (5.66)	0.197 (4.62)	0.119 (2.61)	0.202 (4.66)
Bamboo	0.250 (5.80)	0.153 (4.97)	0.093 (3.02)	0.166 (5.00)
Mixed	0.399 (6.32)	0.216 (5.47)	0.123 (4.15)	0.217 (6.46)
Open and Scrub	0.126 (6.83)	0.079 (6.71)	0.045 (5.56)	0.084 (6.43)

*C:N ratio in parentheses

humus. The average values of C:N ratio in the study area varied between 4.66 to 6.46 (Table 2). Teak, bamboo and sal had a lower C:N ratio compared to the mixed and open and scrub vegetation covers.

The present study lead to the conclusion that among different vegetation covers the mixed forest vegetation cover was comparatively rich in nutrient and fertility status which is the indication of higher nutrient release due to input of varying litter, humus quality and decomposition rate in mixed vegetation compared to mono-cropping system.

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Received 02 May, 2016; Accepted 30 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 832-834

Manuscript Number: 2388
NAAS Rating: 4.47

Development and Evaluation of Pest Management Modules Against *Thrips tabaci* (Lindeman) in Onion

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***Abstracts*:** The four modules of pest management were evaluated to control thrips, a major pest in onion. M-II comprising of repeated application of chemicals viz., first application of monocrotophos 36 SL 0.04% – second spray of Profenofos 50 EC 0.2% – third spray of lambda-cyhalothrin 25 EC 0.2% proved to be best with minimum thrips population followed by pest management module, M-I (barrier crop module). Pest management module, M-III with only eco-friendly approaches proved to be ineffective. The minimum damage rating by thrips was observed in pest management modules, M-II as against maximum in M-IV. Among different module, the highest marketable yield was in M-II, which resulted in maximum net returns. However, the highest BC ratio was recorded in module, M-I followed by M-II. The total marketable yield was 303.52 and 297.51 q/ha with Rs. 38655 and 32786 net returned.

Key Words: Onion, Pest management module, Thrips tabaci

Productivity of onion (*Allium cepa* L.) is affected by many insect pests *viz*., thrips (*Thrips tabaci L.*), cutworm (*Spodoptera litura F.*), head borer (*Helicoverpa armigera Hub.*) and onion fly (*Delia sp*. Meigen), of which onion thrips is one of the most important pests in India causing yield loss by sucking sap from the plants. The present pest management strategy is pesticide intensive and insecticide application to control thrips in onion is adopted by farmers. The use of the IPM program significantly reduced insecticide inputs without adversely affecting onion yield or quality. In addition, insecticide costs and negative environmental impact were reduced significantly in the IPM fields. These demonstrations have shown that IPM module recorded the lower population of aphid (*Aphis gossypii* Glower), jassid (*Amrasca biguttula biguttula* Ishida), whitefly (*Bemisia tobaci* Genna) and thrips (*Thrips tabaci* Lindeman) compared to non-IPM practices (Ameta and Bunker, 2009). Adult thrips migrate from exiting onion field to neighboring newly sown onion crop. Therefore barrier the adult thrips to reach onion crop may be greatly helpful in reducing the initial pest load and subsequent multiplication of pest (Srinivas and Lawande, 2006). Keeping these points in view, four pest management modules were evaluated against *Thrips tabaci* in onion crop.

The field trial was conducted during *rabi* season of 2010-11 and 2011-12 at JNKVV, Jabalpur. Four Pest management modules i.e. First module consist of 2 outer row of maize and 2 inner row of wheat. Second chemical based module consist of 1st spray with monocrotophos 36 SL 0.04%, 2nd spray with profenofos 50 EC 0.2%, 3rd spray with lambda-cyhalothrin 25 EC 0.2%. Third modules was based on botanical and consist of 1st spray with neem oil 1%, 2nd spray with karanj oil 1% were evaluated along with untreated control against *Thrips tabaci*. Onion cv. Agrifound light red sown was in 5X1 sq. m. nursery plot on 4th week of October 2010 and 2011. Fifty five days old onion seedling was transplanted in approximately 250 m^2 plot size under randomized block design. Each module comprising with 40 plots size of 3X2 m^2 under four replications. The row to row and plant to plant distance was maintained as 15 and 10 cm, respectively. In module M-I, the maize and wheat crops were sown on all 4 sides of the module plot in two rows each before 20 days transplanting of onion crop. The spacing was maintained at 25x20 cm for maize however wheat was sown densely. In module M-II and M-III the sprays of insecticides and botanicals, respectively were given 3 times at an interval of 15 days starting from initial appearance of *Thrips tabaci.* Five plants were randomly tagged for counting of thrips population in each plot. From such tagged plants, the pest population was recorded one day prior, 5, 10 and 14 days after each spray. The observations were also made on damage rating at 70-80 days after transplanting (the time at which maximum damage rating found). Damage rating was recorded as per the scale (2 - 5) given by Smith *et al.* (1994) (1-10% leaf damage = 2, 10-25% leaf damage = 3, 25-50% leaf damage = 4, more than 50% leaf damage = 5).

The mean population of thrips nymphs and adults in onion per plant before spray was not significant both years (Table 1). However, significant difference was obtained on the mean count of thrips of 14 DAS in all modules due to the effect of barrier crop, pesticide spray and botanicals as compared to

Table 1. Efficacy of different pest management modules on thrips population, damage rating and marketable yield of onion

Module	Pooled data of both year					
	Mean thrips nymph and adults plant^{-1}				Damage rating	Marketable yield (q ha^{-1})
	BS	5 DAS	10 DAS	14 DAS		
M-I	19.34	21.01 (4.63)	17.38 (4.22)	13.60 (3.75)	3.46	300.51
M-II	23.01	6.23 (2.63)	12.80 (3.64)	13.50 (3.74)	2.33	320.56
M-III	23.51	15.29 (3.97)	15.23 (3.96)	17.23 (4.21)	3.97	282.25
M-IV	23.44	28.33 (5.36)	28.85 (5.41)	29.41 (5.46)	5.16	228.27
CD (p=0.05)	NS	(0.81)	(1.03)	(1.10)	0.38	17.36

BS = before spray, DAS= Days after spray

Table 2. Efficacy of pest management modules on cost benefit ratio in onion

Module	Pooled data of both year					
	Mean yield (q/ha)	Increased in yield over control module	Value of increased yield	Cost of pest management module	Net return (Rs ha^{-1})	B:C ratio
M-I	300.51	72.24	36120	432	35688	1:82.6
M-II	320.56	92.29	46145	1902	44243	1:23.2
M-III	282.25	53.98	26990	1532	25458	1:16.6
M-IV	228.27	-	-	-	-	-

untreated control module M-IV. The thrips population was recorded lowest in M-II module and highest in M-IV module during both the year of studies after 5, 10 and 14 days after spray, which may be due to the fact that monocrotophos, 36 SL 0.04%, Profenofos 50 EC 0.2% and lambda-cyhelothrin 25 EC 0.02%, has long lasting protection period and high insecticidal potency than the others. Profenofos is also potent against neonates (ovi-larvicidal activity) as they hatched from the eggs resulting in lowest population of nymph/plant in this module, compared to the other modules. Profenofos was the best insecticide for controlling *Thrips tabaci* followed by lambda-cyhalothrin and monocrotophos in pest management modules M-II as compared to M-IV. Patel *et al.* (2001) and Sollam and Hosseny (2003) reported that profenofos gave significantly better control of thrips as compared to conventional insecticide in onion. Simon and Victor (2005) reported that the highest larval mortality was with lambda-cyhalothrin. Malik *et al.* (2003) observed monocrotophos 40 SL provided effective control of *Thrips tabaci* in onion. The barrier crop of maize and wheat effectively blocked the mean nymphs and adults thrips by 13.60 plant^{-1} at 10 days after spray in comparison to control (28.85 thrips plant^{-1} at 10 days after spray). In module M-I, the broad leaves of maize and zigzag planting act as a barrier to adult thrips very effective because wheat rows blocked thrips migration at bottom and maize at the above. Similarly, Srinivas and Lawande (2006) reported maize barrier as cultural method for management of thrips in onion. The minimum pooled damage rating 2.33 was recorded in module M-II followed by M-II and M-III modules. All the modules were significantly superior in reducing the damage rating by *Thrips tabaci* as compared to untreated control. The marketable onion bulb yield per quintal of all the modules was significantly superior to the untreated control. Highest marketable bulb yield (320.56 q ha^{-1}) was obtained from module M-II (Table 2). Sollam and Hosseny (2003) and Patel *et al*. (2001) also reported similar results due to less infestation of thrips in chemically controlled onion field. The highest B:C ratio was obtained from module M-I (1:82.6). In module M-II due to application cost of chemicals to control of thrips was higher as compared to module M-I with 1:23.2 B: C ratio.

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Received 31 January, 2016; Accepted 14 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 835-837

Manuscript Number: 2389
NAAS Rating: 4.47

Functional Behavior of Lotus Rhizome Harvested from High Altitude Dal Lake of Kashmir

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Abstract: Lotus rhizomes harvested from high altitude Dal lake, Srinagar, India, were sliced and dried and analysed for various physico-chemical, functional and pasting properties. The moisture content, protein, fat, ash, fibre, carbohydrate and starch content in lotus rhizome were recorded as 5.90, 8.23, 2.72, 1.33, 10.80, 71.01 and 53.37%,respectively The water solubility, swelling capacity, water absorption capacity, least gelation concentration, bulk density, foaming capacity, foaming stability, emulsifying activity and emulsifying stability of the flour were recorded as 97.10, 2.90, 245.9, 17.60, 0.77, 5.43, 4.78, 46.60 and 88.40%, respectively. The pasting profile studies demonstrates than peak viscosity of the lotus rhizome flour was little lower (2075 cp) that most flours widely used in food industries.

***Key Words*:** Emulsifying activity and stability, Foaming stability, Foaming capacity, Least gelation concentration, Rhizome, Swelling capacity

Lotus, *Nelumbo nucifera* is a rhizomatous aquatic, ornamental, edible and medicinal plant, which is grown as a non-conventional vegetable commonly in China, India, Japan and Australia. In India lotus plant reportedly grows in almost all lakes and other water bodies, both at high altitudes of 1400 m above mean sea level e.g., Kashmir (North India) and low altitudes of 0.30 m above mean sea level e.g., Kanyakumari (Southern India). However, the lotus from the Kashmir valley is of prime importance owing to the geographic location and climate in which it grows. Biochemically, lotus rhizomes are composed of proteins, fats, carbohydrates and minerals besides being good source of energy. The rhizomes are used as popular health food. The alkaloid (liensinine) extracted from them is effective to treat arrhythmia (Ling *et al*., 2005), sunstroke, fever, dysentery, diarrhea, dizziness and stomach problems (Lee *et al*., 2005). The rhizome extracts also possess anti-obesity (Ono *et al*., 2006) and anti-diabetic properties (Mukherjee *et al*., 1997).

In Jammu and Kashmir State, the lotus rhizomes are popularly used as vegetables, however, the consumers usually do not prefer the smaller size rhizomes. These small size rhizomes are being locally used for development of some fried products. Despite its nutritional and medicinal importance, the lotus rhizome has remained an underutilized crop in Jammu and Kashmir. Therefore, the lotus rhizomes need to be exploited for the development of value added products, for which the critical evaluation of its functional behaviour is important. Functional properties are the fundamental physico-chemical properties that reflect the complex interaction between the compositions, structure, molecular conformation and physio-chemical properties of food components together with the nature of environment in which these are associated and measured (Kinsella, 1976; Kaur and Singh, 2006; Siddiq *et al*., 2009). Therefore, the objective was to collect data on functional properties of the lotus rhizome flour of high altitude Dal Lake of Srinagar, India. This will provide useful information to the industry people and other alike about the possibility of lotus rhizome flour in food formulations.

Dal Lake is located in Srinagar city at surface elevation of 1,583mts. The latitude and longitude of the Lake is 34°07' N and 74°52'E. The Lake is famous for lotus rhizome production. During November 2014, lotus rhizomes were harvested from Dal Lake and sorted based on size. The small sized lotus rhizomes were sliced and dried in cabinet drier at 50°C for 8 hours. The slices were ground to flour and stored in dry and air tight containers for analysis purposes.

Proximate composition: The proximate compositions i.e. moisture content, crude protein, crude fibre, ash and starch content of the raw material were determined using (AACC, 2000) methods. The crude fat and carbohydrate content were determined by using Soxtec 2045 (Foss instrument, Sweden) and difference method respectively.

Functional properties: The solubility and swelling capacity (SC) were determined by the method described by Leach *et al*. (1959) with slight modifications. The water absorption capacity (WAC) of the flour was determined using the methods suggested by Beuchat (1977). The gelation properties of the flour were determined by the method described by Coffman and Garcia (1977). The procedure of Akpapunam and Markakis (1981) was used to determine the preweighed (W_1) bulk density of the flour. Foaming capacity

(FC) of the flour was determined by the known method (Coffman and Garcia, 1977). The foam was allowed to stand for 8 hours at room temperature and the foam stability (FS) was expressed as the percentage retention of the of initial foam volume. Emulsifying activity (EA) and emulsion stability (ES) were determined by following the method of Neto *et al*. (2001). The emulsion stability (ES) was determined by heating the emulsion at 80°C for 30 minutes followed by centrifugation at 1100 × g for 5 minutes. The pasting properties were determined using Rapid Visco-Analyser **(**RVA).

The physico-chemical, functional and pasting properties of lotus rhizome are depicted in figure 1, 2 and 3, respectively. The moisture content, protein, fat, ash, fibre, carbohydrate and starch content in lotus rhizome were recorded as 5.90, 8.23, 2.72, 1.33, 10.80, 71.01 and 53.37%, respectively (Fig. 1). Some differences were found between the physico-chemical properties of the present study and those reported by Reid (1977), may be due to differences in geographical locations and altitude of the water bodies.

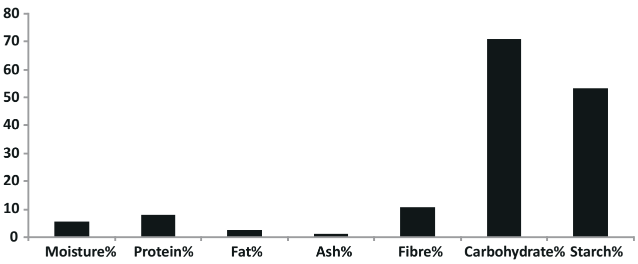

Fig. 1. Proximate composition of lotus rhizome flour

The per cent water solubility and swelling capacity of the flour were recorded as 97.10 and 2.90 respectively (Fig. 2). The water absorption capacity represents the ability of a product to associate with water under conditions where water is limited (Singh *et al*., 2001). The higher the amount of starch and fibre in the flour, the higher will be the water absorption capacity of the flour. The water absorption capacity of the lotus rhizome flour was found to be 245.9% (Fig. 2). The least gelation concentration of 17.60% indicates that the lotus rhizome flour formed gel at higher (17.60 g/100ml) concentration (Fig. 2). The lotus rhizome flour has a good protein and starch content. The physical competition for water between protein gelation and starch gelatinization influences the gelation capacity in the flour (Kaushal *et al.*, 2012). The particle size and initial moisture content of the flour determines the bulk density of the flour. Flours of high bulk density are suitable for food preparations, whereas, flours of low bulk density are suitable in the formulation of complementary foods (Akpata and Akubor, 1999). The bulk density of the lotus rhizome flour was recorded as 0.77% (Fig. 2). The protein content of the flour determines the foaming capacity of the flour. The protein dispersion lowers the surface tension at the water air interface. Therefore, the continuous cohesive film around the air bubbles in the foam are due to proteins. The foaming capacity and foaming stability of the lotus rhizome were recorded as 5.43 and 4.78% respectively (Fig. 2). The emulsifying properties of the flour are influenced by the hydrophobicity of proteins (Kaushal *et al.,* 2012). The capacity of proteins to enhance the formation and stabilization of emulsions is vital for many food applications. For food products, varying emulsifying and stabilizing capacities are important as the food composition and processes varies (Adebowale *et al.,* 2005). In the present study, the emulsifying activity and emulsifying stability of lotus rhizome flour were recorded as 46.60 and 88.40% respectively. The perusal of the results depicted in fig. 2 indicates that lotus rhizome flour has good functional properties and can be very well explored for the development of nutritionally rich value added products.

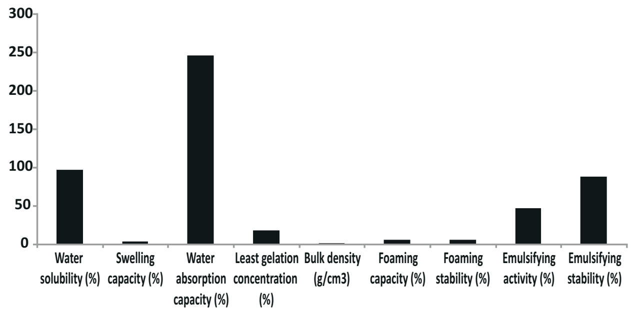

Fig. 2. Functional properties of the lotus rhizome flour

Pasting is the phenomenon following gelatinization in the dissolution of starch. The pasting properties are important for different industrial food uses. The pasting properties of the lotus rhizome are summarized in fig. 3. The pasting temperature, peak viscosity, hold viscosity, final viscosity, breakdown viscosity and setback viscosity of lotus rhizome flour were found as 89.75^{0}C, 2075, 1614, 2456, 461 and 842 centipoises (cp), respectively. The peak viscosity of the lotus rhizome flour was little lower (2075cp) than most common flours (rice and wheat flour) used in food industries

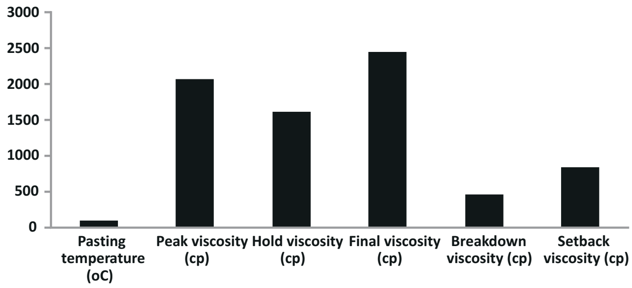

Fig. 3. Pasting properties of lotus rhizome flour

which indicates its structural rigidity than these flours. However, the other pasting properties (like hold, final, and bulk and setback viscosities) were found on the lower side except the pasting temperature. The higher pasting temperature of the lotus rhizome flour demonstrates its higher gelatinization temperature than flours taken from rice and wheat.

The data generated during the present study regarding the proximate compositional, functional and pasting properties of lotus rhizome of Dal lake, Kashmir may provide a guide line for its use in development of food products through baking, extrusion and other processes.

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Received 13 June, 2016; Accepted 15 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 838-840

Manuscript Number: 2390
NAAS Rating: 4.47

Economic Evolution of Safed Musli *(Chlorophytum borivilianum L.)*: A Study of Malwa region of Madhya Pradesh

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Abstract: The primary data were collected from 120 randomly selected safed musli growers of Indore and Dhar districts to study the economics of the crop. The total cost of cultivation was Rs. 3,16,612 ha^{-1} including total variable and fixed cost of Rs. 3,11,124 (98%) and Rs. 5,496 (2%) ha^{-1}, respectively. The expenditure on planting material (seed) was maximum i.e. Rs.2,46,167 (77%) per hectare of the total cost. At overall level, average production ha^{-1} of safed musli was 22.58 quintal. The farm business income, family labour income and cost of production were worked out to be Rs. 1,132; 10,8254 and 15,424 ha^{-1}, respectively. The net return of Rs. 75,070 ha^{-1} and cost-benefit ratio 1:1.21 indicates tremendous scope for cultivation of safed musli and its commercialization in large scale in the area under study.

Key Words: Economic evolution, Economic importance, Safed musli

Safed musli (*Chlorophytum borivilianum*) is one of the important medicinal plant and is used in medicines like Ayurvedic, Allopathic and Unani.The genus C*hlorophytum* includes about 300 species, which are distributed throughout the tropical and subtropical parts of the world. In India it is widely distributed in Madhya Pradesh, North Gujarat and Southern Rajasthan. It has got a good indigenous and globally market demand (Parmar *et al.,* 2007). Due to huge demand of safed musli plant product and profitable enterprises it can be considered in the cropping pattern as a cash crop by the growers. In this way it would generate income and employment opportunities especially in the potential areas of safed musli plant. So the present research work was undertaken to assess the economics of production of safed musli growers in Malwa Plateau of Madhya Pradesh.

The investigation area confined to Malwa Plateau of Madhya Pradesh, which comprises of nine district *viz.,* Indore, Dhar, Shajapur, Dewas, Ratlam, Mandsoure, Neemach and Rajgarh. Out of nine districts, the Indore and Dhar were selected purposively on the basis of maximum area covered by safed musli. Two blocks from Indore and four blocks from Dhar were selected and from each block two villages were selected randomly. A list of safed musli growers was prepared and ten farmers from each village were selected randomly constituting the sample size of 120 safed musli growers of which 20, 40 and 60 were small, medium and large growers, respectively. The proportionate random sampling method was used for selection of respondents. The survey method was adopted for collection of required data through pretested interview schedule. The collected data have been tabulated and analyzed to estimate the cost of cultivation, cost of production, net income and cost-benefit ratio of safed musli.

At overall level, total cost of cultivation of safed musli was Rs.3,16,612 ha^{-1} and major costs was operational cost, which accounted 98.26 per cent of the total cost. Among operational cost planting material accounted 77.62 per cent. Other important items were hired human labour, manure and interest on working capital which accounted about 19 per cent to total operational cost. Only 1.74 per cent of total cost was accounted as fixed cost. The cost of cultivation across different size of holdings revealed more or less same pattern of expenditure on different item of cost. In case of small medium and large holdings, the cost of planting material accounted for 81.1, 77 and 74.61 per cent, respectively. The labour charges accounted for 14, 16 and 18 per cent in case of small, medium and large holdings. The variation in total cost ranges from Rs. 3,01,849.6 to 3,37,356.68 from large to small size of holding. It can be concluded that this crop requires high investment of at least 3 lakhs per hectare of which planting material was the major item of cost. The average yield of safed musli was 22.58 q ha^{-1}. Out of which, planting material upto the extent of 12.7 q was used to directly sold to the market in fresh form and the remaining 9.87 q. was converted in to dry musli. While drying, tubers converted into one fifth of the total fresh tubers kept for drying. Thus, on an average dry musli obtained was 2.02 q ha^{-1}. The return obtained from planting material was Rs. 2.81 lakhs ha^{-1} and from dry musli Rs. 1.42 lakhs ha^{-1} resulted into gross income of Rs. 4.23 lakh ha^{-1}. Similar results were

Table 1. Break-up of cost of cultivation (Rs. ha^{-1}) of safed musli across various size of holdings

Items	Size of farms			Overall
	Small	Medium	Large	
Operational cost (Rs. ha^{-1})				
Labour cost				
Family labour	2699 (0.8)	1242 (0.4)	621 (0.2)	1521 (0.47)
Hired human labour	40820 (12.1)	48459 (15.6)	51616 (17.1)	46965 (14.83)
Bullock labour	1687 (0.5)	590 (0.19)	272 (0.09)	850 (0.27)
Machine labour	2092 (0.62)	2765 (0.89)	335 (1.11)	2736 (0.87)
Total	47297 (14.02)	52466 (16.29)	55860 (18.50)	5207 (16.44)
Material cost				
Planting material (seed)	273627 (81.10)	239659 (77.15)	225217 (74.61)	246168 (77.62)
Value of plant protection				
FYM/manure/	5400 (1.6)	5902 (1.9)	8452 (2.78)	6584 (2.07)
Bio-fertilizer	-	-	-	-
Other charges				
Interest on working capital	5736 (1.7)	6525 (2.10)	6641 (2.20)	6301 (1.99)
Irrigation charge				
Total Operational cost	332061 (98.43)	305143 (98.23)	296170 (98.12)	31112 (98.26)
Fixed cost				
Land revenue	10	10	10	10
Rental value of owned land	4050 (1.2)	4050 (1.3)	4050 (1.34)	4050 (1.28)
Interest on fixed capital	810 (0.24)	994 (0.32)	1147 (0.38)	984 (0.31)
Depreciation of implements and farm building	438.5 (0.13)	466 (0.15)	482.95 (0.16)	462.48 (0.15)
Total fixed cost	5298 (1.57)	5510 (1.77)	5680 (1.88)	5496 (1.74)
Total cost	337357 (100)	310647 (100)	301850 (100)	316613 (100)

Figure in brackets show the percentage of the total cost

Table 2. Comparative analysis of cost concepts (Rs./ha^{-1}) for safed musli across different size of holdings

	Size of farms			
Cost	Small	Medium	Large	Overall
Cost A_1	329800 (88.87)	304376 (89.07)	29604 (89.15)	310076 (89.02)
Cost A_2	329800 (88.87)	304376 (89.07)	296041 (89.15)	310076 (89.02)
Cost B_1	330609 (89.09)	305370 (89.36)	297188 (89.5)	311059 (89.30)
Cost B_2	334659 (90.18)	309420 (90.54)	30123 (90.72)	315109 (90.47)
Cost C_1	333308 (89.81)	306612 (89.75)	297810 (89.68)	312538 (89.74)
Cost C_2	337358 (90.90)	310662 (90.90)	301860 (90.90)	31663 (90.90)
Cost C_3	371095 (100)	341729 (100)	332046 (100)	34829 (100)

Figure in brackets shows the percentage to cost C_3

reported by Puran Mal *et al.* (2010).

The result revealed that the average net profit per hectare obtained from cultivation of safed musli by the sample farmers was 75 thousand. The net profit was found to be more than two fold in case of large holding size farm than the small holding size. It was Rs. 89 thousand ha^{-1} for large holding size farm as compared to Rs. 43 thousand ha^{-1} in case of small holding farm. On an average, farm business income, family labour income per hectare was Rs. 1.13 lakh and 1.08 lakhs, respectively. It revealed that for safed musli farm business income and family labour income increases as the size of farm increases showing directly proportionate relationship between income and size of holdings. The farm business income per hectare ranged from 84 thousand to 1.25 lakhs from small to large size of farm. Similarly the family labour income per hectare ranged from 79 thousand to 1.20 lakhs from small to large size. The cost benefit ratio was higher in case of large size of farm 1:1.29 followed by medium 1:1.25. and small size of farm i.e. 1:1.11.

The total production of safed musli crop of sample

Table 3. Output and value of Safed Musli across size of holdings

Items	Size of farms			Overall
Output (q ha^{-1})	Small	Medium	Large	
Total tubers	21.43 (100)	23.12 (100)	23.19 (100)	22.58 (100)
Planting material	14.54 (67.84)	12.67 (54.80)	10.91 (47.04)	12.70 (56.28)
Tubers for conversion of dry farm	6.89 (32.15)	10.45 (45.19)	12.28 (52.95)	9.87 (44)
Converted dry musli	1.38 (20)	2.10 (20.12)	2.47 (20.12)	2.02 (704.33)
Value of main product (Rs ha^{-1})				
Tuber	318426	280007	244384	281089.1
Dry musli	95910	147100	177346	142274.66
Gross income	414336	427107	421730	423363.76

Figures in bracket shows percentage to total tubers

Table 4. Net farm profit of safed musli across different size of farm (Rs ha^{-1})

Items	Size of farms			Overall
	Small	Medium	Large	
Total return (Gross income)	414336	427107	421730	423364
Total cost (Gross expenses)	371094	341729	332046	348293
Net farm profit	43241	85378	89684	75071

Table 5. Farm profit of safed musli growers across different size of holdings (Rs ha^{-1})

Items	Size of farms			Overall
	Small	Medium	Large	
Farm business income	84536	122731	125689	1132.88
Family labour income	79676	117687	120492	108254.44
Cost benefit ratio	1:1.11	1:1.25	1:1.29	1:1.21
Cost of production (Rs q^{-1}.)	17317	14781	14318	15424.85

farmers was 3159 quintals as tubers and an average productivity was 22.58 quintal per hectare. Parmar *et al.* (2007) observed that **c**ultivation of this crop is much more profitable than any other crop of this season.

There is an urgent need for identification and conservation of different species of safed musli, which can be used for commercial cultivation taking into consideration the demand and supply position. Financial assistance to the safed musli growers is also required for its cultivation in large scale across all the categories of the farmers. In the wake of world trade organization and intellectual property right patenting of this crop should also be encouraged. Ensuring availability of various inputs especially quality plant material and technical guidance to the cultivators is the need of the hour.

Received 26 April, 2016; Accepted 14 May, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 841-843

Manuscript Number: 2391
NAAS Rating: 4.47

Pollination Compatibility Among Different Apple Cultivars Under Kashmir Conditions

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Abstract: Four crab apple species (*Malus floribunda,* Golden Hornet, Manchurian and Fenna) and Golden Delicious were used as pollinizers for the five apple cultivars *viz.,* Red Chief, Red Fuji, Red Delicious, Gala Must and Summer Red on M_9 rootstock. The results revealed that *Malus floribunda* was significantly superior from other pollinizers in terms of phenological characters and cross compatibility studies followed by Golden Hornet and Manchurian.

Key Words: Apple, Compatibility, Crab, Pollination, Pollinizers, Phenology

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. Improper pollination management and lack of appropriate number of pollinizers in the apple orchards has became the most common issue of apple in recent years. Pollination is one of the keys to profitable apple production. The transportation of pollen from flowers of one variety to those of another is probably the most critical single process in the series of events leading to the production of a good quality fruit (Sanzol and Herrero, 2007).The Pollination management is regarded as a production factor in its own right for the apple crop as it can affect the agronomic and economic yields and there by many components such as fruit set, fruit quality and seed content. Apple varieties are generally self-unfruitful and do not fruit by their own pollen due to the antagonism that prevents pollen grains from growing on to stigmas of the same variety. Genetically apples show gametophytic self-incompatibility which necessitates the pollen transfer from another pollinizer variety to set fruit in marketable quantities. For cross pollination to be effective it is very important that the cultivars bloom at approximately the same time, produce the sufficient quantity of viable and compatible pollens. The present investigation was aimed to harness the benefit of early and long blooming period of crab apples, to find the compatible pollen source (crab) for different promising apple cultivars under study.

Pollination compatibility among different apple cultivars was undertaken during 2014-2015. Each variety constituted an experimental unit and each variety was replicated four times while as the pollen parents served as the treatments. The details of crossing plan is given as:

Pollinizer	Red Delicious (A_1)	Red Fuji (A_2)	Red Chief (A_3)	Gala Must (A_4)	Summer Red (A_5)
Golden Delicious (B_1)	A_1B_1	A_2B_1	A_3B_1	A_4B_1	A_5B_1
M. floribunda (B_2)	A_1B_2	A_2B_2	A_3B_2	A_4B_2	A_5B_2
Golden Hornet (B_3)	A_1B_3	A_2B_3	A_3B_3	A_4B_3	A_5B_3
Manchurian (B_4)	A_1B_4	A_2B_4	A_3B_4	A_4B_4	A_5B_4
Fenna (B_5)	A_1B_5	A_2B_5	A_3B_5	A_4B_5	A_5B_5

Floral phenology: The apple cultivars (Red Delicious, Red Fuji, Red Chief, Gala Must and Summer Red) were evaluated for their blooming period. Prior to flowering branches of selected apple cultivars in four directions were tagged and evaluated for blooming period and accordingly the dates of blooming were calculated.

The initial bloom was recorded visually for the female varieties, when around 10 per cent of the flowers opened in a tagged branch. The date of occurrence for each tagged branch was recorded and then converted to days after reference date (DARD) fixed arbitrarily as 1st April. Full bloom was observed visually for the female varieties when around 80 per cent of the flowers opened in a tagged branch.

Petal fall: This stage was recorded visually when around 10 per cent of the flowers shed their petals in a tagged branch. The date of occurrence for each tagged branch was recorded. Complete petal fall was recorded when around 80 per cent flowers shed their petals in a tagged branch. The date of occurrence for each tagged branch was recorded. The dates thus recorded were converted to days after taking reference date into consideration (1st April).

Flowering duration: The Duration of flowering was worked out as the period (days) between the initial bloom and petal fall in each tagged branch of each selected cultivar.

(Days after petal fall DARD was taken as Ist April).

Pollen collection and emesculation: Pollinizer flowers were bagged at bloom stage and removed at full bloom when the maximum anthers had dehisced. Pollen grains were collected in small vials for further studies. Four branches on each tagged tree with most of flowers at pop corn stage (that one which is likely to open next day) were selected and emasculated. Open flowers were removed. The selected flowers were counted and after emasculation i.e. removal of stamens, covered with muslin cloth bags to avoid cross pollination.

Hand cross pollination: The emasculated flowers were cross pollinated. Flowers at popcorn stage that are likely to open next day were selected and emasculated. The emasculated flowers, covered with bags were then pollinated, 24 hours after emasculation with the pollen of the parent as per crossing plan. The pollinated flowers were labeled and again covered with muslin bags which were removed after 15, 20 days of pollination and at harvest. Fruit set was determined after 15 and 21 days of pollination and at harvest by counting the number of fruits on the selected branches to determine the final fruit retention.

Floral phenology: Variations were observed in the phenological aspects of different varieties from the initial bloom to complete petal fall stages. Initial bloom stage was first noticed at 11.00 days after reference date (DARD) in the cultivar 'Red Chief' and late (21.00 DARD) in 'Golden Delicious' followed by 'Fenna' (Table 1).Variation recorded as per the date of full bloom stage reflected that 'Red Chief' and 'Gala Must' exhibited early full bloom stage at 16.00 DARD and 'Golden Delicious' was the last to exhibit this stage. Similar results were obtained by Sharma *et al*. (2007) Remarkable differences also existed in the data of petal fall and complete petal fall. Red Chief reached early into the petal fall stage (22.00 DARD). However Fenna and Golden Delicious (32.00 DARD) were last to enter this stage. Red Chief (26.00 DARD) was earliest to record the end of flowering or complete petal fall stage while as Golden Delicious, *Malus floribunda* and Fenna (36.00 DARD) were late to reach the complete petal fall stage. The duration of flowering (initial bloom to complete petal fall) ranged from 24.00 days in '*Malus floribunda'* to 13.00 days in 'Red Delicious'.

Fruit set: The highest fruit set at 15 days of pollination was with the pollinizer '*Malus floribunda*' and lowest with 'Golden Delicious'. (Table 2).The highest fruit set at 15 days of pollination was between 'Red Chief × *Malus floribunda'* and lowest fruit set between 'Gala Must × Golden Delicious', the number of fruits set at 15 days after pollination in almost all combinations of pollination was relatively high and did not differ significantly for the applied pollinizers. The fruit set percentage at 21 days (Table 3) under hand pollination showed significant differences for various cultivars and pollinizers used during the study. The highest final fruit set (Table 4) was with '*Malus floribunda*' and lowest final fruit set with the pollinizer Golden Delicious. Significant differences were found in fruit set percentage of cultivar, pollinizers and cultivars x pollinizers, however the degree of compatibility was higher when *Malus floribunda w*as used as a pollinizer as compared to other pollinizers under study. This was evidenced from the significantly higher fruit set when *Malus floribunda* was crossed with other cultivars as per the crossing plan. The maximum fruit set percentage was due to pollination of healthy flowers only and also by taking proper

Table 1. Phenological stages (DARD)* and flowering duration of pollinizers and the varieties under study

Varieties	Initial bloom (10%)	Full bloom (80%)	Petal fall (10%)	Complete petal fall (80%)	Flowering duration (Cpf-Ib)
Golden Delicious	21.00	26.00	32.00	36.00	15.00
Malus floribunda	12.00	19.00	30.00	36.00	24.00
Golden Hornet	16.00	22.00	30.00	35.00	19.00
Manchurian	12.00	17.00	23.00	27.00	15.00
Fenna	19.00	25.00	32.00	36.00	17.00
Red Delicious	17.00	21.00	27.00	30.00	13.00
Red Chief	11.00	16.00	22.00	26.00	15.00
Red Fuji	12.00	17.00	24.00	30.00	18.00
Gala Must	12.00	16.00	24.00	27.00	15.00
Summer Red	14.00	19.00	24.00	30.00	16.00
CD(p =0.05)	1.01	1.13	1.91	0.95	1.34

* DARD= Days after reference date taken as 1st April; Cpf= complete petal fall; Ib= initial bloom

Table 2. Effect of pollen source on fruit set (%) after 15 days of hand pollination

Varieties → / Pollinizers ↓	Red Delicious	Red Fuji	Red Chief	Gala Must	Summer Red	Mean
Golden Delicious (control)	77.57 (8.85)	80.12 (9.00)	75.25 (8.70)	66.68 (8.22)	68.25 (8.32)	73.57 (8.63)
Malus floribunda	87.33 (9.39)	77.56 (8.84)	88.13 (9.44)	86.88 (9.37)	80.68 (9.01)	84.12 (9.21)
Golden Hornet	78.37 (8.89)	83.93 (9.20)	82.95 (9.15)	82.88 (9.14)	71.00 (8.48)	79.83 (8.98)
Manchurian	84.30 (9.23)	79.23 (8.94)	82.47 (9.11)	79.46 (8.95)	75.38 (8.70)	80.17 (8.98)
Fenna	82.17 (9.11)	83.31 (9.17)	76.07 (8.76)	79.65 (8.97)	75.93 (8.75)	79.43 (8.95)
Mean	82.11 (9.10)	80.83 (9.03)	80.81 (9.02)	79.11 (8.93)	74.25 (8.65)	79.42 (8.95)

The values in the parenthesis is the square root transformation; CD ($p \leq 0.05$)- Pollinizer (P) - 0.35; Variety (V) - NS; P X - NS

Table 3. Effect of pollen source on fruit set (%) after 21 days of hand pollination

Varieties → / Pollinizers ↓	Red Delicious	Red Fuji	Red Chief	Gala Must	Summer Red	Mean
Golden Delicious (control)	71.36	67.25	71.61	74.88	51.58	67.34
Malus floribunda	85.52	80.68	81.28	84.09	78.43	81.99
Golden Hornet	81.84	80.62	80.62	81.81	69.40	76.77
Manchurian	80.60	81.72	80.88	76.68	72.63	78.50
Fenna	79.28	81.12	80.51	77.15	72.18	78.04
Mean	79.72	78.27	78.98	78.92	68.84	76.90

CD ($p \leq 0.05$) Pollinizer (P) -6.30; Variety (V)- 6.30; P × V - NS

Table 4. Effect of pollen source on fruit set of hand pollinated at harvest

Varieties → / Pollinizers ↓	Red Delicious	Red Fuji	Red Chief	Gala Must	Summer Red	Mean
Golden Delicious (control)	67.38	57.84	68.98	63.48	47.54	61.04
Malus floribunda	84.87	74.87	80.35	84.09	58.97	76.63
Golden Hornet	75.81	73.01	80.62	79.38	67.43	75.80
Manchurian	80.60	76.92	79.67	75.68	66.13	75.25
Fenna	78.71	80.76	73.65	75.25	65.32	74.73
Mean	77.47	72.68	76.65	75.57	61.07	72.69

CD ($p \leq 0.05$) -Pollinizer (P) : 1.38; Variety (V) : 1.38; P X V: 3.10

care during pollination, moreover the compatibility relationship varies with the change in pollinizer variety indicating genetic differences between genotypes (Sharafi and Bahmani, 2010). Weather conditions during the blooming period under temperate conditions may be unfavorable for flight of pollinating insects necessary for fruit set. Cool temperature also affects pollen tube growth and fertilization consequently low cross pollination levels are usually one of the yield limiting factors (Dennis, 2003).

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Received 23 March, 2016; Accepted 07 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 844-846

Manuscript Number: 2392
NAAS Rating: 4.47

Studies on Variability, Heritability and Genetic Advance in Garlic (*Allium sativum* L.) for Yield Related Traits

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***Abstract**:* Genetic variability studies in garlic (*Allium sativum* L.) indicated high PCV and GCV values for average weight of cloves, average bulb weight and pseudostem length, indicating that a greater amount of genetic variability was present for these characters and thus there is greater scope for further improvement by genetic manipulation. High heritability coupled with high genetic advance as percent of mean was observed for average weight of cloves, average bulb weight, marketable yield and total yield, which indicated that these traits were under the strong influence of additive gene action, and hence, simple selection based on phenotypic performance of these traits would be more effective.

Key Words: Garlic, Variability, PCV, GCV, Heritability, Genetic advance

In present scenario, the demand of garlic powder is also increasing day by day due to its use in the food industry as condiment. In India, the area under garlic during the year2013–14 was 2.31 lakh hectares and production of 12.52 lakh tonnes with average productivity of 5.4 t/ha. In India, MadhyaPradesh followed by Rajasthan, Gujarat and Uttar Pradesh are the leading states where Madhya Pradesh alone accounts for morethan 27% of the area and 21% of the production with*an* average yield of 4.5 t/ha (Anonymous, 2014).

The phenotypic expression of the plant characters is mainly controlled by the genetic makeup of the plant and the growing environment. Further, the genetic variance of any quantitative trait is composed of additive variance (heritable) and non-additive variance including dominance and epistasis (non-allelic interaction). Therefore, it becomes necessary to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic advance. Further, the genetic advance can be used to predict the efficiency of selection. The amount of work done on the genetics of the most important quantitative character *i.e*. yield is meager. Therefore, the present study was undertaken.

The experimental materials consisted of 25 genotypes of garlic maintained CCS Haryana Agricultural University, Hisar. The genotypes were planted on last week of October 2014 in Randomized Block Design with three replications. The cloves of each genotype were planted manually in flat beds of 3x2 m size at a spacing of 15x10 cm. The bulbs were harvested on third week of April. The observations were recorded at maximum growth stage on randomly selected 10 plants in each replications for all the characters The genotypic and phenotypic variances and coefficients of variation were worked out as per the method of Burton (1952) and heritability and genetic advance by following the method suggested by Lush (1949), Robinson *et al*. (1949) and Burton and De Vane (1953).

Higher values for phenotypic coefficient of variability were obtained than that of genotypic coefficients of variability values, indicating the influence of environment on these traits. The total soluble solids followed by number of leaves per plant, leaf length and pseudostem length had larger differences between PCV and GCV values as these were most influenced by the environment. Remaining characters recorded smaller differences between PCV and GCV values as they were less influenced by the environment, indicating reliability of selection based on these traits. Genetic variability studies showed high PCV and GCV values for average weight of cloves (37.1 and 36.7%), average bulb weight (32.8 and 31.8%) and pseudostem length (21.3 and 18.6%), indicating that a greater amount of genetic variability was present for these characters. Moderate PCV and GCV values for marketable yield, total yield, number of cloves per bulb, leaf width, number of leaves per plant, total soluble solids, polar diameter of bulb and equatorial diameter of bulb indicated that a moderate amount of genetic variability was present in these characters, which provided average scope for selection. Low PCV and GCV were recorded for leaf length and plant height. Days to harvesting indicated limited scope for improvement among these traits. Based on the variability assessed in the present study and those by earlier workers Kassahun *et al.* (2010)*,* Tsega *et al*. (2010), Singh *et al*. (2012), Yadav *et al.* (2012), Vatsyayan *et al.* (2013) in garlic, it can be stated that there existed ample scope of variation in these traits, which could be utilized for

Table 2. Mean, range, phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic advance as % of mean for different characters in garlic

Characters	General mean	Range of mean		Coefficient of variation		h^2	Genetic advance	Genetic advance % of mean
		Minimum	Maximum	Phenotypic	Genotypic			
Plant height (cm)	78.168	63.23	95.5	10.512	9.680	84.788	14.352	18.361
Number of leaves per plant	10.779	7	14.3	17.449	13.001	55.516	2.151	19.955
Leaf length (cm)	35.671	29.53	42.16	12.082	9.819	66.049	5.864	16.438
Leaf width (cm)	2.240	1.36	3.55	18.823	17.997	91.417	0.794	35.446
Pseudo-stem length (cm)	28.605	16.7	38.06	21.366	18.670	76.358	9.614	33.608
Polar diameter of bulb (cm)	40.567	28.56	53.8	14.562	13.227	82.508	10.040	24.750
Equatorial diameter of bulb (cm)	40.937	30.2	49.6	13.889	13.340	92.254	10.805	26.394
Average bulb weight (g)	32.964	18.5	51.60	32.815	31.836	94.122	20.973	63.625
Number of cloves per bulb	33.741	21.9	44.4	19.588	17.987	84.313	11.480	34.022
Average weight of cloves (g)	52.584	30.0	108.86	37.163	36.794	98.024	39.460	75.043
Total yield (q ha^{-1})	106.013	55.13	140.27	19.875	19.308	94.377	40.964	38.641
Marketable yield	103.911	53.44	138.5	20.152	19.622	94.810	40.898	39.359
Days to harvesting	171.493	167.67	182.66	2.297	1.272	30.676	2.489	1.451
T.S.S (%)	36.469	27.00	43.43	15.816	8.461	28.616	3.400	9.323

Table 1. List of germplasm lines and standard released varieties included in the study

Sr. No.	Genotype	Sr. No.	Genotype
1.	HG 1	14.	GRS 1340
2.	HG 2	15.	GRS 1345
3.	HG 3	16.	GRS 1349
4.	HG 4	17.	BGSD 1222
5.	HG 5	18.	BGSD 1225
6.	HG 6	19.	BGSD 1230
7.	HG 7	20.	BGSD 1232
8.	HG 8	21.	CGSD 1232
9.	HG 17	22.	CGSD 1247
10.	HG 27	23.	CGSD 1249
11.	GRS 1328	24.	CGSD 1252
12.	GRS 1330	25.	CGSD 1265
13.	GRS 1332		

improvement through selections for the traits investigated in the present material. Further based on total yield in the present investigation, the genotype GRS 1349 followed by HG 27, BGSD 1230 and GRS 1332 appeared to be most promising for their exploitation and utilization for the incorporation of yield potential in other promising materials.

High heritability estimates were for average weight of cloves (98.02), marketable yield (94.8), total yield (94.3), average bulb weight (94.1), equatorial diameter of bulb (92.2) and leaf width (91.4), whereas, moderate heritability estimates were observed for plant height, number of cloves per bulb, polar diameter of bulb, pseudostem length and leaf length. High and moderate estimates of heritability for these traits advocated that the selection based on phenotypic performance of these characters would be more effective. Low heritability estimates were found for number of leaves per plant days to harvesting and total soluble solids, which indicated that selection on phenotypic performance basis would not be much effective for these traits.High heritability coupled with high genetic advance as percent of mean was observed for average weight of cloves, average bulb weight, marketable yield and total yield, which indicated that these traits were under the strong influence of additive gene action, and hence, simple selection based on phenotypic performance of these traits would be more effective. Moderate heritability and low genetic advance values were observed for the characters plant height, number of leaves, leaf length, leaf width, pseudostem length, polar diameter, equatorial diameter and number of cloves per bulb. The results of the present investigation are also in agreement with previous studies carried out on garlic by several workers Tsega *et al*. (2010), Sonkiya *et al*. (2012) and Yadav*et al*. (2012). Thus, the material assessed possessed ample scope of their improvement through selection and utilization in breeding for higher yield and quality.

The new garlic varieties can be obtained to increase the production and productivity substantially.

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Received 21 March, 2016; Accepted 09 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 847-848

Manuscript Number: 2393
NAAS Rating: 4.47

Manipulation of Planting Density and Branching Pattern for Extended Availability of Tomato under Protected Conditions

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***Abstract*: ** The present studies revealed that Shalimar Tomato Hybrid-2 at spacing 60 cm x 45 cm with two shoots plant^{-1} performed better in terms of maturity traits taking least number of days for flowering (21.66 days), first fruit set (31.33 days) and first fruit harvest (62.00 days). However, Shalimar Tomato Hybrid-1 at spacing 60 cm x 30 cm with one shoot plant^{-1} exhibited the highest number of days to last fruit harvest viz., 217 days, hence extending the availability of tomato fruit up to 155 days of fruiting and also exhibiting highest fruit yield per plant i.e., 7.92 kg.

***Key Words*: ** Availability, Maturity, Protected, Tomato

In J&K, tomato is grown over an area of 0.008 million hectares with an annual production of 0.14 million metric tonnes (Anonymous, 2013). The state with varied agro-climatic conditions favours cultivation of tomato throughout the year. In Kashmir valley, tomato is grown as a summer crop. However it is difficult to obtain higher yields of good quality fruits throughout the year under open conditions. Due to erratic weather conditions, the crops grown in open field are often exposed to fluctuating levels of temperature, humidity, rainfall and wind velocities *etc*. which ultimately affect the crop productivity adversely (Ochigbo and Harris, 1989). With its ever increasing demand in the valley during the off season, it has become necessary to increase the longevity of crop. This has necessitated cultivating tomatoes under protected conditions such as green houses or polyhouses. The growing of tomato under protected conditions not only increases the yield and quality but also extends its longevity which is highly appreciable. Although cultivation of tomato hybrids under polyhouses is gaining importance but rampant growth under polyhouses makes them unmanageable. Hence training of plants and maintaining of plant density are very important in order to check plant growth.

The present investigation was carried out during kharif 2012 under semi controlled polyhouse conditions. Two indeterminate hybrids of tomato Shalimar Tomato Hybrid-1 and Shalimar Tomato Hybrid-2 released by SKUAST-Kashmir were planted at two spacing viz., 60 cm x 30 cm and 60 cm x 45 cm and the three levels of trainings: no training, one shoot plant^{-1} and two shoots plant^{-1} were adopted resulting in twelve treatment combinations. The experiment was laid out in Randomized Block Design with three replications. Recommended package of practices (Anonymous, 2012) were adopted to raise the crop. The observations on different maturity traits and yield were recorded from five randomly selected plants from each treatment. The data was analysed as per standard statistical procedures given by Gomez and Gomez (1984).

Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm + Two shoots plant^{-1} recorded earliest flowering viz., 21.66 days, which was statistically at par with Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm + No training i.e., 22 days, Shalimar Tomato Hybrid-2 + spacing 60 cm x 30 cm + One shoots plant^{-1} i.e., 22.33 days, Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm + One shoot plant^{-1} (22.33 days), Shalimar Tomato Hybrid-2 + spacing 60 cm x 30 cm + Two shoots plant^{-1} (23 days) and Shalimar Tomato Hybrid-2 + spacing 60 cm x 30 cm + No Training (23.33 days). Days to first fruit set was recorded to be lowest in Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm + Two shoots plant^{-1} i.e., 31.33 days, which was statistically at par with Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm + No training (31.66 days), Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm + One shoot plant^{-1} viz., 31.66 days, Shalimar Tomato Hybrid-2 + spacing 60 cm x 30 cm + One shoot plant^{-1} (32 days), Shalimar Tomato Hybrid-2 + spacing 60 cm x 30 cm + Two shoots plant^{-1} (32.33 days), Shalimar Tomato Hybrid-1 + Spacing 60 cm x 45 cm + No training viz., 32.66 days, Shalimar Tomato Hybrid-2 + Spacing 60 cm x 30 cm + No Training viz., 32.66 days, Shalimar Tomato Hybrid-1 + Spacing 60 cm x 45 cm + One shoot plant^{-1} viz., 33 days, Shalimar Tomato Hybrid-1 + Spacing 60 cm x 45 cm + Two shoots plant^{-1} viz., 33 days and Shalimar Tomato Hybrid-1 + spacing 60 cm x 30 cm + One shoot plant^{-1} viz., 33.33 days. Generally the wider spacing reduced the competition among the plants for nutrients and moisture and led to better exposure of plants to light resulting in the more accumulation of photosynthates. This resulted in fast growth which ultimately triggered early initiation of flowers.

Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm

Table 1. Influence of spacing and training on maturity and yield traits of tomato (*Solanum lycopersicum* L.) under protected conditions

Treatment	Treatment Combination	Days to first flower	Days to first fruit	Days to first fruit	Days to last fruit	Duration of fruiting	Fruit yield $plant^{-1}$
T_1	Shalimar Tomato Hybrid-1 + Spacing 60 cm x 30 cm +	26.66	35.00	70.33	207	143	5.560
T_2	Shalimar Tomato Hybrid-1 + Spacing 60 cm x 30 cm + One shoot $plant^{-1}$	26.33	33.33	70.66	217	155	7.920
T_3	Shalimar Tomato Hybrid-1 + Spacing 60 cm x 30 cm+ Two shoots $plant^{-1}$	25.66	35.00	70.00	210	141	6.850
T_4	Shalimar Tomato Hybrid-1 + Spacing 60 cm x 45 cm + No Training	24.66	32.66	69.33	205	138	6.500
T_5	Shalimar Tomato Hybrid-1 + Spacing 60 cm x 45 cm + One shoot $plant^{-1}$	25.00	33.00	68.66	215	148	8.130
T_6	Shalimar Tomato Hybrid-1+ Spacing 60 cm x 45 cm + Two shoots $plant^{-1}$	26.00	33.00	69.66	208	140	6.850
T_7	Shalimar Tomato Hybrid-2 + Spacing 60 cm x 30 cm + No Training	23.33	32.66	69.33	204	136	6.140
T_8	Shalimar Tomato Hybrid-2 + Spacing 60 cm x 30 cm + One shoot $plant^{-1}$	22.33	32.00	67.33	213	141	6.700
T_9	Shalimar Tomato Hybrid-2+ Spacing 60 cm x 30 cm + Two shoots $plant^{-1}$	23.00	32.33	68.45	207	137	6.740
T_{10}	Shalimar Tomato Hybrid-2 + Spacing 60 cm x 45 cm + No Training	22.00	31.66	62.00	203	132	6.475
T_{11}	Shalimar Tomato Hybrid-2 + Spacing 60 cm x 45 cm + One shoot $plant^{-1}$	22.33	31.66	66.66	209	136	7.300
T_{12}	Shalimar Tomato Hybrid-2+ Spacing 60 cm x 45 cm + Two shoots $plant^{-1}$	21.66	31.33	61.50	206	138	7.060
CD (p<0.05)		1.87	2.26	3.97	5.03	5.75	1.010

+ Two shoots $plant^{-1}$ recorded least number of days to first fruit harvest i.e., 61.50 days which was statistically at par with Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm + No training i.e., 62 days. Shalimar Tomato Hybrid-1 + spacing 60 cm x 30 cm + One shoot plant-1 exhibited the highest number of days to last fruit harvest i.e., 217 days that was statistically at par with Shalimar Tomato Hybrid-1 + spacing 60 cm x 45 cm + One shoot $plant^{-1}$ i.e., 215 days and Shalimar Tomato Hybrid-2 + spacing 60 cm x 30 cm + One shoot $plant^{-1}$ i.e., 213 days. Longest duration of fruiting was recorded in Shalimar Tomato Hybrid-1 + spacing 60 cm x 30 cm + One shoot $plant^{-1}$ i.e., 155 days followed by Shalimar Tomato Hybrid-1 + spacing 60 cm x 45 cm + One shoot $plant^{-1}$ viz., 148 days and Shalimar Tomato Hybrid-1 + spacing 60 cm x 30 cm + No training viz., 143 days. The increased number of days to last fruit harvest might be due to availability of favourable microclimate under the green house for a longer period of time resulting in prolonged availability of crop as compared to that grown under open field conditions. Plants trained to one shoot continued growth for longer period of time because of better living conditions.

Shalimar Tomato Hybrid-1 + spacing 60 cm x 45 cm + One shoot $plant^{-1}$ exhibited the highest fruit yield $plant^{-1}$ of 8.130 kg which was statistically at par with Shalimar Tomato Hybrid-1 + spacing 60 cm x 30 cm + One shoot $plant^{-1}$ with 7.920 kg and Shalimar Tomato Hybrid-2 + spacing 60 cm x 45 cm + One shoot $plant^{-1}$ with 7.300 kg. Pinching in plants had a promotive effect on fruit yield $plant^{-1}$, due to less competition for nutrient, more assimilation of carbohydrates and proteins and good exposure of plants to light.

In the present study, Shalimar Tomato Hybrid-2 recorded superiority with respect to all maturity attributes. However Shalimar Tomato Hybrid-1 exhibited longest duration of fruiting. Wider spacing and training to one shoot $plant^{-1}$ resulted in enhanced fruit yield $plant^{-1}$.

Received 26 April, 2016; Accepted 11 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 849-850

Manuscript Number: 2394
NAAS Rating: 4.47

Studies of Soil Microbial Diversity and Physiochemical Properties of Tropical Humid Plantation in Western Chhattisgarh

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***Abstract*: Studies were conducted under *Peltophorum ferrugineum, Dalbergia sissoo and Eucalyptus globules* plantation to measure the diversity of culturable bacterial and fungal communities with physico-chemical properties. Organic carbon was found 57mg ha^{-1},48mg ha^{-1} and 39mg ha^{-1}, respectively for *Peltophorum ferrugineum*, *Dalbergia sissoo* and *Eucalyptus globulus*. N content of *Peltophorum ferrugineum* contained 370.8 mg ha^{-1} of N and the remaining two species (*Dalbergia sissoo* and *Eucalyptus globulus*) had low N content i.e.,230.7mg ha^{-1} and 215.5mg ha^{-1}, respectively. The phosphorus content in *Eucalyptus globulus* were high (15.1mg $ha^{-1)}$ but *Peltophorum ferrugineum* showed higher content of K (445.6 mg ha^{-1}). *Eucalyptus globulus* showed the maximum number of bacterial colonies (5.38 x 10-^{2}), whereas sample of *Peltophorum ferrugineum* has least number of colonies (7.5 X 10-^{2}). Fungal colonies *Dalbergia sissoo* had greater number 7.3 x 10^{2} growing in each dilution as compared to *Peltophorum ferrugineum* and *Eucalyptus globulus* 2.3 X 10-^{2}, 2.9 x 10-^{2}, respectively.

***Key Words*: Fungi, Microflora types, Soil bacteria, Soil enrichment, Top soil

Soil is a big biological laboratory had varied population of living organisms (bacteria, fungi, actinomycetes, algae, and protozoans) inconceivable in number. The number of bacteria in 1 gram of soil may range from 100,000 to several billion depending on soil conditions. Soil micro-organisms constitute the basic consumer tropic level of the decomposer subsystem. As such, they control the breakdown of organic matter and hence the release of nutrients and their availability to other organisms to maintaining long-term agricultural sustainability of the agro ecosystem (Jenkinson,1988; Robertson *et al.,* 1994).

Large quantities of readily decomposable organic matter are added to soils every year as crop residues or animals waste and have a significant outcome on soil microbial communities. The plant species growing on the soil also equally influence the population and species composition of the soil fungi (Hackl *et al*.,2000). Fungi and bacteria play a focal role in nutrient cycling by regulating soil biological activity (Arunchalam *et al*.,1997). However, the rate at which organic matter is decomposed by the microbes is interrelated to the chemical composition of the substrate as well as environmental condition. Therefore, a study was conducted to assess the life in soil under plantations.

The study was conducted during 2014 January to 2015 January in plantations raised in Bilaspur, Chhattisgarh. The area is located at 81°45' to 82°15' E longitude and 21°45' to 22°8' N latitude. Physiographically, the area comes under Satpura and Maikal mountain ranges. The climate being sub- humid to humid tropical monsoonal, with distinct winter (Nov.-Feb.), summer (March- mid June) and June-Sep rainy (late). But, due to the presence of lush green vegetation in area a favourable microclimate is maintained. Average annual rainfall varies from 1220–1600mm**.** Mean monthly minimum temperature ranges from 10.9 – 25.6°C and mean monthly maximum temperature from 25-44°C.

The soil of area is deep, red and laterite with good content of organic matter, which affects various properties of soil PH (6.4-7.5). Water holding capacity is good, cation exchange capacity is high, soil profile is well developed, soil is loamy to sandy loan in texture, natural clodal structure are developed which have granular or crumby structure. The soil is rich in nutrients and biological properties. The compactness and consistency of soil varies from place to place, soil aeration and soil water are affected by the texture and organic matter content. The vegetation of the area is composed of both artificial as well as natural vegetation and the most common species are *Eucalyptus globulus, Butea monosperma, Delonix regia, Peltophorum ferrugineum, Dalbergia sissoo, Acacia nilotica, Pongamia pinnata, Jatropha curcus, Albizia procera, etc.*

Soil sample were collected randomly from 10-15 places for each site (15cm depth) plantation of three species namely *Dalbergia sissoo, Peltophorum ferrugineum* and *Eucalyptus globulus.* Samples were mixed thoroughly, sieved(<2mm) and separated in to parts; one part was air dried while the other was kept in sterilized polythene bags in field moist condition. Organic carbon was determined by Walkley and Black's rapid titration method. Total N by using Kjeldahl digestion method and total P was estimated after $Hclo_4$ digestion method (Jackson,1958). Available N was

Table 1. Physio-chemical prosperities of soil under tree plantations

Plantation	Ph	Organic carbon mg kg^{-1}	Total N mg ha^{-1}	Total P mg ha^{-1}	Av. N mg ha^{-1}	Av. P mg ha^{-1}	Av. K mg ha^{-1}
Dalbergia sissoo	6.96	48	1698	570	230.7	14.3	267.7
Peltophorum ferrugineum	7.27	57	2020	620	370.8	12.3	445.6
Eucalyptus globules	5.23	39	1174	510	215.5	15.1	280.7

Table 2. Biological properties of soils under tree plantation

Plantation	Bacteria*		
	Dilution No.	Dilution factor	Colony forming units
Dalbergia sissoo	10^{-2}	10-^{2}	8.5x10-^{3} (7x10^{-2})
	10^{-3}	10^{-3}	1.7x10^{-3} (3x10^{-3})
	10^{-4}	10^{-4}	6.4x10^{4}
	10^{-5}	10^{-5}	2x10^{-6}
Peltophorum ferrugineum	10^{-2}	10^{2}	7.5x10^{2} (2x10^{-2})
	10^{-3}	10^{3}	4.2x10^{3} (1x10^{-3})
	10^{-4}	10^{4}	5.6x10^{4}
	10^{-5}	10^{5}	1.8x10^{5}
Eucalyptus globulus	10^{-2}	10^{2}	5.38x10^{-2} (2x10^{-2})
	10^{-3}	10^{3}	4.3x10^{-3} (1x10^{-3})
	10^{-4}	10^{4}	5.1x10^{-4}
	10^{-5}	10^{5}	5.0x10^{-5}

*Fungi colony forming units in parentheses

determined by steam distillation using devendra alloy and available P by ammonium molybdate-stannous chloride method. Available potassium in soils by flame photometer. Soil microbiological studies, isolation and enumeration of bacteria and fungi from soil was done by the serial dilution-agar plating method. Fungal colonies were developed on Czapek-Dox agar medium. The numbers of colonies were calculated from each plate through ocular estimation.

The population count of bacteria and fungi in the soils of plantation were influenced by vegetation. However, the macro and micro climate conditions, seasonality and soil nutrient status also has a significant effect on it. It is also understood that the quality of plant residues accumulating in these plantation are furthermore important and may play a vital role in soil nutrient management within the system through microbial decomposition. Comparing the samples from the rhizospheric area of three different plant species *Dalbergia sissoo*, *Peltophorum ferrugineum* and *Eucalyptus globulus* showed that pH of *Dalbergia sissoo* was slightly acidic and of *Eucalyptus globulus* was strongly acidic whereas *Peltophourm ferrugineum* was normally saline nature. Organic carbon was found to be 57 mg ha^{-1} for *Peltophorum ferrugineum* whereas, *Dalbergia sissoo* and *Eucalyptus globulus* showed low level of organic carbon 48mg ha^{-1} and 39mg ha^{-1}, respectively.

The N content also followed the same trend to the organic carbon that *Peltophorum ferrugineum* contained high (370 .8mg ha^{-1}) N, which is supposed to be of medium level and the remaining two species (*Dalbergia sissoo* and *Eucalyptus globulus*) had low N content *i.e.* 230.7 and 215.5mg ha^{-1}, respectively. The phosphorus content in *Eucalyptus globulus* was high level (15.1mg ha^{-1}), whereas, *Peltophorum ferrugineum* had low content of phosphorus (12.3mg ha^{-1}), but higher content of K (445.6mg ha^{-1}) and the other two species *Dalbergia sissoo* (267.7mg ha^{-1}) and *Eucalyptus globulus (*280.7mg ha^{-1}) had relatively low values.

Dalbergia sissoo had greater number of bacterial and fungal colonies. In Bacterial colonies, dilution number 10^{-2} of *Eucalyptus globulus* showed the maximum number of bacterial colonies (5.38 x 10^{-2}), whereas *Peltophorum ferrugineum* has least number of colonies (7.5 x 10^{-2}). It was noted that plantation type significantly influenced species diversity of culturable microbial communities. While *Dalbergia sissoo had greater number of fungal colonies* 7.3 x 10^{-2} growing in each dilution in comparison to *Peltophorum ferrugineum and Eucalyptus globulus (*2.3 x 10^{-2}*,* 2.9 x 10^{-2}, respectively). This study will provide an insight to the microbial population not only for basic scientific research in forestry but to understand species composition and nutrient recycling for regeneration, preservation and stabilization of degraded land.

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Received 16 March, 2016; Accepted 30 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 851-853

Manuscript Number: 2395
NAAS Rating: 4.47

Effect of Visits on Yield and Quality Parameters of *Apis dorsata* on Pumpkin

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***Abstract*:** The maximum number of pumpkin fruit set, fruit weight, fruit length, fruit diameter, number of seeds per fruit, seed test weight, seed germination percentage, seed vigour I and seed vigour II was recorded the highest in five visits by *Apis dorsata* on the flowers of pumpkin followed by four, three, two and one visit in both the pumpkin cultivars (C-1076 and C-1106). Irrespective of number of visits, the fruit all parameters in cultivar C-1076 was significantly higher than in C-1106 except fruit diameter due to round shape of C-1106 cultivar.

Key Word: Honey bee species, Fruit set, Pumpkin, Yield and quality parameters

Pollination is a valuable ecosystem service, providing a variety of benefits including food and fiber, plant-derived medicines, ornamentals and other aesthetics, genetic diversity, overall ecosystem resilience and is significantly contributing to the agricultural productivity. Size and complexity of floral display used to advertise their location is one of the several factors influencing the behavior of pollinators (Goulson, 1999). The high male to female ratio achieves the production of sufficient amount of pollen deposits, thus aids in effective pollination. Inadequate pollination can result not only in reduced yield but also in delayed yield and a higher percentage of inferior fruits. Nicodemo *et al*. (2009) from Brazil reported that Apis mellifera is an effective pollinating agent of pumpkin crop. Fruit production occurred only when the insects visits the flowers up to 0900 hr. Fruit set, fruit size and weight and number of seed increase as the number of visits by Apis mellifera also increased up to 16 visits per female flowers, at which the highest fruit set level was 95 per cent. The study showed that honey bees are the main pollinators of pumpkin in India. It also showed that the behaviour of bees while visiting the pumpkin flowers results to effective transfer of pollen from male flowers to female flowers.

The studies were carried out at Chaudhary Charan Singh Haryana Agricultural University, Hisar during June to December, 2013 on two cultivars of pumpkin viz., C-1076 and C-1106*.* Flowering began during Aug-Sept, 2013. For comparing the effect of number of *Apis dorsata* visits on a single female flowers on fruit set and yield of pumpkin, ten female flowers for each treatment were enclosed with butter paper bags a day before their opening. The butter paper bags were removed after the flowers opening and each such set of flowers were allowed for one, two, three, four and five visits of *A. dorsata* and observations on fruit set, yield and quality parameters namely fruit size (length and diameter in cm), fruit weight (g), number of seeds per fruit, seed test weight (g), seed germination percentage and seed vigour. The per cent fruit set was calculated as total number of fruits/total number of flowers tagged. In each treatment, weight of the individual fruit was taken. The fruit length in centimeter was recorded by measuring the distance from one end to other end of the fruit. Similarly the girth of the fruit was measured in centimeter from three places and then averaged. Number of seeds per fruit was counted manually with hands after picking of the fruit and the weight of the 1000 seeds was taken. To record the seed germination percentage, 100 seeds of each treatment were placed on sufficiently moistened rolled germinating papers (Between the papers) at 20^{0}C in the seed germinator. The data on shoot length, root length and dry weight of the seedlings were recorded on 10 seedlings randomly selected from 8 days old seedlings. After recording the data on shoot and root length in cm, the seedlings was kept in the oven at 85^{0}C till their dry weight stabilized. The data was expressed as dry weight (g) per seedling. The whole set of experiment was repeated with three replications.

Seed vigour I: Germination (%) x seedling length (cm)

Seed vigour II= germination (%) x seedling dry weight (g)

Effect of different visits on the flowers on fruit set: The per cent fruit set by different number of visits on the flowers by *Apis dorsata* differed significantly and the highest 77.84 and 72.09 per cent fruit set per plant was in five visits by *A. dorsata* followed by four, three and two visits in C-1076 and C-1106, respectively. The least per cent fruit set was observed in one bee visit in both cultivars. The record of about 10 honey bees per female flower observed lies within the accepted number required of honey bees per female flower to attain the highest fruit set of pumpkin (Nicodemo *et al*., 2009). Ali *et al.* (2014) reported that in *Cucurbita pepo,* single visit efficacy in terms of fruit set percentage was the highest in *Nomia* sp. (36.66) followed by *A. dorsata* (23.33) and *Halictus* sp. (20).

Effect of number of visits on the flowers on yield parameters: Mean fruit weight (g) of pumpkin was observed maximum in five visits by *A. dorsata* (2787.8) followed by four, three, two and one visit (656.2 g) in C-1076 (Table 2). Likewise in C-1106, maximum fruits weight was recorded in five visit (2365g) followed by four, three, two and one visit. The average fruit length (cm) was maximum in five visits by *A. dorsata* followed by four, three and two and one visits in both cultivars. Irrespective of number of visits, the fruit length of C-1076 in all treatments was significantly higher than the fruit length of C-1106. The average fruit diameter (cm) was maximum in five visits by *A. dorsata* followed by four, three and two visits which was significantly higher than the fruit diameter under one visit in both hybrids. Irrespective of number of visits, the fruit diameter of C-1106 was significantly higher than the fruit diameter of C-1076 due to round shape of C-1106 cultivar. The average number of seeds was maximum in five visits followed by four, three and two visits which were significantly higher than the number of seeds per fruit under one visit in both hybrids. Irrespective of number of visits, the number of seed in C-1076 hybrid was significantly higher than the number of seed per fruit in C-1106. Nicodemo *et al*. (2009) from Brazil reported that *A. mellifera* is an effective pollinating agent of pumpkin crop. The higher the number of visits, up to 16, by *A. mellifera* to female flowers, the greater was the fruit set, fruit size and weight, and number of seeds. In flowers visited by insects from the onset of anthesis until 9 a.m., fruit set was 35%. After 9AM, there was no fruit set, demonstrating the important role of *A. mellifera* as a pollinating agent of pumpkin, since it was the only insect visiting up to 9 AM. Fruit set, fruit size and weight and number of seed increase as the number of visits by *A. mellifera* also increased up to 16 visits per female flowers, at which the highest fruit set level was reached. The flowers open to visitation until 0900 hr originated fruit with 35% fruit set, 171.14 mm in length, 100.29 mm in width, weight of 1340 g and 120.57 seeds. Cucumber requires large numbers of honey bees for adequate pollination because each female blossom is only receptive to being pollinated for one day, and each blossom requires an average of 9 (Hodges and Baxendate, 1976), 10 (Lord, 1985), 18 (Stanghellini *et al*., 1997), 6 (Gingras *et al.,* 1999) and 11 (Meléndez-Ramirez *et al*., 2002) bee visits to set a well-shaped cucumber.

The average seed test weight was maximum in five visits by *A. dorsata* followed by four, three and two visit which was significantly higher than the seed test weight under one visit in both hybrids (Table 3). The least seed test weight 75.13 g and 55.8810 g was observed in one bee visit in C-1076 and C-1106, respectively. Irrespective of number of visits, the seed test weight of C-1076 was significantly higher than the seed test weight of C-1106. The highest seeds

Table 1. Effect of number of visits on the flowers of pumpkin by *Apis dorsata* on fruit set

Number of visits	Mean fruit set (%) in two cultivars		
	C-1076	C-1106	Mean
One	36.08 (34.62)	32.84 (30.42)	34.46 (32.52)
Two	45.35 (42.08)	41.98 (39.78)	43.66 (40.93)
Three	57.24 (49.04)	50.72 (44.98)	53.98 (47.01)
Four	67.77 (54.93)	60.48 (50.76)	64.12 (52.84)
Five	77.84 (61.39)	72.09 (58.09)	74.96 (59.74)
CD (p =0.05)	(4.54)	(3.21)	(3.87)

Figures in the parentheses are angular root transformed values

Table 2. Effect of different number of visits on the flowers of pumpkin by *A. dorsata* on yield parameter of fruit in two cultivars

Number of visits	Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)		No. of seed fruit^{-1}	
	C-1076	C-1106	C-1076	C-1106	C-1076	C-1106	C-1076	C-1106
One	656.20	358.10	18.20	17.25	27.78	36.41	125 (11.21)	87 (9.37)
Two	951.90	642.90	22.75	21.50	32.57	36.83	179 (13.36)	140 (11.79)
Three	1625.40	1175.80	29.90	22.17	37.65	42.28	279 (16.70)	247 (15.53)
Four	2274.00	2012.60	33.00	25.65	41.35	44.31	350 (16.79)	308 (17.48)
Five	2787.80	2635.00	38.15	32.62	43.52	46.25	370 (17.62)	365 (19.05)
CD (p=0.05)	2.15	2.36	0.29	0.41	0.30	4.39	(1.40)	(1.72)

Figures in the parentheses are square root transformed values

Table 3. Effect of different number of visits by *A. dorsata* on quality parameter of fruit in two cultivars

Number of visits	Seed test weight (g)		Germination %		Seed Vigour 1		Seed vigour 11	
	C-1076	C-1106	C-1076	C-1106	C-1076	C-1106	C-1076	C-1106
One	75.13	55.88	86.00 (65.10)	65.00 (56.60)	2378.50	2269.41	3.80	3.77
Two	76.24	60.98	87.88 (65.40)	75.80 (64.10)	2588.61	2461.33	4.02	3.91
Three	79.67	65.17	90.00 (72.16)	80.67 (66.62)	2603.34	2630.91	4.53	4.28
Four	83.25	83.10	92.65 (76.94)	84.20 (72.37)	2743.07	2757.27	4.57	4.33
Five	85.74	84.84	94.85 (80.01)	92.05 (80.04)	2796.03	2767.12	4.59	4.35
CD (p =0.05)	N/S	0.75	(4.24)	(6.62)	NS	NS	NS	NS

Figures in the parentheses are angular root transformed values

germination per cent was 94.85 and 92.05 in five visits by *A. dorsata* followed by four visits 92.65 and 84.20 , three visits 90 and 80.67 and two visits 87.88 and 75.80. The least seeds germination per cent of equal to 86.00 and 65.00 was observed in one bee visit in C-1076 and C-1106, respectively. Irrespective of number of visits, the seed germination percentage of C-1076 was significantly higher than of C-1106. Seed vigour I and Seed vigour II was maximum in five visits by *A. dorsata* followed by four, three, two and one visits in both cultivars. Irrespective of number of visits, the seed vigour I of C-1076 and C-1106 was statistically on par. In cucumber, the best results were achieved when 8-10 bees visited each flower in first day of the flowering (Kochetov, 2004).

CONCLUSION

The maximum number of pumpkin fruit set, fruit weight, fruit length, fruit diameter, number of seeds per fruit, seed test weight, seed germnation percentage, seed vigour I and seed vigour II was recorded the highest in five visits by *A. dorsata* followed by four, three, two and one visit. Similar results with respect to multiplicity of bee visits were recorded in cultivar C-1106. No fruit set occured in without insect pollination. Honey bees are the main pollinators in cross-pollinated vegetable crops such as Cucurbitaceous, Cruciferous, Umbelliferous, Liliaceous and Amaryllidaceous vegetables etc. In both developed and developing countries, the pollination services of honey bees are used to increase the productivity of various agricultural and horticultural crops.

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Received 20 June, 2016; Accepted 14 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 854-856

Manuscript Number: 2396
NAAS Rating: 4.47

Effect of Modified Atmospheres on *Caryedon serratus (Olivier)* in Stored Groundnut

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Abstract: An experiment was conducted to know the effect of different modified atmospheres on the development of the Groundnut bruchid, *Caryedon serratus* (Olivier) in groundnut stored in different packaging material. The packaging systems; namely, aluminium pouches with different atmospheres, Magik bag and jute bag were tested against groundnut bruchid at different exposure periods. A decrease in percent grain damage was with the increase of CO_2 concentration at all the storage periods tested. Magic bag was effective in protecting groundnuts from *C. serratus* damage for long time as the number of adults emerged and grain damage caused by them were minimum because of the hermetic conditions developed within, due to their impermeable nature to the external gases.

Key Words: *Caryedon serratus,* Groundnut, Modified atmospheres

Groundnuts (*Arachis hypogaea* L.) are attacked by a plethora of insect pests in storage. Though most of the insect-pest attack kernels, groundnut bruchid, *Caryedon serratus* (Olivier) is the major one that infests pods and kernels. Apart from the direct loss caused due to insect infestation, indirect loss in terms of quality of the produce, *i.e.,* loss in oil percentage, increase in free fatty acids and crude protein percentage also impacts oil and processing industry. Though effective insecticides are available, concerns over residues limit their use and necessitate the alternate methods for control of this insect pest. Use of carbon dioxide (CO_2) has gained importance as an effective alternative to hazardous chemicals for protecting the stored produce from various insects (*Riudavets et al.,* 2006; Cheng *et al.,* 2012). Concentrations of CO_2 at 30, 40, and 50 per cent of the volume in airtight plastic containers were effective in controlling the groundnut pod borer (Bhogeesh *et al*., 2013). As the information on modified atmospheres with groundnut is limited, an investigation was made to understand the effects of different modified atmospheres with different packaging material on development of bruchid on groundnut kernels at Post Harvest Technology Centre, Bapatla during the two consecutive years; 2014 and 2015.

The packaging systems; namely, aluminium pouches with different atmospheres, Magik bag (M/s Coromandel International Limited) and jute bag were tested against groundnut bruchid at different exposure periods. There were six treatments with gas mixtures of different concentrations along with Magik bag storage and jute bag storage (Table 1). For the first six treatments aluminium pouches were used. Kernels of groundnut variety; TAG 24 free from insect infestation were taken and fumigated to ensure complete kill of prior infestation, if any. Kernels (250 g) were taken in each bag of 500 ml capacity and five pairs of mating adults were introduced before filling with gas mixture. Gas mixtures of CO_2, N_2 and O_2 at required concentrations (v/v) were adjusted by removing the equivalent volume of air and subsequently required volume of gas mixture was injected using the modified atmospheric packaging (MAP) system and then sealed. The insects were exposed to four different periods *i.e.,* 40, 80, 120 and 160 days. There were three replications arranged in completely randomized design for each set of exposure period. Each time, one set was taken out for recording the observations. The concentrations of CO_2 and O_2 in each treatment were recorded with the checkmate II of PBI Dansensor before opening it for taking observations. Data on progeny adult emergence and percent damage in groundnut kernels were recorded and subjected to statistical analyses after suitable transformation.

The progeny emergence of groundnut bruchid and corresponding damage in groundnut kernels due to their development at different atmospheres was estimated in different packaging material at 40 days interval up to 160 days. There was a gradual increase in progeny build up of groundnut bruchid and in per cent grain damage in all the treatments from 40 days to 160 days. The number of adults emerged from groundnut at 40 DAT was significantly less in Magik bag (4.83) and was on par with 90% CO_2 (5.83) (Table 1). The number of adults emerged in jute bag and in aluminium pouch without seal was 9.0. Storage in aluminium pouch without seal resulted in highest number of adults (21.33). Similar trend was observed in progeny development of groundnut bruchid with Magik bag and 90% CO_2 at 80 and 120 DAT. At 160 DAT, Magik bag storage allowed the least

Table 1. Effect of gas mixtures on progeny build up of Caryedon bruchid and grain damage in stored groundnut

Treatment	Caryedon adult emergence (No.)*				Grain damage (%)**			
	40 DAT	80 DAT	120 DAT	160 DAT	40 DAT	80 DAT	120 DAT	160 DAT
CO_2 30 % + N_2 56 % + O_2 14 %	3.17 (1.78)^{de}	3.33 (1.82)^{ef}	6.67 (2.58)^{de}	7.83 (2.80)^{d}	15.5 (23.16)^{e}	19.83 (26.43)^{d}	30.83 (33.7)^{de}	40.67 (39.6)^{ef}
CO_2 50 % + N_2 40 % + O_2 10 %	2.83 (1.68)^{cd}	3.0 (1.73)^{de}	5.67 (2.38)^{cd}	6.83 (2.61)^{c}	11.33 (19.66)^{d}	18.67 (25.58)^{d}	29.17 (32.6)^{d}	36.33 (37.04)^{d}
CO_2 70 % + N_2 24 % + O_2 6 %	1.83 (1.34)^{a}	2.0 (1.41)^{bc}	4.0 (2.0)^{ab}	5.5 (2.34)^{b}	8.0 (16.39)^{b}	9.67 (18.07)^{b}	17.0 (24.3)^{c}	27.33 (31.48)^{c}
CO_2 90 % + N_2 8 % + O_2 2 %	1.0 (1.37)^{ab}	1.5 (1.21)^{a}	3.33 (1.82)^{a}	4.83 (2.20)^{ab}	5.83 (13.92)^{a}	8.67 (17.09)^{ab}	12.0 (20.26)^{b}	23.5 (28.98)^{b}
Normal air with airtight seal	2.17 (1.46)^{bc}	2.5 (1.58)^{cd}	4.67 (2.16)^{bc}	7.83 (2.80)^{d}	9.67 (18.05)^{c}	12.17 (20.39)^{c}	16.67 (24.05)^{c}	37.67 (37.84)^{de}
Normal air without seal	5.83 (2.41)^{f}	8.33 (2.88)^{g}	36.0 (5.98)^{f}	24.5 (4.95)^{f}	21.33 (27.45)^{f}	48.5 (44.12)^{e}	51.5 (45.84)^{f}	79.17 (62.87)^{g}
Magik bag storage	1.5 (1.22)^{a}	1.83 (1.34)^{ab}	3.67 (1.91)^{a}	4.33 (2.07)^{a}	4.83 (12.61)^{a}	7.33 (15.7)^{a}	8.83 (17.28)^{a}	11.17 (19.51)^{a}
Jute bag storage	4.0 (2.0)^{e}	4.0 (2.0)^{f}	7.67 (2.77)^{e}	9.83 (3.14)^{e}	9.0 (17.43)^{bc}	12.83 (20.93)^{c}	34.5 (35.92)^{e}	42.0 (40.38)^{f}
CD (p=0.05)	0.23	0.18	0.24	0.16	1.55	1.67	2.20	1.77
CV%	13.81	10.06	8.93	5.39	8.23	7.01	7.43	4.69

The values in parentheses are transformed (*square root, ** angular) values. DAT- Days After Treatment
For the first six treatments aluminum pouches were used

number of adults to emerge followed by 90% CO_2 (4.83). Similarly, least per cent grain damage was recorded in Magik bag storage which was on par with 90% CO_2 (5.83) at 40 DAT. Even at 160 DAT, the grain damage recorded in Magik bag storage was only 11.17 per cent against gunny bag storage (42.0%) and aluminium pouch with normal air without seal (79.17%). The highest progeny and per cent grain damage were recorded from the groundnut kernels stored in aluminium pouch containing normal air without seal, where as the lowest progeny and grain damage from Magik bag storage at all the times of observation. A decrease in per cent grain damage was observed with the increase of CO_2 concentration at all the storage periods tested. Even at higher concentration of CO_2 (90%), a grain damage of 23.5 per cent was observed probably the CO_2 diffused out within few days.

Magic bag was effective in protecting groundnuts from *C. serratus* damage for long time as the number of adults emerged and grain damage caused by them were minimum because of the hermetic conditions developed within, due to their impermeable nature to the external gases. The results also indicated that apart from the concentration of CO_2, permeability of packaging material is much more important parameter to be considered for maintaining modified atmosphere for a desired period and at a level that can achieve effective management of the insect. The results also suggested that CO_2 fumigation in airtight containers may be a better alternative for control of storage pests in high valued low volume produce.

Though many types of plastic films are available for packaging, very few with certain level of gas permeability are suitable for MAP. The polymer should not be permeable to the external atmospheric oxygen to sustain modified conditions internally. Hence, it is very important to select a polymer with suitable gauge so that the modified atmosphere can be maintained for a longer duration and make it uncongenial for insect development. Hermetic conditions were developed within the Magik bag, due to their impermeability to the external gases. The results were in agreement with the reports of Cabardo *et al*. (2012) that hermetic bags *viz*., IRRI Super Bag, GrainPro SGB IIZ and Kantong Semar not only prevented oxygen from penetrating, but also prevented carbon dioxide from leaking out of the bags. Modified atmosphere containing concentrations of CO_2 at 15 and 20 per cent resulted in cent per cent mortality of *R. dominica* after 45 days of exposure in stored sorghum packed in poly ethylene chloride bags of 700 gauge (Mekali *et al*., 2013). Bhogeesh *et al*. (2013) and Radhika *et al.* (2014) also reported the efficacy of elevated levels of CO_2 against *C. serratus* in groundnut stored in air tight containers. Whereas, Vachanth *et al.* (2010) reported that the mortality per cent of red flour beetle, *T. castaneum* was higher in aluminum pouches (100%) followed by high density polypropylene (40%) and in the low density polypropylene (20%) bags at the gas proportion of 35% CO_2, 52% N_2 and 13% O_2 in processed little millet.

The results clearly indicated that apart from the concentration of CO_2, permeability of packaging material is much more important quality to be considered in order to maintain modified atmosphere at desired level and exposure time for effective management of the insect. This also confirms that in a good packaging material which has low permeability to the gases will certainly be effective in arresting development of insects even at lower concentrations of CO_2.

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Received 20 March, 2016; Accepted 18 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 857-859

Manuscript Number: 2397
NAAS Rating: 4.47

Comstock Mealy Bug (*Pseudococcus comstocki*), a Native Pest of the Chinese Ecosystem Intercepted in Imported Pears and Quince Fruit in India

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Abstract: Live interception consisting of a mixed population of crawlers and female of *Pseudococcus comstocki* (Kuwana 1902) mealy bugs were detected during routine quarantine inspection and subsequent lab analysis in fresh pear and quince fruits imported from China.

***Key Words*:** Comstock mealy bug, Plant quarantine, Pears, *Pseudococcus comstocki,* Quince

The comstock mealy bug is a native pest of the Chinese and Japanese ecosystems. Comstock mealy bugs are pests of pome and citrus fruits. To date, the comstock mealy bugs are a serious pest for the pear processing factory since it degrades the quality of the puree. *Pseudococcus comstocki* is widely distributed in countries such as China, Africa, Armenia, Azerbaijan, Cambodia, Georgia (Republic), Japan, Kazakhstan, Korea (DPR), Korea (Republic of), Kyrgyzstan, Sri Lanka, Tajikistan, Thailand, Turkmenistan, Uzbekistan, Vietnam, Moldova, Portugal, Russian Federation, Ukraine, Canada, Mexico, USA, Argentina. *Pseudococcus comstocki* is a quarantine pest for India. The hosts include pear, apple, lime, pomegranate, banana, peach, apricot, cherry, catalpa and mulberry. Temperature plays a major role in the development of *Pseudococcus comstocki*. The optimum temperature required for its development ranges from 25-30 °C. Maximum development takes place at 26°C. The eggs are bright orange in colour and are covered with waxy substances. They are elliptical in shape and are laid in clusters (groups). The adult female lays its eggs under tree barks, pruning cuts and rarely near the calyx points. The crawlers or young ones are yellowish orange in colour. They are oval shaped and lack body filaments. They undergo three moults. The first instar is pale yellow in colour. The second and third instars are reddish brown in colour. The female crawlers undergo moult twice before they become adults. Pupal stage is within a thin cocoon. The third instar of male crawlers is called as "propupa". Crawlers are generally detected near the blossom points of Pear fruits. The adult males are tiny gnat-like insects. They can fly and can be captured with the help of pheromone traps. They are reddish brown in colour with two long caudal filaments. The males of *Pseudococcus comstocki* are peculiar with 3 pairs of eyes, dorsal, lateral and ventral (Steve and Agnello, 1991). The antennae are ten segmented. The mouth parts are absent. The females are elongate oval shaped and segmented. They are reddish brown in colour and cannot fly. The females are covered with wax and hence appear cottony, fluffy white in colour. They have 17 pairs of filaments. The caudal filaments are long and measure about one-third of the body length. The Comstock mealy bug undergo overwintering phase. This paper deals with the interception of Comstock mealy bug in imported consignments of fresh Pear and Quince from china when the fruits were subjected to quarantine screening during 2011-2012 at Regional Plant Quarantine Station, Chennai. Live infestation consisting of a mixed population of crawlers and female mealy bugs were detected during routine quarantine inspection and subsequent lab analysis.

Systematic and routine quarantine inspections on pears and quince fruit imported from China were carried out subsequently by visual inspection of potentially infested fruits. Pears and quince (fruits as host material) showing fluffy cottony balls /colonies on the fruits, blossom points and stalks (Fig:2,3,4) were collected in plastic bags. Each sample bags (24 fruits/ sample bag) were labelled with details such as import registration number, date of registration, name of the commodity, country from which imported and date of sampling (Tatjana *et al*., 2009). The collected samples were subjected to subsequent lab analysis. The lab analysis techniques include visual, magnoscopy, microscopy, cutting and separation and incubation techniques. Crawler

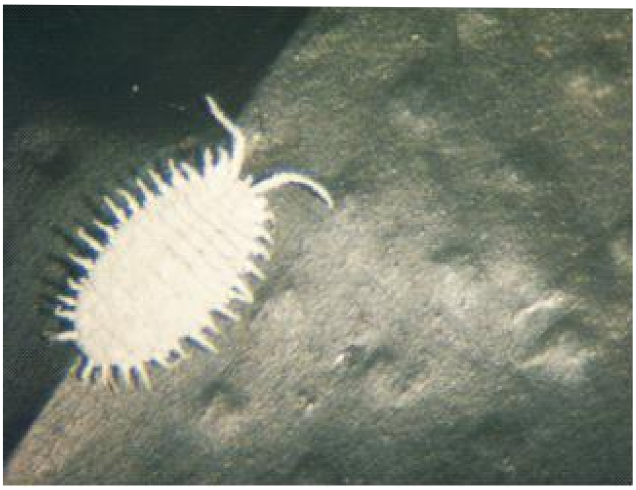

Fig. 1. Comstock Mealy Bug

Fig. 2. Cottony fluffy balls

Fig. 3. Calyx end of the pear fruit with mealy bug infestation

Fig. 4. C.S view of the calyx end with infestation

infestation was determined by thorough examination of the calyx end. The fruits were cut open lengthwise to expose the inner calyx area (Fig.4), which is often concealed in the whole fruit. The migrating activities of the crawlers were also closely monitored. The mealy bugs were observed under high resolution microscopes. The infested fruits were kept in incubation jars for subsequent monitoring. To observe migration and their subsequent development, 500 gm PET jars were taken. The lids of these jars were cut open in the middle. The cut portion was sealed with wired gauze for aeration. The fruits were placed inside the incubation jars and continuously monitored. During inspection, both pre-treated and post-treated samples were drawn to check mortality and ensure complete control of these exotic mealy bugs in the infested consignment.

It was intercepted and recorded for the first time in India (Anonymous, 2012). The infested consignments were subjected to treatment with methyl bromide @ 32gms/CuM for 2hrs at 21°C and above as per the Plant Quarantine order 2003 as a protective measure to facilitate safe trade, filter harmful pests and prevent their establishment in the Indian ecosystem. Pre-treated and post-treated samples were drawn and analysed to ensure complete control and establishment of these exotic mealy bugs. The crawlers and adult mealy bugs were mostly seen near the blossom points/ calyx of the pear and quince fruits. Close observation revealed that crawlers and female mealy bugs seen on the calyx points in the morning migrated to the blossom point in the evening. Mealy bugs suck the plant sap and are mostly found near the growing tips. Honey dew like substances were detected on the fruits. The mealy bugs were identified to be quarantine when observed under high resolution microscopes. They were found to have 17 body filaments and two long caudal filaments. They were sent to the insect identification team of the Indian Agricultural Research Institute (national referral point for quality and standards), New Delhi who later identified these soft bodied insects to be exotic *Pseudococcus comstocki* (Fig. 1). It is a quarantine pest for India as per the PQ order 2003. They are native pests of the Chinese and Japanese ecosystem (Anonymous, 2003). The Quarantine Pathway for the entry, spread and establishment of these exotic *P.comstocki* were found to be infested fruits, infested packing materials and immature / mature crawlers that settle on the fruits during harvesting. The suggested protective quarantine measures includes proper bagging of fruits, thorough and strict inspection, air-brushing, treatment with MBr fumigation @ 32gm/cum for 2 hrs @ 21 °C or above at NAP, effective cold treatment such as pre -shipment cold treatment at 0°C or below for 10 days; 0.55° C or below for 11 days; 1.1°C or below for 12 days plus in-transit refrigeration (Anonymous, 2003).

Received 06 August, 2016; Accepted 24 August, 2016

ACKNOWLEDGEMENT

The authors are thankful to Dr. V.V. Ramamurthy, In-charge, Insect Identification Service, Division of Entomology, Indian Agricultural Research Institute, New Delhi for identification.

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 860-862

Manuscript Number: 2398
NAAS Rating: 4.47

Effect of Organic and Inorganic Sources of Nutrients on Productivity, Nutrient Uptake and Availability of Nutrients in Rice-Wheat Cropping System

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***Abstract*: **Substitution of 50% N through FYM and 50% recommended dose of fertilizers (RDF) in rice and 100% RDF through fertilizer in wheat recorded the highest system productivity (rice equivalent yield 9.58 t ha^{-1}) and nutrient uptake (207.7, 42.9, 233.4 kg N, P and K ha^{-1}) in rice-wheat cropping system. All the organic sources (FYM, wheat straw, *Sesbania* green manure) enriched the soil in organic carbon contents. Farm yard manure (FYM) and green manure of *Sesbania aculeata* improved available N and P levels of soil-whereas wheat straw could bring significant improvement only in available K content of soil.

***Key Words*: **Integrated nutrient management, Nutrient uptake, Rice-wheat cropping system, Soil fertility status, System productivity

Rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) is the major cropping system in India, covering 10-12 million ha area and contributing about 22% to the total food grain production. There are indications of stagnation or even decline in the productivity of this cropping system due to decline in soil organic matter, over mining of nutrient reserves and loss of nutrients (Singh and Wanjari, 2013). Further, the application of chemical fertilizers even in balanced form may not sustain soil fertility and productivity under continuous cropping. However, integrated use of inorganic and organics including crop residues may improve the soil productivity (Bajpai *et al*., 2006). Incorporation of crop residues (*bhusa*), green manuring and farm yard manure are viable sources for improving soil fertility. The residual nature of organic sources makes them more value-based for the whole system as compared to individual crops. With the above facts, these studies were initiated to know the effect of integrated nutrient management on uptake of nutrients and different properties of soil.

Field experiments were conducted in fixed plots at N.D. University of Agriculture & Technology, Faizabad ($26^0$47' N, $82^0$12' E and 113 m above mean sea level), during 2012-13 and 2013-14. The climate of the area is sub humid sub tropical. The soil was silty loam in texture with pH (8.8), organic carbon (3.7 g kg^{-1}), available N (102 kg ha^{-1}), P (13.8 kg ha^{-1}) and K (355 kg ha^{-1}). The experiment was laid out in randomized block design with 12 treatments, replicated 4 times. Out of 12, six promising treatments for rice and wheat were selected for this study viz. T1, N0P0K0 – N0P0K0; T2-75% RDF-75% RDF; T3, 100% RDF- 100% RDF; T4, 50% N through FYM + 50% RDF-100% RDF; T5, 50% N through wheat cut straw + 50% RDF-100% RDF; T6, 50% N through *Sesbania aculeata* as green manure + 50% RDF-100% RDF for rice and wheat, respectively. The recommended fertilizer dose (100% RDF) of N, P and K was 120, 26 and 50 kg ha^{-1}, respectively, for both the crops, of which half of N and full dose of P and K were applied basal. The remaining N was divided into 2 equal parts and applied 21 and 45 days after sowing/transplanting as per treatments. The sources of N, P and K were urea, diammonium phosphate and muriate of potash, respectively. The organic manure viz. FYM, crop residue viz. wheat cut straw and green manure viz. *Sesbania aculeata* were incorporated in soil on the basis of N content as per the treatment, 15 to 20 days before transplanting of rice in *kharif* season every year.

Grain yield: The maximum grain yield of rice, wheat as well as system (Table 1) was with 50% N through FYM + 50% N through chemical fertilizer in rice and 100% RDF in wheat. Pooled mean data for rice equivalent yield under rice-wheat cropping system varied from 23.2 to 95.8 q ha^{-1} and influenced by organic sources. The increase in mean grain yield was 3.7 q ha^{-1} for rice, 2.3 q ha^{-1} for wheat and 6.4 q ha^{-1} for rice equivalent yield as compared to recommended doses of fertilizers (100% RDF) both in rice and wheat. The substitution of 50% N through wheat cut straw significantly reduced the grain yield of the system in terms of rice equivalent yield and reduction was 10.0 q ha^{-1} as compared to recommended doses (100% RDF) of fertilizers in both the crops. The substitution of a part of N through wheat straw did not perform well possibly due to slow mineralization of organic N leading to its deficiency during growing period of rice (Pathak *et al*., 2005). This finding indicated that the combined application of well decomposed organic nutrient source and chemical fertilizers proved to be superior to soil inorganic fertilizer application. Higher availability of nutrients because of favourable effect of organic sources might have improved physiological and metabolic functions inside the plant body which in turn laid down the foundation for higher yield in both the crops (Jat *et al*., 2012, Singh and Wanjari, 2013).

Nutrient uptake: The uptake of N, P and K by rice (Table 2) was the maximum from the treatment substituted 50% N through FYM. The treatment next in order was the one which substituted 50% N through *Sesbania* green manure. Uptake of nutrients by wheat crop was significantly higher in the treatment involving 50% substitution of N through FYM in preceding rice crop and getting 100% NPK through fertilizers in wheat. The substitution of 50% N through wheat cut straw resulted in more K uptake than 100% recommended NPK in inorganic form alone, in wheat crop. Higher biomass production may be the most pertinent reason for higher uptake of nutrients. Higher availability of nutrients due to synergistic effect of organic sources and higher K concentration in different organics might have been responsible for better uptake of nutrients.

Nutrients availability: Addition of organic matter was found helpful in improving status of organic carbon, available N, P and K in soil during experimentation. The FYM was instrumental in build up of significantly highest organic carbon content of soil. The *Sesbania* green manure and wheat straw were the next. Application of even the half of the recommended dose of inorganic fertilizers maintained the original organic carbon level. The control plot exhibited reduction in organic carbon content. The highest available N in soil (Table 2) was noted in treatment receiving FYM followed by *Sesbania* as green manure. The maximum buildup in available P was also observed in plots supplied with FYM followed by green manuring of *Sesbania aculeata* and wheat straw. The plots getting wheat straw as the source of nitrogen substitution exhibited higher available K in soil closely followed by FYM. A considerable increase in P status was noted even in the treatment getting 100% recommended dose of NPK through inorganic forms. Increase in available P in integrated nutrient sources (inorganic + organic) may be due to the release of native P by the solubilization effect of organic matter (Pathak *et al*., 2005). Higher K content in

Table 1. Effect of integrated nutrient management practices on grain yield of rice and wheat and rice-equivalent yield (Pooled value of 2 years)

Treatment	Details of treatment		Grain yield (q ha^{-1})		Rice equivalent yield (q ha^{-1})
	Rice	Wheat	Rice	Wheat	
T_1	N0P0K0	N0P0K0	15.1	7.0	23.2
T_2	75% RDF	75% RDF	40.8	26.1	71.2
T_3	100% RDF	100% RDF	50.2	33.6	89.4
T_4	50% N(FYM) + 50% RDF	100% RDF	53.9	35.9	95.8
T_5	50% N (WCS)+ 50% RDF	100% RDF	40.2	33.6	79.4
T_6	50% N (GM)+ 50% RDF	100% RDF	51.4	33.8	90.8
CD (p=0.05)			3.9	2.8	7.3

Table 2. Effect of integrated nutrient management practices on nutrient uptake by rice and wheat and on fertility status of soil after 30 years of cropping, fertilizer and manure application

Treatment	Nutrient uptake (kg ha^{-1})						Soil organic carbon (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
	By rice			By wheat						
	N	P	K	N	P	K				
T_1	22.0	4.0	32.7	11.2	2.2	15.6	2.5	101	5.3	188
T_2	81.5	14.6	101.5	54.2	10.2	61.5	4.3	162	18.6	234
T_3	109.2	21.6	130.3	80.2	15.8	86.7	4.8	201	24.0	252
T_4	120.1	24.9	138.8	87.6	18.0	94.6	5.8	215	27.1	259
T_5	81.3	15.1	108.2	78.3	15.9	88.9	5.2	198	21.3	272
T_6	112.2	22.2	131.5	83.8	16.6	87.8	5.4	213	25.5	255
* CD (p=0.05)	8.8	1.6	10.9	7.9	2.6	9.9	0.4	10	1.8	12
Initial value (1984)							3.7	102	13.8	355

See table 1 for treatment details

wheat straw than other organic sources might have been the possible reason for higher residual K in soil. The total biomass content of organic sources substituting fertilizers for supply of nutrients in a particular proportion can be assigned to a possible reason for variation in organic carbon content of soil. Similar results were obtained under different cropping sequences in different types of soils of India (Bajpai *et al*., 2006; Laxminarayana, 2006).

It may be concluded from the above results that integrated nutrient management coupled with farm yard manure or green manure of *Sesbania aculeata* and chemical fertilizers sustains the productivity of rice-wheat cropping system and enhances organic carbon and availability of nutrients in long run.

Received 20 February, 2016; Accepted 04 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 863-865

Manuscript Number: 2399
NAAS Rating: 4.47

Performance of Wheat (*Triticum aestivum* L) Sown with Different Methods in Rice Straw

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Abstract: A field experiment was conducted to study the effect of different planting methods on the growth and yield of wheat. Wheat crop sown with zero tillage with rice straw gave maximum grain yield at low cost by skipping the tillage operation for seed bed preparation and to manage the combine harvested paddy straw and ultimately to improve the soil health. Results revealed that plant height was more with conventional tillage without rice straw, which was statistically at par with zero tillage with rice straw and Conventional tillage with rice straw. The grain yield obtained from conventional tillage without rice straw was significantly higher than happy seeder, rotavator with rice straw and zero tillage without rice straw sown wheat but it was statistically at par with zero tillage with rice straw and rotavator without rice straw sown wheat.

***Key Words*:** Conventional tillage, Happy seeder, Rice straw, Rotavator, Wheat, Zero tillage

Conventional tillage operation with mould board plowing gives good preparation of seed-bed with weed free condition and high yield than direct seeding due to the fact that weed manifestation was greater in direct seeding than the conventional method (Yalcin *et al.,* 2005). Rice straw has found no economic local uses and remains unutilized. Rice straw incorporation is practiced by less than 1% farmer as it is energy and time intensive and delay wheat sowing (Sidhu *et al.,* 2010). Developing a cost effective technique for better utilization of this vast resource was an important challenge for the farm engineers. However, there were problems with direct drilling of wheat into combine-harvested rice fields like straw accumulation in the seed drill furrows openers, poor traction of the seed metering drive wheel due to the presence of loose straw and the uneven seed depth due to frequent lifting of the implement under heavy trash conditions. The happy seeder cuts and manages the standing stubble and loose straw in front of the furrow openers, retaining it as surface mulch and sows wheat in a single operational pass of the field. Operational costs for sowing with happy seeder is 50-60% lower than conventional sowing. Farmers generally burn rice residue prior to wheat sowing the cheap and easy option for residue management but burning leads to losses of soil organic matter and nutrients (especially N,S and C) and create environmental pollution (Singh *et al.,* 2007). The Happy seeder technology provides an alternative to burning for managing rice residues and allows direct drilling of wheat in standing as well as loose residues (Gathala *et al.,* 2009). In case of sowing with rotavator, initially it is used in the combine harvested paddy fields to incorporate the paddy straw followed by mixing the broadcasted seed of wheat in the soil.

Rotavator sown crop had shallow root system due to compaction; more weed population as compared to happy seeder but less than farmer's practice. Zero tillage technology is a special technique of establishing crops, without tillage and seedbed preparation. Under this method of irrigation is applied to the rice fields during mid-October before harvesting of rice crop. Wheat is sown through zero tillage drills in the residual moisture to avoid the late sowing. It also saves the cost of water and preparation of seedbed up to 30% (Aslam *et al.,* 1999). It enhances the wheat yield as compared to the other tillage practices and facilitates less use of machinery and hence energy can be saved through less consumption of fuel and is eco-friendly (Grey *et al.,* 1996; Chauhan *et al.,* 2015). The sowing of wheat with happy seeder and rotavator in the combined harvested field can add large amount of nutrients in the soil, which will help to improve the soil productivity. Similar or slightly higher grain yield can be obtained with the sowing of happy seeder (zero tillage) and rotavator (reduced tillage) as compared to farmer s practice, which are most suitable methods for in-situ management of paddy straw and control of weed population (Singh *et al.,* 2013). Planting method has a significant effect on water, nitrogen and phosphorus economy, energy saving sand soil compaction (Troedson *et al.,* 1989). Absorption of photosynthetically active radiations has also been found to be influenced by planting methods (Lal *et al*., 1991). The objective of this study was to find out the suitable method of planting for maximum wheat production.

The field experiment was carried out at University

Table 1. Effect of different planting methods on growth, yield contributing characters and yield of wheat

Treatment	Emergence count	Plant height (cm)	Number of effective tillers (m^2)	1000-grain weight (gm)	Number of grains (m^2)	Ear length (cm)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})
T1	34.00	87.3	230.67	39.30	47.60	9.20	41.12	58.80	99.92
T2	44.33	94.7	297.33	41.45	51.47	10.43	49.61	73.42	123.03
T3	31.00	90.2	251.67	41.35	51.35	10.37	44.38	63.91	108.29
T4	35.77	93.9	282.00	40.86	51.24	10.43	44.58	66.87	111.45
T5	39.67	99.0	305.00	40.63	48.29	9.17	46.48	66.00	112.48
T6	37.67	101.2	315.00	41.16	50.49	10.47	50.09	73.13	123.22
T7	37.33	98.6	311.67	41.00	50.41	10.23	47.89	72.31	120.20
CD (p=0.05)	6.02	3.2	47.74	NS	2.62	NS	4.35	5.49	10.81

T1 - Happy seeder, T2- Rotavator without rice straw , T3 - Rotavator with rice straw, T4- Zero tillage without rice straw, T5 - Zero tillage with rice straw, T6- Conventional tillage without rice straw, T7- Conventional tillage with rice straw

seed farm, Ladhowal, Punjab Agricultural University, Ludhiana during rabi season of 2013-2014 to see the effect of different planting methods on the growth and yield of wheat. Treatments consist of seven planting methods as:T1 - happy seeder, T2- rotavator without rice straw, T3 - rotavator with rice straw, T4- zero tillage without rice straw, T5- zero tillage with rice straw, T6 - conventional tillage without rice straw and T7- conventional tillage with rice straw were laid out in randomized block design with three replications. The soil of the experimental field was sandy loam in texture and normal in pH and organic carbon. The crop was sown according to the treatments in 2nd week of November using HD 2967 variety of wheat with recommended practices (Anonymous 2014-15). The height of plant was measured from the base to the tip of last leaf till ear emergence. After ear mergence, height form the base to apex of the ear was taken as height of the plant. Tillers were counted by using 50 cm x 50 cm quadrate from each plot. In each plot, fresh sample of plants was taken from 25 cm from row length for dry matter production. The collected plant biomass was first sun dried then oven dried at 60^{o}C till the constant weight, was expressed as q ha^{-1}. The crop was harvested on 24 April in 2014.Growth parameters and grain yield were recorded to know the influence of treatments.

Growth characters: The emergence was highest in rotavator without rice straw, which was statistically at par with zero tillage with rice straw and was significantly differed from happy seeder, rotavator with rice straw, zero tillage without rice straw, conventional tillage without rice straw and conventional tillage with rice straw. The plant height was more with conventional tillage without rice straw, which was significantly better than T1, T2, T3 and T4 and statistically at par with treatment T5 and T7. Plant height was greater in conventional tillage than no-tillage was reported by Wiatrak *et al*. (2006). The maximum number of effective tillers was in conventional tillage without rice straw over T1 and T3, which was statistically at par with rest of the treatments. The similar results were reported by Singh *et al.* (2013). They stated that the average numbers of tillers per meter square were higher in the rotavator sown crop followed by farmer's practice and happy seeder. The 1000 grain weight was not influenced by planting methods. The number of grains per ear obtained significantly higher in rotavator without rice straw sown crop than zero tillage with straw and happy seeder sown crop but was statistically at par other treatments.

Yield attributing characters: The data revealed that the planting methods did not influence ear length of wheat. The grain yield obtained from conventional tillage without rice straw was significantly higher than happy seeder, rotavator with rice straw and zero tillage without rice straw sown wheat but it was statistically at par with zero tillage with rice straw and rotavator without rice straw sown wheat. Khan *et al.* (2002) reported that the drill sowing on well prepared soil gave highest grain yield followed by rotavator without rice straw and conventional tillage with rice straw. Wheat sown with rotavator without rice straw recorded significantly higher straw yield than happy seeder, rotavator with rice straw and zero tillage with and without rice straw and was statistically at par with conventional tillage with and without rice straw sown wheat. However, maximum the biological yield obtained from conventional tillage without rice straw sown wheat, which was statistically at par with conventional tillage with rice straw and rotavator without rice straw sown wheat but was significantly differed from happy seeder, rotavator with rice straw, zero tillage without rice straw and zero tillage with rice straw.

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Received 02 March, 2016; Accepted 16 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 866-868

Manuscript Number: 2400
NAAS Rating: 4.47

Phenology, Biomass Accumulation and Nutrients Uptake of Barley Genotypes Under Varying Nitrogen Levels

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Abstract: A field experiment was conducted during the *rabi* 2011-12 at CCSHAU, Hisar to study the effect of nitrogen levels on phonological development, yield and nutrient uptake of barley (*Hordeum vulgare* L.) genotypes. Application of nitrogen significantly prolonged number of days to heading and maturity by 3-7 days. Biological yield and nutrient uptake increased significantly up to 90 kg N ha^{-1} application, whereas, no significant increase in harvest index with increasing nitrogen levels was observed. Days to heading and maturity were significantly influenced by genotypes. The proportion of bold grains was higher in DWR 91. Total uptake of nitrogen and phosphorus was higher in BH 885, whereas, total potassium uptake was more in DWR 91.

Key words: Barley, Genotypes, Nitrogen levels, Nutrient uptake, Phenology

Barley (*Hordeum vulgare L.*) is a versatile cereal grain world-wide, ranking fourth in acreage and production after wheat, rice and maize (Kumar *et al.,* 2007). It is a rich source of zinc, copper, phosphorus, calcium and iron. Being a good source of protein, it is used as a feed for livestock. Barley is considered as an industrial cereal due to its demand for manufacture of alcoholic beverages, such as beer, whisky and other non-alcoholic malted food products like baby food, cocoa malt drinks, vinegar and in ayurvedic medicines. Being salt resistant it holds promise under irrigated eco-system with marginal and salt affected soils. In the major barley growing countries of the world, more than 80 per cent of barley is utilized for manufacture of brewing and malting (Devaraja and Hegde, 2006). The potential of the latest developed genotypes of barley can be fully exploited through appropriate management of agronomic practices. Barley crop like wheat requires cool climatic conditions and responds to nutrient management practices under irrigated eco-system.Nitrogen is the most important element for realizing potential yield of crops, but it increases protein content in barley grain which is undesirable for brewing (Singh *et al.,* 2013). Since nitrogen is deficient in most soils, there is need to study the graded dose of nitrogen, being variability of new genotypes to respond to this nutrient. So the present study was undertaken, with varying levels of nitrogen, to assess phenology, yield and nutrient uptake in barley genotypes.

The field experiment was carried out at Research farm of CCS Haryana Agricultural University, Hisar during the *rabi* season of 2011–12. Hisar is situated at an elevation of 215.2 meters above mean sea level with latitude of 29^0 10' North and longitude of 75^0 46' East. The soil was sandy loam, with pH 8.3, low in available nitrogen (133 kg ha^{-1}), medium in available phosphorus (16 kg ha^{-1}) and high in available potash (328 kg ha^{-1}). Experiment was laid out in split-plot design with three replications. Treatments comprised of five nitrogen levels (0, 30, 60, 90 and 120 kg ha^{-1}) in main plots and five genotypes (DWR 91, DWRUB 64, DWRUB 52, DWR 71 and BH 885) in sub-plots. Nitrogen was applied in 2 equal splits–as basal and first irrigation (45 days after sowing) stage as per treatment; however, phosphorus was applied @ 30 kg ha^{-1} through single super phosphate as a basal dose. The crop was sown on 16 December 2011 using a seed rate of 100 kg ha^{-1} with a row-to-row spacing of 18 cm. Two irrigations were applied to the crop.

Days to emergence generally took 10 to 11 days due to low temperature during December. However, statistically, there was no significant difference for days to emergence for the factors N and genotypes (Table 1). During germination the seedling mostly depends on stored food than on external nutrient. Days to heading and maturity was significantly affected by nitrogen levels and genotypes. All nitrogen levels resulted in significantly delayed heading as compared to control. Delay in maturity time of barley was greater at higher rates of N. The higher N rates i.e. 90 and 1200 kg ha^{-1} were at par among each other and they were significantly different from the other three treatments. About seven more days were required for the 120 kg N ha^{-1} treatment when compared to the control which took 113 days to maturity. This might be attributed to the behavior of the fertilizer N which increases vegetative growth of crops whereby it delays maturity time. Number of days taken to heading was significantly more in DWR 91 as compared to DWRUB 64, DWR 73 and BH 885, but at par with DWRUB 52. Number of days taken to maturity was significantly less in BH 885 as compared to other genotypes. Genotypic variation in days taken to heading has also been reported by Sardana and Zhang (2005).

Nitrogen levels influenced the barley biomass significantly. All the nitrogen levels resulted in significantly higher crop biomass as compared to no nitrogen application. Successive increase in nitrogen application upto 90 kg ha^{-1} significantly increased the crop biomass, however, the difference between 90 and 120 kg N ha^{-1} was non-significant. Application of 90 kg N ha^{-1} produced 23.19 and 7.72 per cent higher biomass as compared to 30 and 60 kg N ha^{-1}, respectively. Biomass accumulation was also significantly influenced by the genotypes. The highest biomass was recorded in DWR 91, which was significantly higher than other genotypes *viz*. DWRUB 64, DWRUB 52, DWR 73 and BH 885. The crop biomass of DWRUB 64, DWRUB 52, DWR 73 and BH 885 was statistically at par with each other. The lowest biomass was recorded in DWR 73. Differences among varieties in relation to yield were also observed by Kaur and Singh (2011).

Nitrogen levels did not influence the harvest index significantly, however, genotypes behaved in different manner in relation to harvest index. The harvest index of BH

Table 1. Effect of nitrogen levels on days to emergence, heading and maturity; biological yield and harvest index of barley genotypes

Treatment	Days to			Biological yield (kg/ha)	Harvest index (%)
Nitrogen levels (kg ha^{-1})	Emergence	Heading	Maturity		
0	10.4	77.3	112.6	7188	40.83
30	10.0	80.6	115.6	8526	42.51
60	10.3	82.7	117.2	9751	42.58
90	10.0	83.6	118.9	10504	42.88
120	10.2	84.2	119.4	10705	42.91
CD (p=0.05)	NS	0.7	0.7	258	NS
Genotypes					
DWR 91	10.1	82.4	117.4	9809	41.96
DWRUB 64	10.2	81.4	117.4	9281	41.49
DWRUB 52	10.1	82.1	117.1	9299	43.03
DWR 73	10.6	81.1	115.3	9080	41.80
BH 885	10.0	81.4	116.6	9203	43.44
CD (p=0.05)	NS	0.4	0.7	407	1.26

Table 2. Effect of nitrogen levels on proportion of bold and thin grains and nutrient uptake of barley genotypes

Treatment	Bold grain (%)	Thin grain (%)	Total N (kg ha^{-1})	Total P (kg ha^{-1})	Total K (kg ha^{-1})
Nitrogen levels (kg ha^{-1})					
0	86.00	3.44	49.74	12.65	68.26
30	89.03	2.60	70.65	16.36	83.61
60	91.37	2.14	90.81	19.73	97.92
90	92.63	1.67	106.04	21.84	107.18
120	93.55	1.37	111.47	22.42	111.08
CD (p=0.05)	2.10	0.33	3.68	1.87	5.47
Genotypes					
DWR 91	96.42	1.16	85.85	19.51	97.78
DWRUB64	86.66	2.92	82.13	16.88	91.37
DWRUB52	90.80	2.62	81.90	19.01	92.75
DWR 73	87.70	2.24	83.86	17.56	90.30
BH 885	91.00	2.18	91.62	19.90	94.39
CD (p=0.05)	1.79	0.29	4.95	0.88	4.42

885 being at par with DWRUB 52 was significantly higher as compared to DWR 91, DWRUB 64 and DWR 73.

Nitrogen application effects were significant on the proportion of bold and thin grains. The proportion of bold grains increased significantly up to 60 kg N ha^{-1}. The proportion of thin grains decreases with corresponding increase in nitrogen application. Maximum thin grains proportion (3.44 %) was recorded in control plots. A significant decrease in thin grains was recorded up to 90 kg N ha^{-1}. Similar results were also reported by Kumar *et al.* (2007) who revealed the increase the in proportion of bold grains and decrease in thin grains with increased fertilization levels. Genotypes effects were also significant in relation to bold grain and thin grain percentage. The highest level of bold grains proportion was recorded in DWR 91, whereas, lowest in DWRUB 64. Sharma and Verma (2010) also reported varietal variation in bold and thin grains proportion.

The total uptake of nitrogen increased significantly with the increase in nitrogen application. The total uptake of nitrogen increased by 20.91, 20.16, 15.23 and 5.43 kg ha^{-1} with every additional increase of 30 kg N ha^{-1}.The highest uptake of phosphorus and potassium was recorded with 120 kg N ha^{-1} application but at par with 90 kg N ha^{-1} and significantly higher than other treatments. The positive relationship between rate of fertilizer N and plant N, P and K is consistent with the results of Ma³ecka and Blecharczyk (2008); Kumawat and Jat (2005); Halvorson and Reule (2007). Total uptake of N, P and K was also influenced significantly with genotypes. Maximum uptake of nitrogen and phosphorus was reported in BH 885, whereas, total uptake of potassium was found in DWR 91.Varietal variation in nutrient uptake has also been reported by Yadav *et al.* (2004).

Received 26 March, 2016; Accepted 14 August, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 869-871

Manuscript Number: 2401
NAAS Rating: 4.47

Economic Viability of Integrated Nutrition Garden Model for Sustaining Livelihood of Farm Households in Punjab

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Abstract: The demonstrations of Integrated Nutrition Garden (ING) model were conducted at the fields of 50 farmers in Moga district of Punjab. Seeds of recommended varieties and technical information were provided by the scientists of Krishi Vigyan Kendra (KVK), Moga. The present study was conducted to analyse economic viability of the recommended ING model for sustaining livelihood of farm households. The adoption of Integrated Nutrition Garden model by the farmers has helped them to ensure the household requirements of vegetables and pulses from their own fields with the saving in family expenditure. The average gross returns from ING model were estimated to be Rs.31545/- per annum when calculated at retail market price of the produce. The important constraints faced by the farmers in adoption of integrated nutrition garden at their fields were found to be shortage of time for ING activities, safeguarding the field produce from theft, non-involvement of other family members and difficulty in insect-pest management

Key Words: Adoption, Economic returns, Evaluation, Integrated nutrition garden, Viability

Punjab with just 1.53 per cent geographical area of the country produces about 18 per cent of wheat and 11 per cent of rice production of the country and has contributed about 43 per cent of wheat and 28 per cent of rice to the central pool of food grains during 2013-14 (Anonymous, 2014). Paddy-wheat is the prevalent cropping pattern followed on more than 80 per cent cropped area in the state. About 34 per cent of the farmers in the state operate on land holding of less than two hectares (Anonymous, 2014) and socio-economic condition of these small and marginal farmers is deteriorating day by day. According to reports, Punjab peasantry is reeling under debt and 89 per cent of farming families are indebted to the tune of Rs.3.5 lakh per farm family (Singh *et al.,* 2012). It implies that livelihood of small and marginal farmers is not secure and there is mismatch between agricultural productivity and prosperity of farming families. It is also observed that half of the number of children below the age of four year was malnourished and 60% women are anemic (Pandher, 2006). Indian society is predominantly vegetarian and as such consumption of meat and fish is generally avoided. Health experts of Indian Council of Medical Research (ICMR) advocate consumption of balanced diet consisting of 300g vegetables, 85g pulses and 50g fruits per person per day. However, in rural area the human diet is primarily cereal based and average consumption is merely 180 g vegetables, 40 g pulses and negligible quantity of fruits per person per day (Anonymous, 2005). The intake of protective foods like pulses, vegetables, milk and fruits are very low among rural population which leads to many nutritional deficiency disorders. Due to Indiscriminate use of chemical pesticides and non-observance of prescribed waiting period, the vegetables available in the market are generally found to contaminated and possess chemical residue. Consumption of such contaminated vegetables, fruits and pulses from the market may cause ill-effects on human health, besides increasing the family expenditure. Although farmers possess land, they usually purchase the vegetables and pulses from market due to lack of awareness and aptitude. To improve health parameters in rural area and to curtail domestic kitchen expenditure, Punjab Agricultural University (PAU) has developed a model of Integrated Nutrition Garden (ING) on an area of 1500 m^2, which enables a family consisting of eight members to meet their domestic requirement of vegetables, fruits and pulses. In this backdrop, the present study was conducted to analyse the economic viability of the recommended Integrated Nutrition Garden model for sustaining livelihood of farm households.

Integrated Nutrition Garden model was demonstrated on the fields of 50 farmers in purposively selected village Nidhanwala in Moga district of Punjab. Out of the total area of 1500 m^2 under demonstration, an area of 500 m^2 was used to cultivate seasonal vegetables i.e. peas, carrot, radish, spinach, coriander, metha and methi during winter and okra, summer squash, bottle gourd, bittergourd, cucumber during summer season whereas an area of 1000 m^2 was put under pulses i.e. gram, lentil, summer moong, summer mash cultivation for meeting domestic requirements. Although fruit plants were part and parcel of ING model, but due to perennial nature, their production was not taken into account for the present study. Krishi Vigyan Kendra (KVK), Moga provided improved seeds of vegetables and pulses to the selected farm families. For judicious use of fertilizers, soil and water of demonstration plots were got tested from PAU, Ludhiana. Package of practices recommended by Punjab Agricultural University, Ludhiana for cultivation for vegetables and pulses were followed in conducting these demonstrations. However in case of vegetables, farmers were advised to use organic manures i.e. FYM to meet the fertilizer requirement of crops and to practice hand hoeing for weed management. Manual as well as mechanical methods were to be preferred over the chemical methods of pest control. Chemical control measures were used as last resort. Retail market price of the produce was taken for calculating average returns from these demonstrations. Production of vegetables and pulses was recorded to calculate economic returns of the ING model.

The average total returns from the area of 500 m^2 used for vegetable cultivation under integrated nutrition garden were worked out to be Rs 13700/- per annum (Table 1).The average production of gram, lentil, summer moong and summer mash grown in nutrition garden was 82 kg, 44 kg, 50 kg and 45 kg, respectively from an area of 500 m^2 put under each crop. The yield obtained in nutrition garden was found to be less than the potential yield of vegetables and pulses. It might be due to non application of organic manure like FYM in appropriate quantity or some damage by pests might have occurred as farmers were advised to use minimum pesticides in nutrition garden.

The total returns from pulses grown on an area of1000 m^2 under integrated nutrition garden were worked out to be Rs.17845/- per annum. On aggregate, the average gross returns from ING model were estimated to be Rs.31545/- per annum. Taking into account the average yield of wheat (20 q $acre^{-1}$) and rice (30 q $acre^{-1}$) of the selected village, the gross return from rice-wheat crop rotation were calculated at MSP rates during the year 2012-13 and projected to be Rs.24525/- per annum from an equivalent area of 1500 m^2.

The study showed the adoption of Integrated Nutrition Garden model by the farmers has helped them to ensure the household requirements of vegetables and pulses from their own fields with the saving in family expenditure. It can also be inferred from the data that a farming family of eight members could save Rs 7020/- annually by developing nutrition garden on an area of 1500 m^2 when compared with returns from same area under rice-wheat crop rotation. Thus, it is evident that nutrition garden not only helps to achieve nutritional security among rural families but also results in overall reduction in household expenses. Similar results were also reported by Kumar and Singh (2009).

Table 1. Average production of crops and economic returns from Integrated Nutrition Garden (ING)

Crop	Average production (Kg)	Standard Deviation (SD)	Average market price (Rs/kg)	Returns (Rs.)
Vegetables				
Coriander	62.8	16.9	5	314
Metha	23.6	7.1	5	118
Methi	29.4	8.0	5	147
Chinese Cabbage	49.6	9.1	5	248
Spinach	125.4	14.9	5	627
Peas	64.5	13.2	20	1290
Carrot	122.6	15.3	10	1226
Turnip	57.2	4.1	5	286
Radish	121.8	9.8	5	609
Summer Squash	23	7.2	20	460
Bottle gourd	190	53.5	10	1900
Bitter gourd	67	23.1	15	1005
Cucumber	152	60.9	10	1520
Long melon	53	16.4	10	530
Ash gourd	86	32.7	5	430
Cowpea	60	21.1	20	1200
Okra	42	21.9	20	840
Radish	95	31.4	10	950
Sub-total (a)				13700
Pulses				
Gram	82	2.73	65	5330
Lentil	44	3.14	85	3740
Summer moong	50	15.78	90	4500
Summer mash	45	10.9	95	4275
Sub-total (b)				17845
Total returns from ING (a+b)				31545

Constraints in adoption of integrated nutrition garden at farmers fields: Farmers were also asked about various constraints faced by them in adopting integrated nutrition garden at their fields. Majority of the farmers (84%) felt that they could not find sufficient time for maintaining nutrition garden regularly due to more important farm activities of commercial crops (Table 2). The problem of safeguarding the produce of nutrition garden from theft was realized by 78 per cent of the farmers. The problem related to fear of theft of produce was also reported by Sharma *et al.* (2011). Development and maintenance of nutrition garden is a collective effort of all the family members, however 68 per cent of the farmers faced the problem of non-involvement of family members in different activities of nutrition garden like sowing of seeds, irrigation, picking and harvesting of produce

Table 2. Constraints faced by the farmers in adopting Integrated Nutrition Garden at their fields (n=50)

Constraint	Percentage
Shortage of time for maintaining nutrition garden	84.0
Safeguarding the field produce from theft	78.0
Non-involvement of other family members	68.0
Difficulty in insect-pest management	62.0
Lack of marketing of surplus produce	56.0
Lack of knowledge about processing and preservation of surplus produce	52.0
Timely availability of seeds and planting material	46.0
Non availability of FYM	42.0

etc. As many as 62 per cent of the farmers faced difficulty in managing insect-pests of various crops grown in nutrition garden. Optimum utilization of surplus produce of nutrition garden was also reported as a problem by the farmers. The data revealed that nearly half of the farmers found it difficult to sell the surplus produce (56%), whereas 52 per cent of the farmers could not process or preserve it due to lack of technical knowledge. Other problems faced by the farmers were timely availability of seeds and planting material (46%) and non availability of FYM (42%).

A scientifically developed nutrition garden helps to meet the domestic requirements of vegetables and pulses for a family all the year round. The vegetables and pulses are consumed by purchasing them from the market but rural farming families may find it difficult to include them in their daily diet. It is more important in rural areas where people have limited income and poor access to markets. Thus, nutrition garden may be seen as a low cost sustainable approach for increasing awareness of vegetable production, increasing working hours and achieving nutrition and livelihood security of farm families.

Received 14 February, 2016; Accepted 09 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 872-874

Manuscript Number: 2402
NAAS Rating: 4.47

Effect of the *Melia azedarach* L. Fruit Extract on Swelling of Non-durable Wood Species

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Abstract: Among different selected concentration of fruit extract of *Melia azedarach* L., swelling of wood has been recorded maximum in *Pinus roxburghii* Sargent in radial [5.19 (2.28)] and tangential [6.20(2.48)] plane while, in longitudinal plane [0.73 (0.85)], the maximum swelling was recorded in *Bombax ceiba* L. The lowest swelling in radial [2.88 (1.70)] and tangential plane [4.80 (2.19)] was recorded in *Bombax ceiba,* while the minimum swelling in case of longitudinal plane [0.62 (0.79)] was observed in *Pinus roxburghii*. The maximum volumetric shrinkage coefficient value has been recorded in *Pinus roxburghii* [12.24% (3.50)] and minimum in *Bombax ceiba* L.[7.90% (2.81)].

***Key Words*:** Bio-preservative, Eco-friendly, *Melia azedarach*, Non-durable species, Swelling

Wood is hygroscopic material, which changes dimensions with changing moisture content because the cell wall polymers contain hydroxyl and other oxygen containing groups that attracts moisture through hydrogen bonding. The hemicelluloses are the most hygroscopic component in the wood cell wall, but cellulose and lignin also contribute to hygroscopicity. Moisture swells the cell wall, and the wood expands until the cell wall is saturated. Water beyond this point is free water in the cell lumen and does not contribute to further expansion. It is reversible process and the wood shrinks with loss of moisture (Stamm, 1964).

The wood is anisotropic in nature hence; shrinkage and swelling of wood are not uniform in different directions of the wood for the same change of moisture content. These dimensional changes are the least in the longitudinal direction (along the tree trunk) and much greater in the transverse directions. The lower winding angle of the micro-fibrils causes wood to shrink or swell more in the transverse (radial and tangential) plane than in the longitudinal direction (Bowyer *et al.,*2003; Hill 2006). The longitudinal shrinkage or swelling in mature/outerwood is generally very small. However, in the case of juvenile wood and reaction wood of radiata pine longitudinal shrinkage of up to 2.9 per cent has been observed (Xu *et al.,* 2009). In the transverse direction, shrinkage or swelling is more in the tangential than in the radial direction by a factor of 1.5-3. This is mainly due to the anatomical features of wood such as the presence of ray tissues, frequent pitting on radial walls, micro-fibrils arrangements and earlywood - latewood interaction (Bowyer *et al.,* 2003; Walker 2006).

The present investigation was carried out in the Department of Forest Products, Nauni, Solan (H.P.) during the session and the work was done in the Laboratory of Department of Forest Products Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). Wood samples of *Bombax ceiba* L., *Celtis australis* L. and *Pinus roxburghii* S. of size 5cm x 2.5cm x 2.5cm $\pm$.25cm x .15cm x .15cm (longitudinally x radially x tangentially).The experiment was conducted in Completely Randomized Design (CRD) factorial with three replications.

The fruits of *Melia azedarach* L. collected dried finely powdered, which was extracted with methanol in Soxhlet apparatus on a boiling water bath by using the T6m 59 (Anonymous, 1959). After complete extraction, methanol was completely distilled off from the extract and the residue was dried under vacuum. A total of 400g of such extract was collected. A total of 2.5 litres stock solution of 10 per cent concentration was prepared by dissolving the vacuum dried extract in 5 per cent methanol. From the prepared 10 per cent stock solution, different concentrations for dip treatment were prepared. The wood specimens of *Bombax ceiba* L., *Celtis australis* L. and *Pinus roxburghii* Sargent were dipped in 0.25%, 0.5%, 1%, 1.5% and 2 % (w/v) *Melia azedarach* L. extract solution for 72 hours. The samples meant for control were dipped in distilled water. After dipping treatment specimens were first dried in air to avoid splitting and then dried at 105$\pm$2°C to constant weight.

The dimensions were measured with the help of digital calliper and weights were recorded in grams on electronic balance. The treated samples were also dried at 105$\pm$2°C to constant weights and dimension of the samples in longitudinal, radial and tangential directions were measured in centimetres. After taking data with the help of the digital calliper swelling percentage in different planes were determined after following Okon (2014).

The values displayed in Table 1 revealed significant differences in swelling of wood in longitudinal, radial, tangential plane as well as volumetric swelling among different species and treatments. The data elucidated that maximum swelling of 0.73 (0.85) per cent was recorded in *Bombax ceiba* L. and the minimum swelling of 0.62 (0.79) per cent was found in *Pinus roxburghii*. Among the treatments highest value of 0.76 (0.87) per cent was noticed in control, which was at par with 0.25 per cent concentration [0.73% (0.85)] and the lowest value of 0.56 (0.74) per cent was recorded in T_5 (2% concentration). The interactions between species and treatments were also observed to be significant. The maximum value of 0.88 (0.94) per cent was found in *Celtis australis* L. at Control. The minimum value of 0.31 (0.56) per cent was recorded in *Celtis australis* L. at 2 per cent concentration. The critical scrutiny of Table 1 illustrated that the swelling of wood in radial plane among different species and treatments was found to be statistically significant. The highest value of 5.19 (2.28) per cent swelling was recorded in *Pinus roxburghii* Sargent and the lowest value of 2.88 (1.70) per cent was observed in *Bombax ceiba* L. Among the treatments maximum value of 4.23 (2.04) per cent was noticed in control, which was statistically at par with T_1 [4.22% (2.04)]. The minimum value of 3.79 (1.93) per cent was observed in T_5 (2% concentration). The interaction between species and concentrations was also found to be significant. The highest value of 5.24 (2.29) per cent was noticed in *Pinus roxburghii* in S_3xT_6 and the lowest value, 2.82 per cent (1.68) was recorded in *Bombax ceiba* L. in S_1xT_5. The swelling of wood in tangential plane showed significant values for species and treatments (Table 1). The maximum swelling of 6.20 per cent (2.48) was noticed in *Pinus roxburghii* and minimum value of 4.80% (2.19) was recorded in *Bombax ceiba*. It is apparent from the results that swelling of wood in tangential plain in different treatments was significant at 5 per cent level of significance. Among the treatments maximum value of 5.56 (2.19) per cent was noticed in control. The minimum value of 5.15 (2.26) per cent was observed in T_5 (2% concentration). The combined effect of species and concentrations was also found to be significant. The highest value of 6.22 (2.49) per cent was observed in *Pinus roxburghii* at control, which was statistically at par with S_3xT_4 [6.19 %(2.49)] and minimum value of 4.56 (2.13) per cent was recorded in *Celtis australis* L. wood at 2.00 per cent concentration. The data on volumetric swelling coefficient of wood in different species and treatments were observed to be statistically significant. The highest volumetric swelling coefficient of 12.37 (3.52) per cent was recorded in *Pinus roxburghii* wood and lowest value of 8.60 (2.93) per cent was observed in *Bombax ceiba* L. Among the treatments

Table 1. Effect of treatments on swelling of wood in longitudinal, radial, tangential plane and volumetric swelling (%)

Treatments	Longitudinal plane (%)				Radial plane (%)				Tangential plane (%)				Volumetric swelling (%)			
	Bombax	*Celtis*	*Pinus*	Mean	*Bombax*	*Celtis*	*Pinus*	Mean	*Bombax*	*Celtis*	*Pinus*	Mean	*Bombax*	*Celtis*	*Pinus*	Mean
T_1 (0.25%)	0.71	0.87	0.61	0.73	2.92	4.62	5.13	4.22	4.86	5.65	6.14	5.55	8.68	11.48	12.25	10.80
T_2 (0.50%)	0.72	0.79	0.61	0.70	2.93	3.68	5.13	3.92	4.85	4.94	6.15	5.32	8.69	9.66	12.29	10.21
T_3 (1.00%)	0.73	0.64	0.62	0.66	2.88	3.54	5.20	3.87	4.77	4.87	6.16	5.27	8.58	9.29	12.35	10.07
T_4 (1.50%)	0.73	0.49	0.62	0.61	2.88	3.54	5.22	3.88	4.78	4.86	6.19	5.28	8.58	9.13	12.42	10.04
T_5 (2.00%)	0.73	0.31	0.62	0.56	2.82	3.34	5.21	3.79	4.73	4.56	6.16	5.15	8.45	8.45	12.39	9.76
T_6 (Control)	0.75	0.88	0.65	0.76	2.88	4.58	5.24	4.23	4.79	5.66	6.22	5.56	8.63	11.46	12.51	10.87
Mean	0.73	0.66	0.62		2.88	3.88	5.19		4.80	5.09	6.17		8.60	9.91	12.37	
CD (p=0.05)																
CD Species		0.001				0.003				0.001				0.002		
CD Treatment		0.002				0.004				0.001				0.002		
CD Species × Treatment		0.003				0.006				0.001				0.004		

*Values in parenthesis are square root transformed values.

maximum value of 10.87 (3.29) per cent was noticed in control. The minimum value of 9.76 (3.11) per cent was found in 2.0% concentration. The species and treatments interactions were also found to be significant. The highest value of 12.51 (3.54) per cent was established for S_3 x T_6 and the lowest value of 8.45 (2.91) per cent was noticed in S_1 x T_5 and S_2 x T_5 [8.45% (2.91)]. Homan and Jorissen (2004) and Sahin (2010) have reported considerable reduction (50 to 90%) in shrinking and swelling after the treatment. Bowyer *et al*. (2003) and Hill (2006) have reported that the lower winding angle of the microfibrils in the S_2 layer of cell wall causes wood to shrink or swell more in the transverse (radial and tangential) planes than in the longitudinal direction. The longitudinal shrinkage or swelling in mature/outer wood is generally very small. Xu *et al*. (2009) have observed that in case of juvenile wood and reaction wood of radiata pine, the longitudinal shrinkage is up to 2.9 per cent. Bowyer *et al*. (2003) and Walker (2006) have studied that in the transverse direction, shrinkage or swelling is more in the tangential than in the radial direction by a factor of 1.5-3. This is mainly due to the anatomical features of wood such as the presence of ray tissues, frequent pitting on radial walls, microfibril arrangements and earlywood - latewood interaction. Gupta (2012) and Devi (2013) have also observed significant reduction in swelling of wood after treatment with *Lantana camara* L. and *Ageratum conyzoides* L. extracts, respectively. The species and treatment interactions have also been found to be significant.

Received 06 April, 2016; Accepted 30 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 875-877

Manuscript Number: 2403
NAAS Rating: 4.47

Effect of Pruning Intensities of *Dalbergia sissoo* and Different Dates of Sowing of Turmeric on Carbon Sequestration in Agri-silvicultural System

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Abstract: The experiment conducted on pruning intensity effect on turmeric crop yield sown at different dates resulted in higher yield under 75% pruned *D. sissoo* trees. However, carbon% and carbon sequestered were significantly maximum under open conditions. Maximum fixed carbon %, carbon sequestration, weight of CO_2 sequestered in the crop per year was maximum in turmeric grown under 25% pruned trees. Fresh weight, dry weight, fixed carbon %, carbon sequestered and weight of CO_2 sequestered in the crop year^{-1} was maximum on mid date of sowing of turmeric The rhizome yield of turmeric crop was significantly higher with 25% pruned *D. sissoo*. in early sown crop. 25% pruning recorded higher dbh, basal area, tree volume, above ground biomass, carbon sequestration, weight of carbon dioxide sequestered by the tree and weight of carbon dioxide sequestrated by the tree year^{-1} and it was minimum in 75% pruned trees. Overall agri-silvicultural system (*D. sissoo* + turmeric) was more efficient in sequestering atmospheric carbon as compared to crop or tree alone.

Key Words: Agri-silvicultural system, Carbon sequestration, Shisham, Turmeric

Global warming is a great challenge influencing the biodiversity and climatic conditions of our planet. Unfortunately, the imbalance which we have created between our life and earth is already showing the signs disasters in the form of flood, cyclones, landslides, tsunami, drought, etc. Much of the increase in global average temperature in the present centaury is due to the increase in concentration of green house gases (GHGs.) Carbon-di-oxide is the most important GHG. We all are aware of the fact that plants through the process of photosynthesis fix atmospheric CO_2 in plants and return a part of CO_2 to the atmosphere through respiration. Increased atmospheric Carbon dioxide is attributed mainly due to fossil fuel combustion and deforestation worldwide (Hamburg *et al.,* 1997) Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass. The carbon sequestrated depends mainly upon the type of species, agro-climatic region, system, site quality etc. The practice of growing trees in farmland has been expanding to meet various needs like fuel wood, pulpwood, fruits and industrial use along with the benefit of additional income especially in case of less income for crops and high risk of crop failure due to climatic hazards.

The photosynthetic rate of trees is stimulated by increasing the atmospheric CO_2 concentration and may result in increased growth rates and biomass production. Warren and Patwardhan (2008) have reported the total carbon shared in forest including soil to be 9578 Mt.

In view of the dwindling forest cover agroforestry seems to be a potential and low cost method to sequester atmospheric carbon and is being recognized as a strategy for climate change mitigation (Alavalapati and Nair, 2001; Chauhan *et al.,* 2015; Sharma *et al.,* 2016). Keeping in view the present investigation has been conducted under agri - silviculture system in JNKVV, Jabalpur.

The soil of experiment was clay loam in texture with pH 6.0, medium in organic carbon (0.46), medium in available nitrogen (207kg ha^{-1}) and phosphorus and low in available potash (170.45 kg ha^{-1}). In intercropping turmeric variety suroma was sown in 45 × 30 cm spacing fertilized with recommended dose of fertilizers (100:50:40 N:P:K kg /ha).

The diameter at breast height (1.37 m from ground) was measured at fifteen years of tree growth. A 5 cm thick disc of wood sample was collected from main bole. Turmeric plants were uprooted and fresh wt. of all tree and crop samples was taken and oven dried at 70°C till constant weight. The powdered samples of wood and turmeric crop were burnt in a muffle furnace at 550°C for 4-6 hours and residue was weighted a ash content. Carbon content in all the samples of tree and crop has been estimated by multiplying dry biomass with carbon content. For calculating CO_2 equivalent, total carbon was multiplied with a factor of 3.6663 on the basis of atomic weight ratio of CO_2 to C. For calculating CO_2 sequestration rate of individual tree species, total CO_2 was divided by age of trees (15 years).

Carbon sequestration potential of turmeric crop: The fresh and dry weight of turmeric (gm) were significantly higher in the crop sown under 75% pruned *Dalbergia sissoo* trees and fresh weight was at par in the crop under 50% pruned trees. The values for the above parameters were significantly minimum in the crop grown under unpruned trees. The rhizome yield (q ha^{-1}) of turmeric was at par in the crop sown under trees, which varied significantly from the crop sown in open condition which had significantly minimum rhizome yield. Turmeric is a potential shade loving crop and requires more moisture for development of rhizome and moisture was available for longer duration in the under crop. Hence, resulted in more photosynthate accumulation in the rhizomes. The fixed carbon content (%) and carbon sequestration (t ha^{-1}) was significantly maximum in the crop alone under open condition and was significantly minimum in P_0. The turmeric crop does not sequester much carbon. However total carbon sequestration and monetary gain of cultivator is more than growing *D. sissoo* or turmeric crop alone.

As per effect of date of sowing the fresh weight and dry weight of turmeric and fixed carbon% and carbon sequestered was significantly maximum at mid date sowing (D_2). The rhizome yield was significantly maximum under early sown conditions as longer degree days requirement and longer growth period resulted in more translocation of photosynthate from source to sink. The fresh weight and dry weight of turmeric and rhizome yield was significantly minimum in late sown turmeric as it received lesser degree days and less time period for translocation of photosynthate. The, fixed carbon% and carbon sequestered (t ha^{-1}) was significantly lower in early sown turmeric and at par with that under late sown conditions (Table 2).

Carbon sequestration potential of tree: A perusal of the data on *Dalbergia sissoo* revealed that the DBH, basal area, above ground biomass, carbon sequestration (ton/ha), weight of CO_2 sequestered in the tree and weight of carbon sequestered in the tree $year^{-1}$ were significantly higher in 25% pruned trees and at par with unpruned and 50% pruned trees (Table 1).Chourasia (2012) reported highest biomass (580 kg $tree^{-1}$) and highest carbon sequestration potential (261 kg C $tree^{-1}$) in *Dalbergia sissoo* Pires *et al.* (2002) also reported dbh, volume to be inversely associated with tree pruning intensities. Sowing dates had non-significant effect on the above mentioned parameter.

Carbon sequestration potential of agri-silviculturals system (t ha^{-1}): The study (Fig. 1 & 2) revealed that carbon sequestration potential was significantly higher under managed agroforestry system. Turmeric in combination with 25% pruned *Dalbergia sissoo* sequestered maximum carbon and was at par with unpruned trees. The values were significantly minimum in open (crop alone). Owing to high energy conversion, *Dalbergia sissoo* resulted in higher biomass and carbon accumulation (Bohre *et al*.,2012).

CONCLUSION

Early sown Turmeric + *Dalbergia sissoo* (25% pruned) grown under agri-silvicultural system can be a proper combination for sequestration of carbon-di-oxide and maximum rhizome productivity.

Table 1. Morphological growth characters and carbon sequestration of *D. sissoo* as influenced by different pruning intensities in agri-silvicultural system (Turmeric + *D.sissoo)*

Treatment	DBH (cm)	Basal Area (m^2)	Above ground biomass (kg $tree^{-1}$)	Carbon content (%)	Carbon sequestration (t ha^{-1})	CO_2 sequestered in the tree (t ha^{-1})	CO_2 sequestered in the tree per year (t ha^{-1})
Pruning intensities							
P_0- No Pruning	23.8	0.046	347.75	51.12	71.26	261.25	17.42
P_1- 25% Pruning	24.1	0.046	431.47	54.21	91.78	336.49	22.43
P_2- 50% Pruning	21.5	0.037	320.56	56.09	71.82	263.31	17.55
P_3- 75% Pruning	16.7	0.023	179.36	55.83	39.90	146.28	9.75
SEM	1.0	0.004	44.62	0.63	9.04	33.16	2.21
CD (p= 0.05)	3.2	0.011	142.73	2.00	28.93	106.06	7.07
Date of sowing							
D_1 – 20 June 2013	22.2	0.040	386.68	54.04	82.20	301.37	20.09
D_2 - 27 June 2013	22.4	0.041	374.53	53.61	79.84	292.71	19.51
D_3 - 03 July 2013	20.2	0.032	239.34	54.88	52.14	191.15	12.74
Tree alone	21.3	0.038	278.61	54.71	60.58	222.11	14.81
SEM	0.9	0.0034	33.3	0.66	7.32	26.84	1.79
CD (p= 0.05)	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of different pruning intensities in *D. sissoo* and sowing dates on productivity and carbon sequestration of turmeric under agri-silvicultural practice

Treatment	Fresh wt. of turmeric (g)	Dry wt. of turmeric (g)	Rhizome yield (q ha^{-1})	Fixed carbon %	Carbon sequestration (t ha^{-1})	Wt. of CO_2 sequestered in the crop per year (t ha^{-1})
Pruning intensities						
Po- No Pruning	65.1	12.3	29.09	16.14	1.3	4.9
P_1- 25% Pruning	81.3	18.4	31.98	22.99	2.3	9.5
P_2- 50% Pruning	118.8	20.6	31.19	17.52	2.1	7.6
P_3- 75% Pruning	120.8	22.6	28.39	17.72	2.5	9.1
Open	74.2	19.5	27.64	27.06	3.2	3.2
SEM	4.0	0.4	1.36	0.9	0.045	0.38
CD (p= 0.05)	12.31	1.3	4.2	2.8	0.14	1.17
Date of sowing						
D_1 – 20 June 2013	90.9	18.3	34.77	19.04	2.2	6.5
D_2 - 27 June 2013	102.0	20.5	30.02	22.15	2.5	7.4
D_3 - 03 July 2013	83.1	17.3	24.18	19.67	2.3	6.7
SEM	1.68	0.2	1.4	0.6	0.045	0.08
CD (p= 0.05)	5.80	0.6	4.3	2.0	0.15	0.27

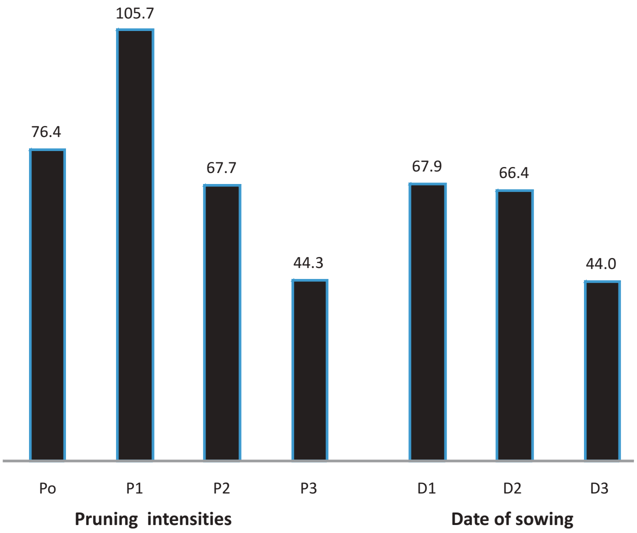

Fig. 1. Mean carbon sequestration (t ha^{-1}) in agri-silviculture (Turmeric + *D. sissoo*) based agroforestry system

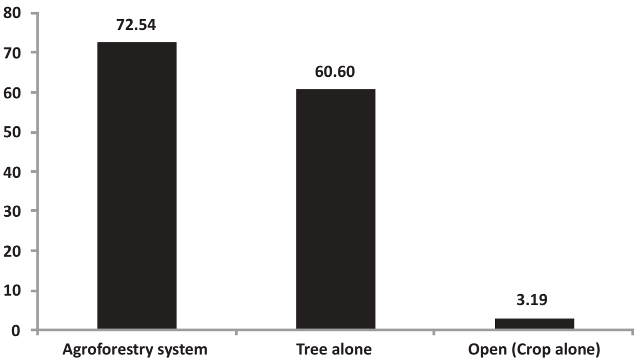

Fig. 2. Carbon sequestration (t ha^{-1}) under different practices

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Received 24 June, 2016; Accepted 05 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 878-879

Manuscript Number: 2404
NAAS Rating: 4.47

Effect of Altitude and Aspect on Soil Organic Carbon of Shankaracharya Forest

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***Abstract*:** The present investigation was conducted between an altitude of 1575 to 1967 m asl and a latitude of 34°04'35.56? N and 74°51'08.63?E longitude. The s**oil organic carbon** analysis was estimated at three different aspects along the three altitudinal range. Organic carbon varied significantly and increased with the increase in altitude. The maximum values of organic carbon were recorded at upper elevation (OC =2.1%) followed by middle elevation (OC = 1.86%) and lower elevation (OC = 1.65%). The content of soil organic carbon (SOC) recorded at Northern aspects was higher as compared to Southern aspects. The upper altitudinal gradient had higher SOC content as compared to lower altitudinal gradient. The higher organic carbon content in the soils on Northern slopes can be attributed to higher litter fall due to more tree density and canopy coverage on this aspect. The overall average SOC content in soils of Shankaracharya forest was 2.3%.

***Key Words*:** Altitude, Aspect, Soil organic carbon, Shankaracharya forest

The soil and vegetation have a complex inter-relation because they develop together over a long period of time. The vegetation influences the chemical properties of soil to a great extent. The selective absorption of nutrient elements by different tree species and their capacity to return them to the soil brings about changes in soil properties (Singh *et al.*, 1986; Chauhan *et al.,* 2010a). Concentration of elements in the soils is a good indicator of their availability to plants. The spatial variation in soil properties is influenced by both abiotic and biotic factors viz., topography-induced microclimate differences, altitude, parent material and vegetation community (Johnson *et al.*, 2002). The microclimatic variations with altitude dramatically influence the weathering rates and leaching intensity, resulting in feedback on soil properties such as amount and quality of organic matter (Hutchins *et al.*, 1976). Aspect is a potential significant factor in generating differences in edaphic characteristics (Sardinero, 2000). The soil organic carbon stocks in soils exhibit variations with vegetation community and topographic aspect inducing differences in microclimatic conditions viz., lowering of soil temperature and reduced soil moisture evaporation particularly on North facing slopes. These conditions result in less organic matter decomposition and consequently more organic carbon. The present study was carried out at Shankaracharya forest to study the soil organic carbon development at different altitude and aspect due to plantations.

A total of 18 soil samples were collected at two depths of 0-15 and 15-30 cm at each sampling site. The soil samples were air dried and processed through a 2mm sieve whilst twigs, roots and gravel were removed. The sieved fraction of soil was homogenized and used for organic carbon estimation . Organic carbon percentage was estimated by wet combustion method of Walkley and Black (1954). The data collected in the field was statistically analysed according to well designed procedures prescribed by Gomez and Gomez (1984).

The results on organic carbon content (OC) in soils of Shankaracharya reserve forest are summarized in Table 1. The results reveal that mean values of organic carbon on lower altitudinal gradient of 1575-1705m were 1.9, 2.1 and 0.96% on North West, North East and South East aspects respectively. The OC content along the two soil depths was significantly different ($p \leq 0.05$) with mean values of 1.83 and 1.51 at the depth of 0-15 and 15-30 cm, respectively. The Organic carbon content on middle altitudinal range of 1705-1835m was in the order of 2.2, 2.3 and 1.09% on North West, North East and South East aspects, respectively. The mean values of organic carbon varied significantly ($p \leq 0.05$) from 2.03 to1.7% along the soil depths 0-15 and 15-30 cm, respectively. The soil organic carbon values on the available aspects at the upper altitudinal range of 1837-1967m were 2.3, 2.5 and 1.7% on North West, North East and South East exposures, respectively. The mean values of OC along the soil depth varied significantly ($p \leq 0.05$) and decreased from 2.3 to 2.0% at the soil depth of 0-15 and 15-30 cm, respectively.

The mean organic carbon values recorded in the present study (Table 1) at lower altitudinal gradient (1575-1705 m) was 1.9% on North Western aspect, 2.1% on North Eastern aspect and 0.96% on South Eastern aspect. At middle altitude (1705-1835m), the SOC values were in order

Table 1. Soil organic carbon of Shankaracharya Reserve Forest across the available aspects along an altitudinal gradient

Parameters	Depths	Altitude (amsl)											
		1575-1705				1705-1835				1837-1967			
		Aspect				Aspect				Aspect			
		NW	NE	SE	Mean	NW	NE	SE	Mean	NW	NE	SE	Mean
Organic carbon	0-15	2.27	2.3	0.99	1.83	2.4	2.5	1.19	2.03	2.6	2.7	1.8	2.3
	15-30	1.7	1.9	0.94	1.51	2.0	2.1	1.0	1.7	2.1	2.3	1.60	2
	Mean	1.9	2.1	0.96		2.2	2.3	1.09		2.3	2.5	1.7	
CD ($p \leq 0.05$)	Depth (A) = 0.01; Altitude (B) = 0.14; Aspect (C) = 0.11; A×B = 0.19;A×C = 0.19; B×C = 0.20												

of 2.2, 2.3 and 1.09% on North Western, North Eastern and South Eastern aspects respectively. Similarly at upper altitudinal range (1835-1967 m), the SOC content was 2.3% on North Western aspect, 2.5% on North Eastern aspect and 1.7% on South Eastern aspect. The higher organic carbon content in the soils on Northern slopes can be attributed to higher litter fall due to better tree density and canopy coverage on this aspect (Gupta and Singh, 1990). Organic carbon content generally remain higher in the Northern aspects than the South facing slopes and it decreases with increase in soil depth on both the aspects (Bhat, 2010). Similarly, the high SOC content in soils at upper altitude can be ascribed to low temperature, which restricts microbial population that decompose litter (Lahiri and Chakravati, 1989). The results on soil organic carbon are in consonance with Dhar *et al.* (2001) who has reported SOC range of 1.2 to 2.7% in soils of Shankaracharya hills.

The results of the present study also reveal that SOC levels decreased from 2.03 to 1.7% in 0-15 and 15-30 cm of soil depth, respectively indicating that organic carbon levels were 16.25% higher in upper soil layer as compared to lower depth. These results support the hypothesis that the rate of decomposition gets slower with increase in soil depth (Degryze *et al.*, 2004; Chauhan *et al.,* 2010b, 2012). The relative distribution of SOC between the top and subsoil are comparable with the findings of Sombroek *et al.* (1993).

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~~*Received 26 August, 2015; Accepted 14 September, 2015*~~

Indian Journal of Ecology (2016) 43 (Special Issue-2): 880-881

Manuscript Number: 2405
NAAS Rating: 4.47

Correlation Coefficient Between Physico-chemical Properties Wood of *Tectona grandis L.*

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Abstract: Correlation coefficient among eleven wood characters in teak were assessed and found positive relationship between specific gravity and height (0.383), holocellulose content and height (0.392) and alcohol-benzene soluble extractives and cold water soluble extractives (0.366). Negative correlation coefficients were observed between cold water soluble extractives and diameter (0.461) and lignin content and alcohol-benzene soluble extractives (0.381). These association among the parameters could help in establishing indirect approach for selection in teak.

Key Words: Correlation, Teak, Timber quality, Tree improvement

In tree improvement programme, a clear understanding of the nature and degree of association among different traits is of great important because the choice of one character can favour the appearance or disappearance of the other. Correlation, an important statistical tool, helps in determining such association among different factors under consideration. *Tectona grandis* is the impotent timber species in India. Teak is extensively used in construction, railway sleepers, wagons and coaches. Teak is one of the most preferred timber for door, window frames and shutters. It is the only timber classified as class I for these purpose in India standards. In India, teak is recognized as the best timber the manufacture of furniture and cabinet making because of its moderate weight, appropriate strength, dimensional stability, and durability, easy workability and finishing qualities and most appealing grain, texture, colour and figure (Bailleres and Durand, 2000). In the present investigations, relationship of physico-chemical properties of selected provenances of *Tectona grandis* height, diameter, grain angle, bark percentage, specific gravity, fibre length, cold and hot water soluble extractives and alcohol-benzene soluble extractives and lignin percentage of wood and holocellulose percentage of wood have been studied.

The study was conducted on thirty selected provenances at National Teak Germplasm Bank, Lohara, Chandrapur (Maharashtra). The wood samples were collected from these selected provenances of teak and analyzed for different wood properties in the departmental laboratory of Forest Products and Utilization, College of Forestry, Akola (MS). Observation were recorded for eleven growth and quality parameters, viz., height, diameter, grain angle, bark percentage, specific gravity, fibre length, cold and hot water soluble extractives and alcohol-benzene extractives and lignin percentage of wood and holocellulose percentage of wood. The specific gravity of wood, water solubility extraction and alcohol-benzene soluble extraction and lignin percentage of wood and holocellulose of wood determined as per the methods suggested.

Among the correlation coefficient for all the character with of 55 combination of simple correlation, five combinations had found positively significant and two were negatively but significantly correlated. The values for simple correlation coefficient between different physico-chemical properties of wood of different provenances of teak are presented in Table 1. Out of five positively correlated combination, two were significantly at 1 per cent level and three at 5 per cent level of probability, whereas, in two negatively correlated combinations were significant at 5 per cent of probability. Highly significant and positive correlation coefficients were obtained between cold water and hot water soluble extractives (0.865).

Correlation coefficient found between specific gravity and height (0.383), holocellulose content and height (0.392) and alcohol-benzene soluble extractives and cold water soluble extractives (0.366) were positive. Negative correlation coefficient was observed between cold water soluble extractives and diameter (0.461) and lignin content and alcohol-benzene soluble extractives (0.381). Similar relation had been reported by Kumar and Sharma (2005) between two characters reveals that the growth parameters like height, diameter, sapwood percentage, heartwood percentage showed highly significant positive and negative correlation as compared to the wood extractive like cold water soluble extractives of sapwood, hot water soluble extractives of sapwood, alcohol-benzene soluble extractives of heartwood. Nimkar *et al.* (2007); Sehgal and Chauhan

Table 1. Simple correlation coefficient between physico-chemical characteristics of wood of provenances of *Tectona grandis*

Observations	Height	Diameter	Bark thickness	Grain angle	Specific gravity	Fibre length	Hot water	Cold water	Alcohol-benzene	Lignin	Holo-celulose
Height	1										
Diameter	0.490**	1									
Bark thickness	-0.026	0.210	1								
Grain angle	0.230	-0.051	-0.120	1							
Specific gravity	0.383*	0.292	-0.001	0.154	1						
Fiber length	0.082	0.021	-0.351	0.164	0.065	1					
Hot water	0.057	-0.324	-0.058	0.248	-0.300	0.304	1				
Cold water	-0.077	-0.461*	0.087	0.216	-0.321	0.302	0.865**	1			
Alcohol-benzene	-0.055	-0.049	0.328	0.070	0.031	-0.102	0.332	0.366*	1		
Lignin	-0.316	-0.108	-0.282	-0.321	-0.309	0.173	-0.075	-0.004	-0.381*	1	
Holocellulose	0.392*	0.204	0.089	0.051	0.267	-0.016	0.052	0.024	-0.077	-0.147	1

**Significant at 1 percent level (r= 0.463); *Significant at 5 percent level (r= 0.361)

(1995); Sehgal *et al.* (1987) observed positive correlation between oleoresin yield and different traits of high resin yielders in chirpine and negative correlation between diameter of tree and bark percentage of wood. Sehgal and Chauhan (1995) established indirect selection through strong correlation of different morphological parameters with quality parameters.

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Received 06 February, 2016; Accepted 14 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 882-884

Manuscript Number: 2406
NAAS Rating: 4.47

Applications of Factor Analysis to Horticultural Crop – A Statistical Approach

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Abstract**:** The paper deals with the usefulness of factor analysis for determining the relative contribution of morphological characters responsible in increasing the yield of apple crop. An optimum sample size of 105 trees was taken for recording the observations on tree height, canopy spread, trunk girth, flower density (FD), flower density index (FDI), flowering intensity (FI), fruit set (FS), crop density (CD), LD ratio and fruit weight. Four basic factors were extracted, which explained 79.34% of total variation and as such played a major role in the analysis. Thus, factor analysis has brought out some of the basic parameters associated with morphological characters of apple tree and can be considered as important tool for optimizing apple yield.

Key Words: Apple, Factor analysis, Morphological characteristics

The applications of multivariate techniques have increased tremendously to analyze data represented in terms of many variables. The researchers in biological, physical and social sciences frequently collect measurements on several variables. Generally data is analyzed by taking one variable at a time. The inferences drawn by analyzing the data for each of the variable may be misleading. This is so because univariate analysis does not consider the correlation or inter-dependence among the variables. That is why the multivariate statistical methods are being used increasingly in biological research to investigate the responses of organisms considered as a whole, whereas established statistical methods are usually concerned with measured characteristics considered one at a time (Morrison, 1976). These techniques have been discussed at great length in standard statistical books (Rao, 1955; Anderson, 1958; Kendal and Stuart, 1968). Factor Analysis is among the various multivariate methods used widely in the field of biology, agriculture, forestry, etc. as a large number of variables are involved in this field of study. Factor analysis allows the user to extract a specified number of synthetic variables, fewer than original set, leaving the remaining unexplained variation as error. The extracted variables are known as latent factors, each one may be supposed to account for covariation in a group of observed variables. Horticultural researchers often measure complex traits such as vigour, reproductive performance, morphology, or adaptability, develop relationship with treatments. Apple **(***Malus domestica* Borkh) yield is a complex trait, which is influenced by several factors and identifying a single variable representative of the complex trait (yield) may not be reliable, thus researcher is faced with the possibility of separately examining many related variables. A series of univariate statistical analyses for each of the variables does not hold promise as it ignores the correlation among the variables. On the contrary, multivariate analysis takes into account the relative importance of the various influencing characters. An attempt has been made to bring out the basic factor contributing significantly towards apple yield by using Factor Analysis.

Field experiment was conducted in 2014-15 at farmer's apple orchard in Jubbal block (coordinates: latitude 31° 10' N & longitude 77° 66' E) of Shimla district. An optimum sample of 105 trees were selected and four branches from each of the tree in four directions as per the practice in vogue were selected and the following observations were recorded i.e. yield (Y), tree height (X_1), canopy spread (X_2), trunk girth (X_3), FD: flower density (X_4), FDI: flower density index (X_5), FI: flowering intensity (X_6), FS: fruit set (X_7), CD: crop density (X_8), LD: length diameter ratio (X_9), and fruit weight (X_{10}). Factor Analysis was carried out to bring out the basic components associated morphological characters of apple.

The data were collected from randomly selected 105 trees of apple at Sahri, Jubbal-Shimla, Himachal Pradesh for various above mentioned parameters. The trees were classified into five diameter classes with five centimetres class interval viz. 5-10 cm, 10-15 cm, 15-20 cm and 20-25 cm and 25-30 cm. The maximum apple yield (182.92 kg tree^{-1}) and canopy (6.86 m) was found in diameter class 20-25 cm. Maximum FD (4.49), fruit set (0.35), crop density (1.67) and LD ratio (8.70) was found to be in diameter class 5-10 cm. Diameter class 15-20 cm had maximum FDI (0.41). Maximum height (9.87 m) and fruit weight (0.21 kg fruit^{-1}) was found in diameter class 25-30 cm. However, FI was same in all the diameter class except in diameter class 5-10 cm.

Four of the ten factors have eigen values greater than unity (Gutman's lower bound), which played the main role in the analysis. The variables loading for first factor is highest for three characters height, canopy and trunk girth. This component was interpreted as vegetative characteristics. The second factor comprised of flower density and flower density index, flowering intensity, crop density and fruit weight, which were collectively termed as flowering and fruiting characteristics. The third factor was comprised of fruit set and fourth factor was comprised of LD ratio. These components explain 31.70%, 24.24%, 13.15% and 10.25%, respectively of the total variation. Together they account for 79.34% of total variation of the original variables. Thus, factor analysis has brought out some of the basic factors associated with morphological characters of apple tree and can be considered as important tool for optimizing apple yield. Ignoring the non-significant correlations, the orthogonal factors extracted can be expressed as

$F_1 = 0.841X_1 + 0.813X_2 + 0.840X_3$

$F_2 = 0.622X_4 + 0.690X_5 + 0.527X_6 + 0.656X_8 + 0.696X_{10}$

$F_3 = -0.901X_7$

$F_1 = 0.931X_9$

Holland (1969) has discussed some applications of multivariate methods viz. factor analysis in biological sciences. Ramchander *et al.* (1979) used factor analysis in a study on onion. Two factor representing indices of plant vigour and flowering, determined from a trial to assess seed yield are expressed in the form of equation based on number and height at flowering stalks, umbel diameter, 1000 seed weight and total seed yield. EL-Geddwani (1992) used factor analysis in sugarcane. Three cultivars GT34/9, G74/96 and G70/368 were planted in the autumn and the characters were recorded for simple correlation coefficient and factor analysis. Characters were divided into four factors, which explained 77% of the total variability. Jalicap *et al.* (1992) used factor analysis in grape. An analysis of data in 50 seed weight and 6 fruits or bunch characters collected from 23 varieties during 1981-1982 is briefly reported. Chernudubov (1994) used factor analysis for studying the morpho-anatomical traits of *Pinus sylvestris* in Insular pine forest of the South Russian plain. Schervens *et al.* (1995) used factor analysis and biplots to characterize the quality evolution of tomatoes during shelf-life in relation to specific treatments (for instance, storage temperature).

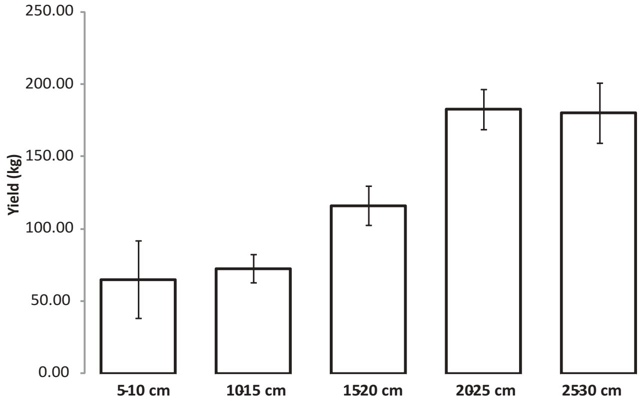

Fig. 1. Diameter class-wise yield (kg) of apple

Table 2. Factor pattern of factor analysis

Characteristics	Factor pattern				Communality
	F1	F2	F3	F4	
Height (m)	0.841	0.365	0.122	0.018	0.855
Canopy (m)	0.813	0.241	0.165	0.051	0.748
Tree girth (cm)	0.840	0.373	-0.082	-0.088	0.859
FD (Flower density)	-0.571	0.622	0.255	0.076	0.784
FDI (Flower density index)	-0.365	0.690	0.110	-0.113	0.635
FI (Flowering intensity)	-0.093	0.527	0.410	-0.157	0.479
Fruit set	-0.143	0.141	-0.901	-0.287	0.935
CD (Crop density)	-0.635	0.656	-0.112	-0.073	0.852
LD Ratio	-0.149	0.134	-0.188	0.931	0.941
Fruit weight (kg)	0.427	0.696	-0.402	0.132	0.845
Eigen Value	3.170	2.424	1.315	1.025	
% of Variance	31.700	24.239	13.155	10.250	
Cum. % of variance	31.700	55.940	69.094	79.345	

Table 1. Diameter class wise vegetative and reproductive characteristics of apple

Diameter class (cm)	Yield (kg tree^{-1})	Height (m)	Canopy (m)	FD	FDI	FI	Fruit set	CD	LD ratio	Fruit weight (kg)
5-10	65.20	3.68	2.27	4.49	0.36	0.40	0.35	1.67	8.70	0.17
10-15	72.50	4.99	3.94	4.43	0.36	0.41	0.28	1.21	8.23	0.16
15-20	116.38	6.23	4.48	3.59	0.41	0.41	0.32	1.12	8.08	0.19
20-25	182.92	8.09	6.86	3.20	0.31	0.41	0.33	1.03	8.32	0.21
25-30	180.47	9.87	6.69	3.04	0.32	0.41	0.31	0.88	8.01	0.21

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Received 26 March, 2016; Accepted 04 August, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 885-887

Manuscript Number: 2407
NAAS Rating: 4.47

Effect of Different Spacings of *Eucalyptus tereticornis* on Wheat Yield and Soil Health

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Abstract: Significant higher organic matter and nutrient (NPK) were found under canopy cover than in open, whereas, grain yield and production were lower. Higher soil fertility was found at closer spacing (3 x 3m) in *Eucalyptus tereticornis* while grain yield and production of crops increased with increased spacing 17×1×1 m (paired row). Grain yield and straw yield parameters of wheat was lower in crop grown under eucalypts compared to open field. The yield of DPW-621-50 wheat variety was higher than other wheat varieties though lower under eucalyptus canopy than in open. *Eucalyptus tereticornis* evergreen tree species so we can say that shading was important factor responsible for the lower yield and growth of crops at closer spacing as compared control.

***Key Words*:** *Eucalyptus tereticornis*, Grain yield, Growth, Nutrient, Soil fertility

Agroforestry is one of the best option to increase the tree cover outside the forest. The need of agroforestry has been necessitated in many parts of the country, which face several agricultural and ecological problems, predominant of which are soil degradation, large scale deforestation, increasing population pressure of human beings and livestock, and decreasing land : man ratio. Intercropping, especially during the tree gestation period, could be economically profitable and is environmentally sound indeed. Farmers do realize the importance of trees in a combined production system not only to meet their basic needs but also for cash benefits (Puri and Monga, 1990; Chauhan *et al.,* 2012;2015). However, reports on the effects of trees on crop and soil productivity are inconsistent. Trees and crops when combined together compete for growth resource such as light, water and nutrients. Further, trees may influence its neighbouring species not only adding or removing of some factors but also by affecting environment or weather conditions such as temperature, light or wind speed. However, information based on critical field observations and experimental studies on the potentialities of tree-crop combination is very scanty. The present experiment was therefore planned to study performance of wheat genotypes in association with *eucalypts* plantation. *Eucalyptus tereticornis* commonly known as 'red gum', is native of Australia and Papua New Guinea. It is one of the most widely planted exotic species that has been extended to other parts of the globe. It has been promoted in many tropical countries owing to its fast growth rate, adaptability to wider climatic and edaphic conditions and multiple uses (Evans, 1992). *Eucalypts* clones have revolutionized the productivity and profitability of the plantations in many states of our country (Lal, 2005) and most popular choice to be planted along the edges or bunds of agricultural fields, and appears to be well incorporated and accepted in agroforestry in India (Tejwani, 1994). Saline and alkaline soils are of widespread occurrence in arid and semi-arid regions of northern India, which need to be revegetated profitably.

The studies on eucalypts-based agroforestry was carried out during rabi season of 2013-14 in the research farm of Department of Forestry, CCS Haryana Agricultural University, Hisar at $29^{o}\ 10^{'}$ N latitude and $75^{o}\ 40^{'}$ E longitude. The climate of site is semi-arid and mainly characterized by a very hot summer, a short rainy season and a cold winter.

Eucalyptus plantations were raised at 3 x 3m, 6 x 1.5 m and 17 m x 1 m x 1 m spacing during 2007 and the wheat crop was raised with the recommended cultural practices under eucalypts plantation during 2013-2014. The adjoining field also with the same crop wheat was taken as control. Soil samples were collected from surface soil (0-15 cm depth) at two stages *i.e.* before sowing of the wheat crop in October and after harvest of wheat in April from different spacing of eucalypts and also from control field for the study of nutrient status and physico-chemical properties *viz.,* available nitrogen, phosphorus and potassium, organic carbon. The available N in the soil was determined by Kjeldhal's method, organic carbon by Walkley and Black method and available K by neutral normal ammonium acetate method.

The wheat crop was raised with the recommended cultural practices under eucalypts plantation during 2013-2014. The adjoining field also with the same crop wheat was taken as control. Data on different yield and yield contributing parameters were recorded and analysed to interpret the results.

Soil EC and pH: The soil EC and pH content were significantly lower in the closer spacing (3×3) of *eucalypts tereticornis.* The trend of increase in average contents of soil EC and pH in agroforestry system with the wider spacing of eucalypts plantation was recorded (Table 1). The higher organic carbon and nutrient status under closer spacing might be due the addition of large quantity of leaf litter in the previous year EC and pH were higher and next year EC & pH were lower due to the increase the tree growth which add the organic matter in soil and increase the soil health. The average contents of EC and pH in eucalypts at 3 x 3m, 6 x 1.5 m, 17 m x 1 m x 1 m and control were 8.09, 8.19, 8.45 and 9.2, respectively.

Soil organic carbon and available macronutrients: The soil organic carbon and available N, P and K content were significantly higher in the closer spacing (3 m × 3 m) of *Eucalyptus tereticornis* based agroforestry system before the sowing of wheat crop and the trend of decrease in average contents of soil organic carbon, N, P and K in agroforestry system with the wider spacing of eucalypts plantation (Table 1) was observed. Among all the different tree spacings the status of organic carbon, N, P, and K were significantly higher in 3 m × 3 m spacing, whereas, it was lowest under control. The average contents of organic carbon in eucalypts based agroforestry system at different spacing were higher by 0.41 ,0.43, 0.25, 0.14 %, respectively. The higher organic carbon and available nutrient content in eucalypts based agroforestry system over the agriculture system may be attributed to litter-fall addition from trees as well as addition residual roots of crops and trees.

Among all the different tree spacing, the status of organic carbon (0.52%), N (199.8 kg ha^{-1}), P (15.6 kg ha^{-1}), and K (226.4 kg ha^{-1}) were also significantly higher in 3 m × 3 m spacing, whereas it was lowest under control. The higher organic carbon and nutrient status under closer spacing might be due the addition of large quantity of leaf litter. The higher decomposition of leaf litter favors the higher nutrient status of the soil.

Table 1. Effect of different eucalypts spacing on change in soil chemical properties before sowing of wheat crop in October 2013 and April 2014*

Spacing (m)	pH (1:2)	EC (d S m^{-1})	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
3 m × 3 m	8.09 (6.88)	0.3 (0.16)	0.41 (0.52)	196.8 (199.8)	14.8 (15.6)	203.8 (226.4)
6 m × 1.5 m	8.19 (7.05)	0.26 (0.18)	0.34 (0.43)	189.9 (189.9)	11.8 (13.8)	194.6 (211.3)
17 m × 1 m× 1 m	8.45 (7.56)	0.29 (0.22)	0.25 (0.32)	175.7 (178.5)	9.8 (11.4)	188.3 (198.7)
Control	9.2 (7.99)	0.37 (0.28)	0.14 (0.27)	156.4 (160.7)	8.9 (10.3)	164.8 (184.4)

*April 2014 values in parentheses

Table 2. Yield attributing parameters of different wheat varieties under different spacing of eucalypts during 2013-14 and 2014-15*

Spacing (m)	Varieties					Mean A
	WH-1105	WH- 542	HD-2967	HD-943	DPW-621-50	
Grain yield (kg ha^{-1})						
3 × 3	0.5 (0.5)	0.8 (0.7)	1.0 (0.9)	0.6 (0.5)	1.4 (1.3)	0.9 (0.8)
6×1½	0.9 (0.8)	1.1 (1.0)	1.4 (1.3)	0.9 (0.8)	1.7 (1.5)	1.2 (1.1)
17×1×1 m (paired row)	1.2 (1.1)	1.5 (1.4)	1.7 (1.5)	1.2 (1.1)	2.3 (2.1)	1.6 (1.5)
Control (without tree)	5.4 (4.9)	4.7 (4.3)	4.3 (3.9)	3.9 (3.6)	3.5 (3.2)	4.4 (4.0)
Mean B	2.0 (1.8)	2.0 (1.9)	2.1 (1.9)	1.7 (1.5)	2.2 (2.0)	
Straw yield (kg ha^{-1})						
3 × 3	1.1 (1.0)	1.3 (1.2)	1.4 (1.3)	1.2 (1.1)	1.8 (1.6)	1.4 (1.3)
6×1½	1.4 (1.3)	1.7 (1.5)	1.8 (1.6)	1.5 (1.4)	2.3 (2.1)	1.8 (1.6)
17×1×1 m (paired row)	1.7 (1.5)	2.0 (1.8)	2.2 (2.0)	1.9 (1.7)	2.8 (2.5)	2.1 (1.9)
Control (without tree)	5.9 (5.3)	5.2 (4.7)	4.9 (4.5)	4.5 (4.1)	4.1 (3.8)	4.9 (4.5)
Mean B	2.5 (2.3)	2.6 (2.3)	2.6 (2.4)	2.3 (2.1)	2.8 (2.5)	

CD grain yield (p=0.05) Spacing: 0.05 (0.08)
Variety: 0.06 (0.09)
Spacing x Variety: 0.11 (0.18)

CD straw yield (p=0.05) Spacing: 0.04 (0.06)
Variety: 0.05 (0.07)
Spacing x Variety:0.010 (0.15)

* 2014-15 values in parentheses

High organic matter and available N, P and K contents in the intercropping treatments could be ascribed to leaf fall before and during crop sowing period. The reduction of soil pH and EC under the tree cover can be attributed to accumulation and subsequent decomposition of organic matter, which releases organic acids (Gupta and Sharma, 2009). Thus, despite the higher addition of litter-fall in closer spacing of eucalypts plantations with the advancement of its age, the increase in available nutrients was sufficiently higher under closer spacing (3×3m) after the harvesting of wheat.

Grain and straw yield of wheat crop under eucalypts based agroforestry system: Grain yield and straw yield parameters of wheat was lower in crop grown under eucalypts compared to open field. The grain and straw yield were significantly higher in the wider spacing (17 m × 1 m ×1 m) of *Eucalyptus tereticornis* based agroforestry system (Table 2). The grain and straw yield was higher in DPW-621-50 as compare to other varieties under eucalypts based agroforestry. The grain and straw yield of wheat under eucalypts decreased significantly as compared to open field (crops without eucalyptus). The decrease in the grain yield and straw yield of wheat .

Received 20 March, 2016; Accepted 20 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 888-890

Manuscript Number: 2408
NAAS Rating: 4.47

Evaluation of Minor Fruits From Jammu Region for Possible Antioxidant Role and Vitamin C

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Abstract: The antioxidant capacities and vitamin C contents of four selected minor fruits viz. aonla, ber, jamun and wild pomegranate growing in Jammu region were evaluated. Vitamin C content was estimated by using 2,6-dichlorophenol indophenols and antioxidants by DPPH (2, 2, diphenyl -1-picryhydrazyl) assay. The dried powders of minor fruits of Jammu region on analysis revealed that that aonla (blanched and grated) had highest amount of vitamin C content. The antiradical efficiency of Jamun seed was found to be maximum followed by aonla blanched powder and grated powder. The lowest antiradical efficiency was observed in dried jamun fruit powder. Jamun seed powder and aonla seed powder posses highest antioxidant activity and can be further explored for the isolation of its bioactive capacity.

Key Words: Antioxidants, Minor fruits, Vitamins

Several minor fruits are present in Jammu region. Several minor fruits are present in Jammu region. But few are analyzed for antioxidant property and vitamin C. Ascorbic acid (vitamin C) is the principle vitamin supplied by the fruit in the diet. About 90 per cent of the person's dietry vitamin C requirement is obtained from fruits and vegetables (Salunkhe *et al*., 1991; Chauhan *et al*., 2010). The Indian gooseberry (*Emblica officinalis* G.) belongs to the family Euphorbiaceae is a native to India, Srilanka, Malaysia and China. Fruits are rich in ascorbic acid and polyphenols and thereby possessing the ability to scavenge free radicals. It has been reported that a single aonla fruit contains almost 20 times more ascorbic acid than two oranges (Yadav *et al.,* 2011). Though the fruit is rich in antioxidants and other nutrients (Rakesh *et al*., 2004). Pomegranate (*Punica granatum* L.) belongs to family Punicaceae, is one of the hardiest fruit that that thrives well under arid and semi-arid climate conditions. Anardana are rich in vitamin-C and minerals (Patil and Karade, 1996). *Syzygium cumini* (L). is a species native from tropical Asia and well adapted in Brazil, which have been used for more than 100 year to control diabetes (Helmstadter, 2008). It is also reported to be an effective antioxidant and to have anti-inflammatory and antibacterial properties (Sari *et al.,* 2012). All these minor fruits can be preserved for longer period if scientifically dried.

Well ripened and healthy fruits of aonla, ber and jamun were collected from different regions of Jammu area. Fruits were cleaned and deseeded to make them free from any possible contamination. One lot of aonla fruit was blanched in hot water and second lot was grated. In wild pomegranate, the aril with seed was manually separated from the fruit. The initial moisture of the aril was 79.34 per cent. After separation, the arils of wild pomegranate, segments of aonla (blanched and grated), ber, jamun and jamun seeds were dried at 55±5^{0}C for 3-4 days in hot air oven. The dried products were grinded to fine powder using mechanical grinder and sieved. The powder was kept in glass bottle and subsequently used for preparation for solvent extraction. 40 g of each dry powder was mixed in 100 ml sterile ethanol (100%) for 48 hours at 24^{o}C with stirring (Liu and Nakano, 1996). The extracts were centrifuged and filtered through Whatman No.1 filter paper and bacterial 0.45 ìm filter (Millipore). Then extracts were evaporated using vacuum evaporator to near dryness and stored in glass vials in dark at 4^{o}C.

DPPH (1,1-diphenyl-2-picrylhydrazyl) free radical scavenging activity: The antioxidant or free radical scavenging activity of the extracts was measured on the basis of decrease in the absorbance of methanol solution of stable 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical (Sreejayan and Rao, 1996). DPPH is one of the few stable and commercially available organic nitrogen radicals (Huang *et al.*, 2005) exhibiting a dark purple color at absorbance 517nm. When free radicals are scavenged, DPPH will be reduced, producing a light yellow coloration reducing the absorbance. 05ml of DPPH (25mg./L) solution was added to 1 ml of sample solution (at different concentrations). Mixture was shaken vigorously and kept at room temperature for 30 min. in dark. Then the absorbance was measured at 517nm and compared with standards. Scavenging activity was calculated as the percentage inhibition (1%) using the following formula:

%DPPH anti-radical activity (1%) =

$$\frac{\text{control absorbance-sample absorbance x 100}}{\text{control absorbance}}$$

Radical scavenging potential was expressed as IC50 value (calculated from linear regression of the graph of concentration vs. 1 %) representing the concentration, which scavenged 50 % of DPPH radicals.

Ascorbic acid content: Ascorbic acid content in the powders were determined with DCPIP visual titration method described earlier by Ranganna (2001).

The vitamin C content in fresh fruits of amla was highest (605.37 mg/100g) followed by ber and lowest in jamun. The same action is found in jamun seed powder having the lowest IC50 ìg/ml followed by aonla blanched and grated poder having value of 25 and 45.07 ìg/ml (Table 1). Thus, jamun seed powder showed the highest antioxidant capacity followed by aonla (blanched and grated). The IC50 DPPH scavenger activity of Jamun seed was 19.75 ìg/ml , which can be considered as very significant activity. Ethanolic extracts of pulp, seed and seed coat showed value of IC50 of 158.0, 8.6 and 48.0 ìg/ml , respectively (Benherld and Arumughan, 2007).

Table 1. Vitamin C content of the minor fruits of Jammu

Fruit	Vitamin C (mg/100g)
Amla	605.37
Jamun	18.0
Anardana	17.24
Ber	106.05

The free radical scavenging activity of methanolic extracts of five minor fruits from Jammu region is expressed as antiradical efficiency. Antiradical efficiency measured by DPPH radical scavenging assay ranged from 1.19 to 50.63 and the average value was 19.65 (Table 2). The antiradical efficiency of jamun seed powder was found maximum (AE$\frac{1}{EC50}$:50.63 ìg/ml) followed by aonla (blanched) having antiradical efficiency of (EC$_{50}$:22.8 ìg/ml) and lowest antiradical efficiency was observed in jamun fruit with antiradical activity of (AE$\frac{1}{EC50}$:1.19 ìg/ml). Hence the seeds seemed to be the fruits part with the most proeminent antioxidant potential.

These minor fruits on analysis revealed that *Emblica officinalis* (aonla) blended dried powder had highest amount of vitamin C (419.2 mg/100g) followed by *Emblic*a *officinalis* grated dried powder having vitamin C (383.14 mg/100g), (47.03mg/100g) in ber powder and (6.78 mg/100 g) in anardana powder . The lowest vitamin C content of (0.98 mg/100g) was observed in jamun seed powder. The highest vitamin C content (605.37 mg/100g) was recorded in fresh *Emblica officinalis* (amla) fruit followed by ber (108.05 mg/100 g), jamun fresh fruit (18.0 mg/100g) and fresh wild pomegranate fruit (17.24 mg/100g). Khomdarm and Devi (2010) reported highest vitamin C content in *Emblica officinalis* (379.7 mg/100g) while determing antioxidant activity and vitamin C of some wild fruit of Manipur.

Table 2. Antioxidant activity, antiradical efficiency and vitamin C content of the minor fruits of Jammu region

Extract	EC50: (ìg/100g)	AE($\frac{1}{EC50}$)	Vitamin C
Amla grated powder	25	40	382.14
Amla blanched powder	45.07	22.8	419.2
Anardana Powder	480.7	2.08	6.78
Jamun seed powder	19.75	50.63	0.98
Jamun fruit powder	833.5	1.19	3.98
Ber fruit powder	800	1.25	47.03

Li *et al.* (2005) reported that 1mg concentrated extract of freshely harvested Chinese jujube produces 33.6 per cent to 98.6 per cent DPPH scavenging activity. Bhatia and Mishra (2009) reported lower EC 50 value for seeds of *Ziziphus mauritiana* about 50 ìg **.** Observation of lower values might be due to their higher antioxidant activity and/or utilization of dried alcoholic/ aqueous extracts for DPPH scavenging assay. From the study, it was observed that the samples stored at room temperature, the combined dried fruit sample of jamun seed powder showed the lowest EC50 value (19.75 ìg) , which might indicate better quality of stored product. The blanching treatment in amla did not show any marked effect on DPPH scavenging activity.

The *syzygium cumini* (Jamun) seed powder, aonla (blanched and grated) powder showed the highest antioxidant, whereas aonla powder showed highest vitamin C content and may serve as valuable source of natural antioxidant. For further isolation and purification of antioxidant capacities, further studies like phenolic content evaluation need to be done to validate and identify the active principle compounds responsible for antioxidant activity.

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Received 26 April, 2016; Accepted 23 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 891-893

Manuscript Number: 2409
NAAS Rating: 4.47

Effect of Pretreatments on Physico-Chemical and Sensory Characteristics of Yellow Carrot *cv*. HCY-1

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Abstract: The present investigation was carried out at CCS Haryana Agricultural University, Hisar to evaluate the effect of different pre-treatments on physico-chemical and sensory characteristics of slices of yellow carrot cv. HCY-1. The slices were evaluated for total soluble solids (TSS), total carotenoids, browning and overall acceptability. TSS of carrot slices decreased after hot water treatment. The pretreatment with 0.2% KMS + 1% $CaCl_2$ retained the highest quantity of carotenoids (7.9 mg/100g). Browning was minimum in pre-treatment 0.2% KMS + 1% $CaCl_2$ + 0.5% citric acid. On the basis of sensory evaluation, carrot slices pre-treated with 0.2%KMS+1% $CaCl_2$ were most acceptable.

Key Words: Carrot, Hot water treatment, Pretreatments, Physico-Chemical, Sensory

Carrot *(Daucus carota L.)* is an important root vegetable of family Umbelliferae and is cultivated throughout the World. The area under carrot in India is 33,000 ha with an annual production of 5.15 lakh tons with Uttar Pradesh, Assam, Karnataka, Andhra Pradesh, Punjab and Haryana being the major producing states (Vanitha *et al*., 2003). It is a rich source of â-carotene, thiamine, riboflavin, other B-complex vitamins and minerals (Walde *et al*., 1992). It is also an excellent source of calcium pectate, a pectin fibre that has cholesterol lowering properties and also reduces the risk of high blood pressure, stroke, heart disease and some types of cancer (Bakhru, 1993). In India, acceptability of intermediate moisture foods based on carrots is less due to less consumer preference. Pre-treatments combined with dehydration influence the quality of dried products (Krokida and Maroulis, 2001). Blanching is one of the most widely used pre-treatment during drying of fruits and vegetables because of its ability to inactivate enzymes, lead to change in structure and shortening of the drying time. Several researchers have reported that calcium chloride retains the firmness in carrots. It can also be used to reduce or prevent browning and to act by blocking the amino group, thereby restraining them from entering into browning reaction (Porntewabancha and Siriwongwilaichat, 2010). Potassium metabisulphite (KMS) and citric acid have also been reported for prevention of browning. No detailed information is, however, available in the literature about the combined effects of $CaCl_{2,}$ KMS and citric acid on carrots. Therefore, the present study has been carried out to evaluate effect of different pre-treatments *viz.*, $CaCl_{2,}$ KMS and citric acid, individually and in possible combinations on physico-chemical and sensory characteristics of yellow carrots cv. HCY-1.

The study was carried out at Chaudhary Charan Singh Haryana Agricultural University, Hisar during the year 2015. Carrot (*Daucus carota* L.) cv. HCY-1 was obtained from Department of Vegetable Science. The carrots were sorted, washed with running water, cut into 5 to 7 mm thick slices and pricked with stainless steel fork. The pricked slices were subjected to hot water treatment (95^{o}C for one minute) by known method (Garba and Kaur, 2014), followed by steeping in 1% $CaCl_2(T_1)$, 0.5% citric acid(T_2), 0.2% potassium metabisulphite (KMS)(T_3), 1% $CaCl_2$ + 0.5% cirtic acid(T_4), 0.5% citric acid + 0.2% KMS(T_5), 0.2% KMS + 1% $CaCl_2(T_6)$ and 1% $CaCl_2$ + 0.5% citric acid + 0.2% KMS(T_7). For each treatment, 50 g carrot slices were dipped in 100 ml chemical solution and carrot slices dipped in distilled water after hot water treatment were treated as control. The treatments were replicated thrice and the samples were evaluated for total soluble solids (TSS), carotenoids, browning and overall acceptability. The fresh carrot samples were analyzed for total soluble solids (TSS), reducing sugars, total sugars, ascorbic acid, pectin, carotenoids, non-enzymatic browning and ash (Table 1). The pre-treated carrot samples were analyzed for TSS, carotenoids, browning and sensory analysis (colour & appearance, taste, texture, mouthfeel and

Table 1. Physico-chemical parameters of carrot cv. HCY-1

Cultivar	TSS (%)	Reducing sugars (%)	Total sugars (%)	Ascorbic acid (mg/100g)	Pectin (%) calcium pectate	â- carotene (mg/100g)	Non- enzymatic browning (OD at 440nm)	Ash (%)
HCY-1	9.0	1.42	4.0	2.2	0.62	8.0	0.27	0.85

overall acceptability). Total soluble solids were estimated at ambient temperature using hand refractometer (0-32%) Erma, Japan and the values were expressed as per cent TSS after correcting at 20^{o}C temperature. Sugars were analyzed by the method of (Hulme and Narain, 1931) using starch as an indicator. Pectin was estimated as calcium pectate (Ranganna, 2003). The ash was determined by the method as reported in the handbook of (AOAC, 1990). Samples were weighed (5g) accurately in a previously cleaned and dried-weighed crucible. At first the crucible containing sample was placed in an oven (100-105^{o}C) for 4 hrs to remove moisture. The moisture free sample was completely charred (free from carbon residues: appears in grayish-white) in a heating mantle followed by heating (ashing) in a muffle furnace at 600^{o}C for 3 hours. Then it was removed from furnace and cooled in desiccators and weighed. To ensure complete ashing, the crucible was again heated in a muffle furnace for one hour. Then this was removed from the furnace and cooled in desiccators and weighed again. Carotenoid was estimated by spectrometric method (Delia *et al., 2004*). Vitamin-C was determined by the titration method as described by (Ranganna, 2003). For this, 10 ml of sample was taken in a volumetric flask and made up to the volume 100 ml with 3% Meta phosphoric acid and filtered. Pipette 10 ml of filtrate into a conical flask and titrated with 2,6-dichlorophenol indophenol dye solution to a pink end-point. The browning of all samples was estimated by method of (Ranganna, 2003). The increase in absorbance of sample extract in ethanol at 440 çm was taken as a measure of non-enzymatic browning The carrot slices were subjected to sensory evaluation by the semitrained panel of 10 judges on a 9-point Hedonic scale (Amerine *et al*., 1965). The experiments were conducted with 3 replications and completely randomized design (CRD) was adopted to calculate the statistical significance.

The results expressed that TSS of carrot slices decreased after hot water treatment (Table 2), this may be due to leaching of soluble solids during treatment. The TSS of pretreatment KMS (T_3) treated samples was found higher than control. Similar findings have been reported by (Sra *et al.*, 2011) in KMS treated dried carrot slices. TSS was higher in $CaCl_2$ along with KMS treated slices as (Mozumder *et al*., 2012) reported about total sugars in pretreated tomato slices. Carotenoids decreased during hot water treatment given alone and in combination with chemicals as reported by (Sharma *et al.*, 2000). KMS and KMS + $CaCl_2$ treated samples showed higher Carotenoids as compared to the control. This may be due to prevention of oxidation by KMS. Similar findings were reported by (Sra *et al.*, 2011) in carrot slices and (Mozumder *et al*., 2012) on tomato slices. There was no significant difference in non enzymatic browning of control as compared to fresh carrots. This is due to the fact that non enzymatic browning is unaffected by blanching (Negi and Roy, 2001). Non enzymatic browning was found lower in KMS+ $CaCl_2$ pretreated samples and lowest in case of $CaCl_2$+KMS+Citric acid treated samples. This is because browning is inhibited by KMS (Mir *et al.*, 2009) and $CaCl_2$ can also be used to reduce or prevent browning and to act by blocking the amino group, thereby restraining them from entering into browning reaction (Hulme and Narain, 1931) and Citric acid is an anti-browning agent, which prevents polyphenoloxidase (PPO) by suppressing the food pH and binding the Cu^{2+} in an active site of PPO to form an inactive complex (Martinez and Whitaker, 1995). In terms of color and appearance as showed in table 3, KMS+ $CaCl_2$ was highest scored followed by control and $CaCl_2$ treated samples. Similarly, in case of taste and texture T_6 scored highest among all pretreatments. But $CaCl_2$ also scored maximum in case of texture along with T_6 due to firmness provided by calcium chloride. Control and KMS samples scored lowest for texture. For mouthfeel, T_6 scored highest followed by Citric Acid and KMS+ CA. The score was found lowest in case of control and KMS+$CaCl_2$+CA. On the basis of above findings, KMS+$CaCl_2$ was found most acceptable followed by $CaCl_2$.

Table 2. Quality parameters of pretreated carrot slices

Treatments	TSS (%)	Carotenoids (mg/100g)	Browning (OD)
T1	8.0	4.9	0.19
T2	7.5	3.6	0.18
T3	8.0	6.8	0.16
T4	8.1	6.3	0.19
T5	7.7	4.6	0.13
T6	8.4	7.9	0.12
T7	7.9	3.9	0.02
T0	7.8	5.9	0.24
CD (p=0.05)	0.13	0.54	0.01

Table 3. Mean Sensory scores of pretreated carrot slices

Treatments	Color and appearance	Taste	Texture	Mouthfeel	Overall acceptability
T1	6.3	6.6	8.3	6.6	7.5
T2	6.6	7.3	7	7.3	7
T3	7.6	7.3	6.6	6.3	6.9
T4	6.3	7	7.3	6	6.5
T5	5.6	7.3	7.3	7.3	6.8
T6	8.6	8.3	8.3	8	8.3
T7	5.6	6.6	6.3	5.6	6.6
T0	8	5.6	6	5.6	5.9

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Received 26 March, 2016; Accepted 14 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 894-896

Manuscript Number: 2410
NAAS Rating: 4.47

Integrated Fish cum Duck Farming: Productivity Enhancement through Technological Interventions

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Abstract: The present study was undertaken to enhance productivity in fish cum duck farming unit and to study its economic viability. Khaki Campbell variety of duck was reared @400/ha (in a duck house raised at the bank of fish pond) with freshwater carps (catla, rohu, mrigal, grass carp and common carp in 3:3:2:1:1 ratio) stocked @15000 ha^{-1} in a fish cum duck farming unit at College of Fisheries, GADVASU, Ludhiana. The total fish production was 6.05t/ha with 80.8% fish survival rate. Economics of fish cum duck farming revealed total variable cost of 2.69lakh $ha^{-1}year^{-1}$, total income of 6.58lakh $ha^{-1}year^{-1}$, net calculated profit of 3.89lakh $ha^{-1}year^{-1}$ and benefit cost ratio was 2.44. It can be concluded that the fish cum duck farming not only increased fish production but also reduced the input costs considerably.

***Key Words*:** Carp, Duck, Economics, Integrated fish farming, Punjab

Aquaculture is a diversified production sector with different production systems and practices. Aquaculture continues to grow more rapidly than all other animal food-producing sectors. Sustainable aquaculture depends upon eco-friendly, economically as well as socially viable culture systems. Supplementary feed, manuring, fertilization constitute the major input cost (around 50-60%) in aquaculture which can be reduced through sustained natural fish food (plankton) production achieved by recycling organic wastes from various livestock farming systems such as cattle, pigs, poultry, ducks etc. Integrated fish farming is a combination of two or more farming systems such as fish-livestock farming, fish-agriculture/horticulture farming etc. The basic principle involved in integrated farming is complete utilization of farm wastes, which are recycled into the fish pond (as manure/fertilizer) to enhance its primary productivity.

In integrated fish cum duck farming system, both fish and ducks are benefited as duck dropping falls directly in to the pond and act as manure thus helps in increasing the pond productivity (Sasmal *et al*., 2010). Duck prey upon insects, tadpoles, larvae and small vegetation present in the fish pond water, helps in cleaning of pond and reduce duck feed cost (Das *et al*., 2003). Ducks also aerates (bio-aerator) the pond water while swimming in fish pond by the movement of its wings and feet (paddling movement). This farming system holds immense scope in terms of optimised resource utilization and productivity enhancement. It is a low input practice for achieving sustainable biomass harvest per unit area and help in reducing environment pollution as well. Therefore, the present study was undertaken to enhance productivity in duck cum fish farming unit and to study its economic viability.

The present study was conducted at College of Fisheries, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana. The fish pond was prepared by following the standard pre-stocking management practices. The duck house of bamboo planks was constructed on the pond dyke in such a way that duck droppings may fall directly into the pond and ducks can visit the pond during day time. Khaki Campbell variety of duck was reared @400/ha with Indian and exotic carps (catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) in 3:3:2:1:1 ratio, fingerlings with average weight and length of 10.2±0.5g and 10.0±0.2cm for catla; 10.4±0.2g and 10.1±0.1cm for rohu; 9.5±0.3g and 9.0±0.1cm for mrigal; 10.5±0.6g and 10.2±0.2cm for grass carp and 9.2±0.3g and 8.9±0.1cm for common carp, stocked @15000 ha^{-1} and average water level in the fish pond maintained at 1.8m throughout the culture period. The ducks were fed with farm made feed formulated by using locally available ingredients, broken wheat (50%), millet/barley (15%), oil cake (15%), rice bran (5%), fish meal (10%), lime stone (3%), vitamin and mineral mixture (2%) @80gm feed/duck/day and Azolla (aquatic fern), while fish were fed (during summer season only) with mustard de-oiled cake and rice police in the ratio of 1:1, once daily in the morning hours@0.5% body weight. Fish sampling was done at monthly intervals to check the growth, health condition and survival of the fish and water quality parameters were monitored during the study period according to standard methods of APHA (1991). The fishes were reared for a period of one year and final harvesting was done to calculate income and production values. Economics were calculated on prevailing market price of fish, ducklings, duck and fish feed, duck eggs and other variable cost.

During the study period, water quality parameters (Table 1) did not vary significantly and were well within the recommended range (Boyd and Tucker, 1998) for supporting optimum growth of fishes throughout the culture period.

Table 1. Water quality parameters during the culture period

Parameter	Experimental pond
Temperature (°C)	30.41 (22.3–35.8)
pH	9.45(8.6–9.7)
Dissolved Oxygen (mgl^{-1})	9.78 (8.5–15.2)
Total Alkalinity (mgl^{-1})	205.37 (115 to 285)
Ammonical-nitrogen (mgl^{-1})	0.047 (0.043 to 0.075)
Nitrate-nitrogen (mgl^{-1})	0.49 (0.44 to 0.58)

Values in parentheses are the range during the culture period

At the termination of experiment, the average length, weight and survival percentage of different fish species was recorded (Table 2).

The average final weight of grass carp was maximum with 85.4 per cent survival and lowest in common carp with 75.9% survival among all the fishes harvested from duck cum fish pond. Whereas, among Indian major carps, the average final weight of rohu was maximum with 83.8% survival rate. The total fish production from the fish cum duck pond was 6.05t ha^{-1} during one year of experiment with 80.8% average fish survival rate. The variable cost was 2.69 lakh/ha/year, whereas total income was 6.58 lakh/ha/year, net calculated profit was 3.89lakh/ha/year with benefit cost ratio of 2.44 (Table 3).

The growth performance of grass carp was recorded best as because Azolla were fed to the ducks during day hours which were also consumed by grass carp and also because of its dominating behaviour over other carps and lowest average weight recorded in case of common carp due its prolific breeding habit. The result was consistent with the findings of Man (2002), who reported that fish yield from ponds with duck was higher as duck manure reduced 20-25% of fish feed requirement In the present study, better performance of fish integrated with duck may be due to higher stocking density of fish (15,000 fish fingerlings ha^{-1}) and ducks (400 ducklings ha^{-1}) which increased plankton production from ducks manure and spilled duck feed which was allowed to fall directly to the fish pond and with additional fish feed @0.5%body weight (in summers). In agreement with the present study, Chand *et al*. (2006) reported that duck stocking @ 300 ha^{-1} resulted best benefit: cost ratio and 400 duck ha^{-1} yielded best profit. The average water level also maintained to 1.8m throughout the experimental period to accommodate more number of fishes in the pond. Whereas, in traditional fish cum duck farming system, ducklings stocked @200 ha^{-1} and fish fingerlings @10,000 ha^{-1} without any additional fish feed and water level also maintained less, around 1.5m. Sasmal *et al*. (2010) studied the role of duck droppings on pond productivity through fish-duck integrated farming system and concluded that it gives better returns in terms of pond productivity, fish growth, survival and profit as compared to fish farming alone. Whereas, Islam *et al*. (2004) studied efficiency of integrated rice, fish and duck polyculture and reported that the growth performances of rohu, catla and mirror carp were highly significant and duck dropping was found very effective for better growth and development of fishes. These results indicated that the practices followed in the present experiment, not only increased fish production but also reduced the input cost of fish culture operations considerably.

Table 3. Economic analysis of integrated fish cum duck farming

Particulars	Cost in Rs. ha^{-1}
Variable cost • Fish (fish seed/fingerlings, fish feed, lime, misc.) • Duck (ducklings, duck feed, medicine, drinker/feeder, electricity, one labour, misc.)	2,69,000
Returns	
Sale of fish (@Rs. 85/Kg)	4,14,250
Sale of eggs* (320female, 48, 000eggs, @Rs. 3/egg)	1,44,000
Gross return	6,58,250
Net return (C-A)	3,89,250
Benefit: cost ratio	2.44

*Ducks start laying eggs at the age of six months, four female and one male duck ratio maintained, khaki Campbell breed lays 300 eggs $duck^{-1}$ $year^{-1}$.
**These ducks lays eggs up to two years of age, so can be kept for next year as well.

Table 2. Average weight, length and survival rate of different fish species at the end of the experiment

Fish species	Average final weight (g)	Average final length (cm)	Average survival (%)
Catla catla	482.8±18.59	25.7±2.34	80.2
Labeo rohita	517.5 ±12.41	28.5±1.89	83.8
Cirrhinus mrigala	454.1±6.67	26.2±1.12	78.6
Ctenopharyngodon idella	582.2±15.34	33.8±2.10	85.4
Cyprinus carpio	92.8±5.82	17.4±0.95	75.9

From the present study, it can be concluded that with intensification in stocking density of fish and duck resulted in increased fish production up to 6.05t ha^{-1} $year^{-1}$ with an annual income of 3.89 lakh ha^{-1} $year^{-1}$, which is 55% higher than the traditional fish farming practices. This kind of integrated farming system should also be encouraged due to its role in waste recycling and reducing environment pollution.

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Received 22 April, 2016; Accepted 12 July, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 897-899

Manuscript Number: 2411
NAAS Rating: 4.47

Impact Evaluation of Front Line Demonstrations on Fish Farming in Sub-tropical Region of Jammu & Kashmir

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Abstract: The fish yield under front line demonstrations ranges from 39.00 to 43.56q ha^{-1}, whereas in farmer practice, it ranges between 28 to 33q ha^{-1}. The technological gap and extension gap were ranging between 16.44 to 21.00 q ha^{-1} and 10.56 to11.00 q ha^{-1}, respectively. The average technology index was 29.62%. The cost benefit ratio was 2.3 to 3.1 under demonstration, while it was 2.0 to 2.3 under control ponds. The farmer obtained 30.4 per cent more economic benefits by following scientific practices in fish farming.

***Key Words*: ** Extension gap, Fish farming, FLD, Technological gap

The technologies and management practices involved in carp culture have raised the average Indian production from still-water village ponds and tanks. The average productivity from ponds at the national level is around 2,500 kg ha^{-1} $year^{-1}$, though in Bihar and UP, it is between 1,500 and 2,500 kg ha^{-1} $year^{-1}$, while in some other states like Andhra Pradesh and Haryana it is more than 5,000 kg ha^{-1} $year^{-1}$ (jpn-virtualvarsity.org). Thus, there is potential for increase in production to 5000 kg ha^{-1} $year^{-1}$ and having potential for both vertical and horizontal expansion in the coming years. The contribution of Jammu and Kashmir State (J&K) is still negligible in total fish production of India even having good natural and water resources. J&K is occupying 22nd position in total fish production among the Indian states with 20,000 tonnes in which Jammu district production contribution was 1075.17 tonnes only (Handbook of Fisheries Statistics, 2014). Traditionally, fisheries in Jammu and Kashmir were developed and popularized as sport fisheries, primarily as a means of attraction for tourists. During the past few years, there has been a reorientation towards development of fisheries as a major food resource. The Jammu district is well endowed with fisheries resources in the form of lakes, seasonal and perennial swampy beels, rivers, tanks, ponds, canal etc. Lakes and water bodies of district Jammu cover the area of 34.8ha in which biggest is Surinsar lake with 28.6ha area (Directory of Lakes and Water Bodies of J&K State, 2012). However, potentialities of these resources have not been fully tapped to fulfil the gap in domestic demand for fish and its supply. By harvesting the potential of fisheries in the state appropriately, considerable impact can be made in terms of fish production, revenue generation and employment creation as well as improving the nutritional level of the common man. Fish production practices in Jammu from the farmers' perspective have not been optimally understood and practiced. The Jammu district is most productive of Jammu province and has the sizeable area under fish production but the productivity level is very low in compare to neighbouring districts of Punjab and Haryana due to poor knowledge, lack of understanding about the dynamics of pond production**,** inadequate supply of quality seeds of fish species at the village level, poor distribution of technical information of management practices in rural areas and insufficient resources. Keeping in view of all these reasons, the present front line demonstrations were conducted to minimize the yield gap through showing the scientific way of fish farming.

Jammu is located at 32.73°N and 74.87°E with an average elevation of 327 m (1,073 ft). The present study was carried out by the Krishi Vigyan Kendra, Jammu in the farmers' pond in adopted villages between 2011-12 and 2014-15 on 46 fish farmers who possess fish pond of 0.10ha having dimensions of 40x25x1.5m covered under FLDs. A total of 4.6ha area was covered from 11 different villages namely Karotana kalan, Beaspur Bangla, Vidhipur, Raipur Sajda, Taliyan, Chak Chimna, Chak Bhagwana, Treva, Makhanpur, Jazzowal and Bisnah. The data on fish species, stocking practices and production in the sites were collected from experimental (FLD plots) as well as control plots (farmers' practices) to compare the effects of the technical interventions. Before conducting FLDs, a list of farmers was prepared from group meeting and specific skill training was imparted to the selected farmers regarding different aspects of cultivation to be followed as suggested. The comparison between demonstration package and existing farmers' practice of the present study with respect to FLDs and farmers' practices is given in Table 2. In case of control, existing practices being used by farmers were followed. In general, soils of the area under study are clay loamy and medium in fertility status. In demonstration ponds, use of quality seeds with recommended stocking density and ratio of different fish species, proper feeding, good water management by replacing 10-30% of water every fortnight, proper liming, fertilization with organic manure and inorganic fertilizers and use of oil soap emulsion to remove the problem of insects in fish pond were adopted.

Visit of farmers and the extension functionaries were organized at demonstration plots to disseminate the message at large scale. The demonstration farmers were facilitated by KVK scientists in performing field operations like seed stocking, pond fertilization, liming, feeding, fish health monitoring and harvesting during the course of training and visits. The necessary step for selection of site and farmers, layout of demonstration, etc. were followed as suggested by Singh (2008). The traditional practices were maintained in case of control. The data output were collected from both FLD ponds as well as control ponds (farmers practices) and finally the extension gap, technology gap, technology index along with the benefit cost ratio were worked out (Samui *et al.*, 2000).

Technology gap= Potential yield-Demonstration yield; Extension gap= Demonstration yield-Farmers yield; Technology index= {(Potential yield-Demonstration yield)/ Potential yield}x 100; B: C ratio = Gross return / Gross cost

Socio-economic profile: The education level of the farmers was poor and the education of the majority of the farmers was upto 8^{th} standard, though the age was well distributed. 56% farmers had less than 1ha land, whereas 36% farmers had 1-2ha land. Pond area is less than 0.5hectare. eighty eight per cent farmers had medium level experience of fish farming and income sources for 64 per cent farmers was less than 1.5 lakhs and remaining farmers had income less than 5lakhs per annum.

Comparison between demonstration package and existing farmers practice: The data pertaining to recommended and farmer's practices were recorded under the study during the front line demonstrations (Table 1). Comparison showed that in traditional practice three to six species (Indian major carps and exotic carps) combination (composite fish culture) was not followed strictly and preference was given to grass carp. This may be due to the higher growth rate of Grass carp in Jammu district as environmental conditions are favourable and suitable with availability of grass. But in this practice, other niches of fish pond are unutilized due to absence of other fish species which incur losses to the farmers. Farmers were stocking the fish as per easily availability and without any ratio. The problem was accelerated as different fish breeding time differ from each other (March to august) which affects the availability of fish seeds. Fish hatcheries are normally situated at distance without good conveyance facilities. When they brought the fish seed, farmers follow very high stocking density (upto 20000 fingerlings ha^{-1}) with little external feeding or reverse. However, there was no water exchange, feeding schedule, regular health and water quality monitoring. The results indicated the reluctance of the farmers in adopting scientific fish farming.

Production, technology gaps, extension gaps, technology index and benefit cost ratio of fish farming: The fish farming practices followed under FLDs namely good water quality management, precautions for transportation of live fish, species combination and stocking density, fish pond fertilization and supplementary feeding to fish in pond produced an average yield of 42.22 q ha^{-1} which was 42.74 per cent higher than the control practices (29.75q ha^{-1}) (Table 2). The fish production was lowest in 2014-15. The reason behind this was the devastating flood and bad weather conditions (heavy rain overflowed the ponds which caused fish escape) during the year but still demonstrations ponds gave higher

Table 1. Comparison between demonstration package and existing farmers practice under fish framing

Parameter	Demonstration	Farmer practice
Species used	Three species (Catla, Rohu and Mrigal @ 4:3:3) and six species (Catla, Rohu, Mrigal, Common carp, Grass carp and Silver Carp @1.5:2:1.5:1.5:2:1.5)	Depend on easy and nearby availability
Stocking rate (fish seed)	6000 to10000/ha	10000 to 20000/ha
Fertilizer	Organic @ 15t/ha/year+inorganic fertilizers (Urea 24kg/ha+DAP 15kg/ha)	Only organic @ 4-5t/ha/year
Supplementary fish feed	Regularly (Pelleted or home made feed @3% body weight of fishes)	Not used or irregular
Lime	Used regularly (65kg/ha monthly)	Not used
Monitoring of water quality	Yes	No
Monitoring of fish health	Yes (Netting on monthly basis)	No

Table 2. Production, technology gaps, extension gaps, technology index and benefit cost ratio of fish farming

Year	Area (ha)	No. of farmers	Yield (q ha^{-1})			% increase over control	Technology gap (q ha^{-1})	Extension gap (q ha^{-1})	Technology index (%)	B:C ratio	
			Potential	Experimental	Control					FLD	Control
2011-12	1.3	13	60	43.56	33.00	32	16.44	10.56	27.4	3.1	2.3
2012-13	1.1	11	60	43.52	32.00	36	16.48	11.52	27.5	3.1	2.2
2013-14	1.5	15	60	42.80	26.00	64	17.20	16.80	28.6	3.5	2.7
2014-15	0.7	7	60	39.00	28.00	39	21.00	11.00	35.0	2.3	2.0
Average				42.22	29.75	42.75	17.78	12.47	29.625	3.0	2.3

production (39q ha^{-1}) in comparison to control (29.75). The result clearly indicates the positive effects of technology over the existing practices in enhancing the fish yield. Moreover, there is still an average extension gap of 12.47q ha^{-1} in fish production which indicates that more impetus should be given to enhance the farmer's technical know-how regarding scientific fish farming which shall result in higher economic benefits. The results also emphasize the need to educate the farmers through various means for adoption of improved production technologies to reduce the gap.

The data pertaining to technology gap (ranging between 16.44 – 21.00q ha^{-1}) reflects the need to reduce the technology gap (Table 2). The technology gap observed might be attributed to the dissimilarity in seed quality (seed quality differ from hatchery to hatchery), pond fertility status and weather conditions. Mukharjee (2003) have also opined that depending on identification and use of farming situation, specific interventions may have greater implications in enhancing system productivity. The average technological gap of 17.78q ha^{-1} reflects that there is need to fine tune the available technology for its better adoptability.

The technology index showed the feasibility of the evolved technology at the farmer's fields. The lower the value of technology index, the more is the feasibility of technology. The technology index (29.62%) may be attributed to the difference in pond fertility status, weather conditions, seed and feed quality. Benefit-cost ratio was recorded higher under demonstration against control (Table 2). The benefit cost ratio of demonstrated and control ponds varied from 2.3-3.5 and 2.0-2.7 during these years respectively. It is summarized that farmer obtained 30.4 per cent more economic benefits by following scientific practices in fish farming.

The results of front line demonstrations convincingly brought out that the fish yield could be increased by 42.75 per cent with the intervention on quality seed coupled with balanced feed and water quality management in the Jammu region. The technological interventions had significant beneficial effect on fish production and use of scientific methods of fish farming can reduce the technology gap to a considerable extent thus leading to increased productivity. The fisheries extension agencies need to provide proper technical support to the farmers through different educational and extension methods.

Received 12 March, 2016; Accepted 01 July, 2016

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Indian Journal of Ecology (2016) 43 (Special Issue-2): 900-902

Manuscript Number: 2412
NAAS Rating: 4.47

Prospects and Constrains of Pangas Catfish Culture in Punjab – A Case Study

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Abstract: Field trial of Pangas catfish culture was conducted in district Fazilka (Punjab). Pangas catfish fry was procured from West Bengal and stocked in 0.40 ha earthen pond @ 15,000 in May and cultured for a period of six months. Fish was fed on commercial floating feed @ 2.5 % of body weight daily in split doses thrice a day. After 6 month of culture period 7.0 tons of fish were harvested from 0.40 ha pond with an average size of 500 g and 93.33% survival rate. Feed Conversion Ratio (FCR) and Specific Growth Rate (SGR) were 1.32 and 5.26, respectively. Net profit of 1.02 lakh rupees was earned within a period of six month from 0.40 ha pond. The results reveal ample scope of introducing Pangas catfish as an alternative for diversification of carp culture as well as aquaculture productivity enhancement in the State.

Key Words: Aquaculture, Diversification, Pangas, Productivity

Scale less Pangas catfish is a species of shark catfish (family Pangasiidae), native to fresh and brackish waters of Bangladesh, India, Myanmar and Pakistan, Cambodia and Vietnam (Pal, 2010) and is excellent food fish with white fine grained sweet flesh thus having high consumer preference. The fish is highly resistant to crowding and low oxygen. The importance of culture of Pangas catfish by small and marginal farmers of India has been studied by Singh and Lakra (2012). Pangas catfish has tremendous potential as an alternative candidate species for aquaculture diversification in many parts of the world. It has been introduced in many countries and has proved to be extremely successful in becoming important food fish. Production of Pangas catfish in Vietnam has significantly made a contribution to economic growth, incomes, employment and foreign exchange at national economic levels (Arthur *et al.,* 2013). This study was conducted with the objective to standardize the culture practice of Pangas catfish in local climatic condition of the State to achieve maximum biomass per unit area.

Experimental site was located at village Panchawali, Fazilka, Punjab. In May 2014 fry of Pangas catfish (length 5.00$\pm$ 0.1 cm and wt. 0.9$\pm$ 0.04g) was procured from Kolkata, West Bengal and stocked in a 0.40 ha earthen pond @ 15000 after conditioning for 10 days in a net enclosure erected within the pond. Fish was fed with commercially available pellet floating feed thrice a day (8.00 am, 2.00 pm and 6.00 pm) to minimize wastage and to obtain better Feed Conversion Ratio (FCR). Feed size and protein and fat content of feed was regulated on the basis of fish body weight (Table 1). Feed was manually broadcasted uniformly for better utilization. Fish was harvested after six months of culture period at the end of second week of November, 2014. The following observations were recorded and evaluated:

Water analysis: Physico–chemical parameters of water samples including water temperature, pH, dissolved oxygen, total hardness and total alkalinity were measured at monthly intervals following standard methods (APHA, 2005).

$$\text{Survival Rate (\%)} = \frac{\text{Number of fish harvested}}{\text{Number of fish stocked}} \times 100$$

Apparent FCR = Total feed given (kg)/Fish biomass harvested

Growth analysis: Random samplings of 30 fish were done to calculate the growth of fish in terms of total length (TL) and total weight (TW) at fortnight intervals. The following parameters were calculated to determine the growth response of the fish:

$$\text{Specific growth rate (SGR)} = \frac{\text{Log}_e\text{ Final weight (g) - Log}_e\text{ initial weight (g)}}{\text{Culture days}} \times 100$$

$$\text{Daily Weight Gain (DWG g day}^{-1}) = \frac{\text{(Wf-Wi) g}}{\text{Culture days}}$$

Where Wf = Final average weight at end of experiment and Wi = Initial average weight at beginning of experiment.

Economics of the culture was also analyzed, where only recurring costs have been taken into consideration.

During the culture period from May to August, water temperature in the trail pond varied between 19 to 34^{0}C, where favourable temperature for growth of Pangas catfish is 23- 28^o C. As the species is very temperature sensitive, fresh water was added 3 times a day (10 am, 1 pm and 4 pm) to

Table 1. Feeding schedule of Pangas catfish

Weight of fish (g)	Feed size	Protein %	Fat %	Feed given on percentage body weight
1.0 – 5.0	800 micron	35.0	6.0	10.0
5.1- 30.0	1.5 mm	32.0	4.0	5.0
30.1- 100.0	2.0 mm	32.0	4.0	4.0
Above 100	4.0 mm	28.0	3.0	2.5

maintain required water temperature ranges. Two fountain aerators (1 HP capacity each) were also operated to cope up with the elevated temperature. At the same time reduced water temperature at night from third week of October till the end of second week of November, was managed through addition of fresh ground water during night also to maintain the water temperature above 20^o C. Reduced acceptability of feed by the species was observed at water temperature <20^o C. Water pH and dissolved oxygen values were recorded in the range of 7.5 to 8.2 and 5.6 to 6.0 ppm, respectively with water salinity recorded < 1.0 ppt throughout the culture duration and were within the range as suggested by Boyd and Tucker (1998) for general aquaculture practices. The total alkalinity and total hardness values were recorded as 390-400 mg L^{-1} $CaCO_3$ and 380-406 mg L^{-1} $CaCO_3$, respectively. Both these range were higher than the preferable range for aquaculture as suggested by Wurts and Durborow (1992).

After 180 days of culture period, fish was harvested with 93.33% survival and apparent FCR of 1.32. Singh and Lakra (2012) reported FCR in the range of 1.1 to 1.3 for *Pangasius hypophthalmus* in open pond culture practices in India. Average weight of fish at the time of harvest was 500 g with range of 450-750 g and total 7 tons of biomass was harvested, which corresponds to the productivity of 17.5 tonsha^{-1} per 6 months (Table 2). Productivity targets achieved in the present study reveals voluminous scope of diversifying carp culture with Pangas catfish for vertical expansion of aquaculture sector, as three times higher productivity than carps can be achieved through Pangas catfish culture.

Table 2. Biological parameters of culture of Pangas

Parameters	Values
Average fish length during stocking (cm)	5.00
Average fish length during harvesting (cm)	33.5
Average fish weight during stocking (g)	0.9
Average fish weight during harvesting (g)	500.0
Range of fish length during harvesting (cm)	29.5 - 41.0
Range of fish weight during harvesting (g)	450.0 - 750.0
Specific growth rate (% day^{-1})	5.260
Daily weight gain (g day^{-1})	2.772
Apparent feed conversion ratio	1.32
Fish productivity (ton 0.4 ha per 6 months)	7.0

Total recurring expenditure was estimated around Rs. 3,87,900 including feed, seed, labour, electricity, medicine and miscellaneous cost with a net profit of Rs 1.02 lakh (Table 3). At present, no hatchery is producing the Pangas seed in Punjab as well as in North India; thus availability of seed solely dependent on other states (mainly West Bengal), which increases the culture cost. Market price of this fish remains low due to oversupply of preserved Pangas from Andhra Pradesh, which restricted the cost of this fish within the State. However, estimated net profit is higher as compared with other finfish species (carps) generally cultured in Punjab. Thus, Pangas catfish may be considered as an alternative candidate species for diversification of carp culture as well as aquaculture productivity enhancement in Punjab. Under the agro-climatic condition in Punjab, the species is suitable for culture for a period of six to seven months (April- October). A few numbers of brood fish can be maintained under polyhouse condition for further breeding and seed production. There is a tremendous possibility of entrepreneurship development of Pangas fish processing unit or cold chain in Punjab. Fish produced and harvested during November onwards could be processed to fetch a good price as per demand in market.

Table 3. Economics of culture of Pangas catfish

Parameters*	Values in INR
Cost of 15000 fish seed (Including transportation cost)	26, 900
Cost of feed	3,16,000
Miscellaneous cost (including labour, electricity, medicine and others)	45, 000
Total recurring expenditure (seed + feed+ miscellaneous cost)	3,87,900
Gross income (on farm fish selling price @ INR 70/ Kg- Total fish produced 7 tons)	4,90,000
Net income	1,02,100

*0.40 ha pond with stocking density of 15000 and six months culture duration

ACKNOWLEDGMENTS

The authors are thankful to Indian Council of Agricultural Research (ICAR), New Delhi, India for providing financial assistance during the course of this research work through Niche Area of Excellence project.

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Received 20 June, 2016; Accepted 09 August, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 903-906

Manuscript Number: 2413
NAAS Rating: 4.47

Antifungal Potential of Dill Seed Essential Oil and its Constituents

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Abstract: The study was conducted to determine chemical composition of dill seed essential oil and evaluation of its antifungal potential. The commercially available dill seed essential oil was analysed by GC–MS. Thirty one compounds were identified which constituted approximately 94% of the dill seed essential oil. The major components were carvone (41.15%), limonene (23.11%), camphor (9.25%), dihydrocarvone (3.75%), butyl acetate (2.65%), dill apiole (1.65%) and dill ether (1.02%), etc. The antifungal activity of the dill seed essential oil, its fractions and isolated compounds were evaluated against plant pathogens *Alternaria triticina* and *Bipolaris sorokiniana* using spore germination inhibition technique. All the tested components showed promising activity against *A. triticina* with ED_{50} and ED_{90} values of less than 0.38 and 2.15 mg mL^{-1} respectively. ED_{50} and ED_{90} values of all the tested compounds against *B. sorokiniana* were less than 0.78 and 2.1 mg mL^{-1} respectively.

Key Words: Antifungal activity, Column chromatography, Dill Seed, Essential oil, Limonene, GC-MS

Fungi are the most important common cause of plant disease**,** since they are the most widespread and destructive parasites of plants (Mohammed, 2014). Generally, phytopathogenic fungi are controlled by synthetic fungicides; however, the use of these is increasingly restricted due to the harmful effects of pesticides on human health and the environment (Harris *et al*., 2001). Therefore, the scientific community at international level is looking for safer alternative products from plants for effective control of pests. Naturally occurring biologically active compounds, such as essential oils and several plant extracts are generally assumed to be more acceptable and less hazardous than synthetic compounds and represent a rich source of potential disease-control agents (Tripathi and Dubey, 2004).

Various plant materials possess antifungal activity and many essential oils exhibit antifungal activity with no side effects on humans and animals (Sokmen *et al*., 1999). Previous *in vitro* and *in vivo* investigations suggested that the essential oils could be used as effective antifungal agents (Adam *et al*., 1998). In recent years, several researchers have reported the mono and sesquiterpene hydrocarbons as the major components of plant essential oils with enormous potential to inhibit microbial pathogens (Cakir *et al*., 2004).

Dill (*Anethum graveolens* L.), an important annual crop of family Apiaceae , is among the aromatic plants which produce essential oils with known biological activities (Kaur and Arora, 2010; Singh *et al*., 2002; Singh *et al*., 2005). The plant is native to south-western Asia and south-eastern Europe and has a long history of cultivation and use (Bailer *et al*., 2001; Kaur and Arora, 2010). The character of oil produced in leaves and stems differs from that of mature seeds. The oil extracted from mature seeds has a high content of carvone and limonene, the herb oil contains considerable amounts of á-phellandrene and dill ether as well (de-Carvalho and da-Fonseca, 2006).

Keeping in view various biological activities of dill essential oil and its components, the present study was planned to study the fungicidal potential of dill seed essential oil and its chemical constituents against *Alternaria triticina* (causing leaf blight of wheat) and *Bipolaris sorokiniana* (causing spot blotch and common root rot of wheat).

The commercially available dill seed essential oil was analyzed for chemical composition using GC-MS. The GC-MS (QP2010 Plus, Shimadzu, Japan), equipped with an Rtx-5 MS capillary column (30.0 m x 0.25 mm i.d., 0.25 ìm film thickness). The GC injector was maintained at 250 °C and operated in split injection mode with the split valve closed for 1 min. Helium gas was used as the carrier gas at a constant pressure of 69 kPa. The column oven was initially maintained at 50 °C for 2 min, raised to 180 °C at 3 °C min^{-1}, then to 280 °C at 10 °C min^{-1}. The interface temperature was 260 °C and the ionization mode was electron impact (70 eV). The mass selective detector was operated in the scan mode between 40 and 600 m/z. Data acquisition was started 3.0 min after injection. MS parameters used were; Ionization Voltage (EI) 70 eV, peak width 2 s, mass range 40–600 amu and detector voltage 1.5 V. Peak identification was carried out by comparison of the mass spectra with mass spectra data available on database of NIST08, WILEY8, Perfumery and Flavor and Fragrance libraries. The GC-MS data of dill seed essential oil is given in Table 1.

Thin layer chromatography of essential oil and its fractions was done. The silica gel G was dissolved in water to prepare the slurry (10g of silica gel/100 mL of water).

Chromatoplates (20x20 cm) were coated with slurry with the aid of an applicator, giving 0.25 mm thickness. The chromatoplates were air dried at room temperature. The dill seed essential oil was dissolved in dichloromethane and applied on the chromatoplate. The spotting of plates was done with the help of capillary tubes. The spot was applied 1cm upward from the lower end of chromatoplate. The chromatographic plates were developed using benzene:ethyl acetate (19:1) as solvent system, air dried, sprayed with methanol: sulfuric acid (19:1) and heated in an electric oven at 100°C for 5 min in order to reveal the spots. The R_f values and colour of the spots were noted.

The dill seed essential oil (10g) was subjected to column chromatography for isolation of pure compounds. Column was packed with silica gel 60-120 mesh size activated at 110°C for one hour. The essential oil was adsorbed on silica gel for 5 min and column was eluted with petroleum ether and the polarity was increased using dichloromethane. The compounds isolated along with their spectral data are listed in Table 2.

Pure cultures of *Alternaria triticina* and *Bipolaris sorokiniana* were obtained from the Department of Plant Pathology, PAU, Ludhiana,Punjab, India. The isolates were collected from the diseased samples and maintained on Potato Dextrose Agar (PDA) slants and plates at 4°C. The antifungal activity was evaluated by spore germination inhibition technique.

Spore germination inhibition method: Antifungal activity was tested using spore germination inhibition technique. Ten-day old cultures of the test fungi (*Alternaria triticina and Bipolaris sorokiniana)* were taken from PDA slants and spore suspension was made by adding sterilized distilled water. In order to remove mycelial and agar bits, the suspension was filtered through three layers of sterilized cheese cloth after shaking the tube thoroughly under aseptic conditions. Haemocytometer was used to form standardized spore suspension. Small droplets (0.02 mL) of test solution and spore suspension in equal amount were seeded in the cavities of the cavity slides. These slides were placed in petri plates lined with moist filter paper and incubated for 20 hrs at 24±1°C.The number of spores germinated were counted and percent spore germination inhibition was calculated as:

$$\text{Per cent spore germination inhibition} \quad \frac{\text{Spore germination in control- Spore germination in treated}}{\text{Spore germination in control}} \times 100$$

The fungicide carbendazim (Bavistin 50WP) was used as the standard to compare the activity of the compounds. The antifungal activity was expressed in terms of ED_{50} and ED_{90} values.

Statistical analysis: Experiment was replicated thrice for each concentration. Factorial CRD with arc sine transformation was applied to data using CPCS1 software. Significant differences between transformed values were detected and significance was set at 5%.

The essential oil was soluble in organic solvents like acetone, benzene, dichloromethane and insoluble in water. Thin layer chromatography of the dill seed essential oil showed four coloured spots having R_f values 0.84 (yellowish), 0.70 (orange), 0.65 (grey) and 0.59 (pink). The non-polar fraction showed one yellowish spot with R_f value 0.84 and polar fraction showed three spots with R_f values 0.70 (orange), 0.65 (greyish) and 0.59 (pink).

Chemical composition of dill seed essential oil: GC-MS analysis (Table 1) of dill seed essential oil showed the presence of thirty one compounds. The major components were carvone (41.15%), limonene (23.11%), camphor (9.25%), dihydrocarvone (3.75%), butyl acetate (2.65%), dill apiole (1.65%), dill ether (1.02%), etc. Carvone mainly contributes to the aromatic odour of the dill seed essential oil. The pure compounds were isolated by column chromatography and characterized by spectral data (Table 2).

Antifungal activity: Dill seed essential oil, its fractions and compounds isolated were evaluated *in vitro* for their

Table 1. Chemical composition of dill seed oil

Name	Retention Time(min)	Area (%)
á-Pinene	7.946	1.06
Sabinene	9.226	0.68
â-Pinene	9.402	0.29
Myrcene	9.791	2.36
Octanol	10.047	0.07
Nonanal	10.273	0.41
á-Phellandrene	10.404	0.80
Limonene	11.683	23.11
Terpinene	12.336	0.57
Decanol	12.719	0.16
Terpinolone	13.316	0.09
Cymenene	13.469	0.10
Ethyl heptanoate	13.710	0.43
Linalool	13.823	0.49
Chrysanthenol	14.660	0.09
Limonene oxide	15.071	0.29
Isopulegol	15.711	0.12
Isomenthone	15.937	0.09
Menthol	16.877	0.39
Dill ether	17.098	1.02
Camphor	17.751	9.25
Dihydro carvone	17.949	3.75
Terpineol	18.941	0.32
Carvone	20.161	41.15
Caryophyllene oxide	22.035	0.39
Butyl acetate	22.779	2.65
Cadinene	26.544	0.12
Bicyclogemacrene	27.345	0.16
Dill apiole	31.800	1.65
Isobenyl isobutyrate	47.892	0.17
Docosene	54.194	0.22

antifungal potential against *A. triticina* using spore germination inhibition method at different concentration levels *viz*. 0.25, 0.5, 1.0 and 2.0 mg mL^{-1} (Table 3). Polar fraction of dill seed oil found to be more fungitoxic than all other components. The ED_{50} and ED_{90} (Figure 1) values were observed in range 0.2-0.38 mg mL^{-1} and 1.54-2.15 mg mL^{-1}, respectively. At 50 percent spore germination inhibition the order of antifungal activity obtained was:

Camphor > Polar fraction > Limonene > Non-Polar fraction > Dill seed oil

Statistical analysis of data showed that there was a positive correlation between concentration and antifungal activity. The antifungal activity increased with increase in concentration. Dill seed essential oil, its fractions and isolated compounds were evaluated *in vitro* for their antifungal potential against *B. sorokiniana* by spore germination inhibition technique at different concentration levels *viz.* 0.25, 0.5, 1.0 and 2.0 mg mL^{-1} (Table 4). Dill seed oil, its polar fraction and camphor showed significant difference (better activity) in activity at 2 mg mL^{-1} than non-polar fraction and limonene. The ED_{50} and ED_{90} (Figure 2) values were observed in range 0.1- 0.78 mg mL^{-1} and 0.77-2.1 mg mL^{-1}, respectively. At 50 per cent spore germination inhibition the order of antifungal activity obtained was:

Limonene> Non-polar > Dill oil >Camphor >Polar fraction

Statistical analysis of data (Table 4) showed a direct correlation between concentrations and antifungal activity. The antifungal activity increased with increase in concentration.

The results of antifungal activity of dill seed oil were in consonance with already reported antifungal activity of *Coriander. sativum* essential oil with *complete* inhibition at 2 mg/mL concentration against *Bipolaris oryzae, Alternaria alternata, Drechslera halodes* (Lalitha *et al.*, 2011). Dill seed extract exhibited great antifungal activity against tested fungi by radial growth method. The ED_{50} values of limonene and camphor were in range 0.073-0.2mg mL^{-1} and 0.04-0.083mg mL^{-1} respectively from against pathogenic fungi *Rhizoctonia solani, Fusarium oxysporum, Penicillium digitatum* and *Aspergillus niger* by using mycelial growth inhibitory technique (Gehan *et al*., 2012). In the present study limonene and camphor showed higher ED_{50} values against *Alternaria triticina* and *Bipolaris sorokiniana* by spore germination inhibition technique.

Table 2. Spectral data of isolated compounds

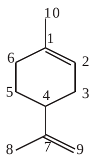
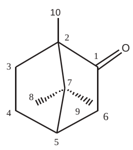
Structure	IR data(cm^{-1})	^1H NMR ($CDCl_3$, 400 MHz) data (ä in ppm)	^{13}C NMR data (ä in ppm)
 Limonene	3070 (=C-H stretching), 2925 and 1446 (C-H stretching of -CH_2-), 1643(C=C stretching) 1375 (C-H bending of CH_3)	1.65(s, 3H, C_{10}), 1.73(s, 3H, C_8), 1.42-1.52(m, 2H, C_5), 1.72-1.82(m, 1H, C_4), 4.70(s, 2H, C_9), 5.39-5.40 (m, H, C_2)	133.75(C_1), 120.65(C_2), 30.60(C_3), 41.09(C_4), 27.92(C_5), 30.81(C_6), 150.28(C_7), 108.3(C_8), 20.82(C_9), 23.47 (C_{10}).
 (2) Camphor	2960 (C-H stretching) 1448(C-H bending) 1742(C=O stretching)	0.49 (s, 3H, C_9), 0.56 (s, 3H, C_8), 0.62 (s, 3H, C_{10}), 1.97-2.03 (m, 1H, C_5)	219.35(C_1), 57.55 (C_2), 29.81 (C_3), 26.97 (C_4), 42.94 (C_5), 46.67 (C_6), 43.18 (C_7), 19.06 (C_8), 19.68 (C_9), 9.18 (C_{10})

Table 3. Mean percent spore germination inhibition at various concentrations against *A.triticina*

Components	Concentrations (mg mL^{-1})			
	0.25	0.5	1.0	2.0
Dill seed oil	31.46 (34.10)	63.46 (52.79)	75.67 (60.43)	98.62 (84.46)
Polar fraction	32.18 (34.55)	64.80 (53.59)	77.57 (61.71)	100 (89.96)
Non-polar fraction	51.34 (45.75)	53.11 (46.76)	67.98 (55.52)	83.38 (65.93)
Camphor	31.66 (34.22)	64.82 (53.60)	75.99 (60.67)	94.92 (77.06)
Limonene	56.30 (48.60)	59.41 (50.40)	73.49 (58.98)	88.15 (69.87)
Carbendazim (Bavistin 50 WP)	100 (89.96)	100 (89.96)	100 (89.96)	100 (89.96)

Values in parentheses are arc sine transformed values; CD (p=0.05) Component: 0.99, Concentrations: 0.81, Interaction: 1.98

Table 4. Mean percent spore germination inhibition at various concentrations against *B. sorokiniana*

Components	Concentration (mg mL^{-1})			
	0.25	0.5	1.0	2.0
Dill seed essential oil	4.28 (11.68)	52.07 (46.16)	83.58 (66.08)	100 (89.96)
Polar fraction	30.09 (33.20)	63.94 (53.07)	85.63 (67.70)	100 (89.96)
Non-polar fraction	17.57 (24.76)	27.04 (31.32)	64.07 (53.16)	87.16 (68.99)
Camphor	71.77 (57.92)	73.79 (59.22)	98.11 (82.19)	100 (89.96)
Limonene	17.58 (24.76)	45.06 (42.15)	77.58 (61.72)	87.90 (69.62)
Carbendazim (Bavistin 50 WP)	100.00 (89.96)	100.00 (89.96)	100.00 (89.96)	100.00 (89.96)

Values in parentheses are arc sine transformed values; CD (p=0.05) Components:1.02, Concentrations: 0.83, Interaction 2.03

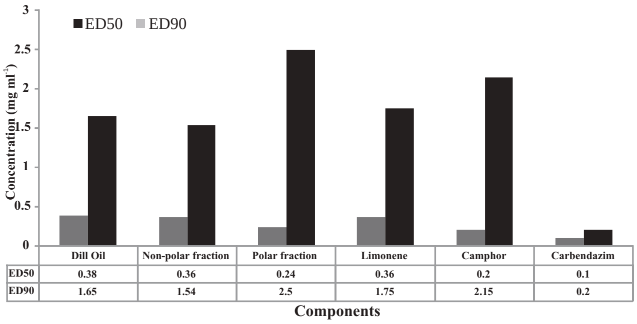


Fig. 1. ED_{50} and ED_{90} values of all components against *A. triticina*

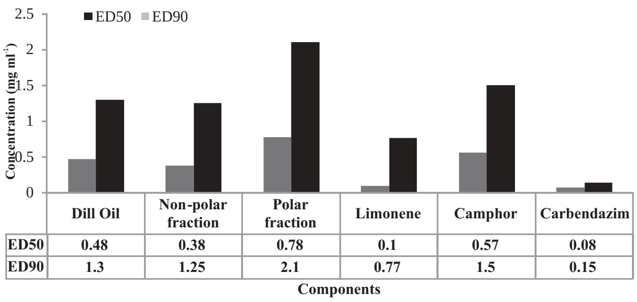


Fig. 2. ED_{50} and ED_{90} values of all components against *B. sorokiniana*

Thirty one compounds were identified in GC-MS analysis which constituted approximately 94% of the dill seed essential oil. Carvone was its major constituent. Dill seed essential oil was found to be fungitoxic against spore germination. The antifungal activity of camphor may be related to the presence of ketone moiety. ED_{50} and ED_{90} values of antifungal activity against tested fungi were in the range 0.1-0.78 and 0.7-2.15 mg mL^{-1} respectively. Dill seed essential oil completely inhibited spore germination under 2.15 mg mL^{-1}, showed a good fungitoxicity. Thus compounds present in dill seed oil can be used as antifungal agents as they were found to possess good antifungal potential.

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Received 26 February, 2016; Accepted 14 June, 2016

Indian Journal of Ecology (2016) 43 (Special Issue-2): 907-909

Manuscript Number: 2414
NAAS Rating: 4.47

Genetic Divergence Studies in Chilli (*Capsicum annuum* L.)

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***Abstract*:** Study on genetic diversity was conducted with eighteen diverse genotypes of chilli at SKUAST, Jammu, India during December to August 2013. The observations were recorded on sixteen traits. On the basis of D^2 analysis the eighteen genotypes were grouped into 5 different clusters. Cluster II was the largest comprising of 5 followed by cluster III and cluster IV (4), cluster V (3) and cluster I (2) genotypes. Highest intra cluster distance was observed in cluster IV while the highest inter cluster distance was recorded between cluster IV and cluster I revealing that sufficient genetic diversity for selecting superior and diverse parents were present and can be further exploited for any chilli improvement programme. The characters namely days to 50 % flowering and days to fruiting contributed maximum towards divergence. The genotypes *viz*. SJPC and SJC-01 were found desirable for yield, whereas, the genotypes *viz*. DKC-8, Cherry pepper, LCA-206 and G-3 were desirable for capsaicin percentage and ascorbic acid, suggesting that these superior genotypes would be useful as better sources for further crop improvement.

Key Words: Chilli, Cluster analysis, D^2 statistics, Genetic divergence

Chilli (*Capsicum annuum* L.) is second most important solanaceous vegetable after tomato grown worldwide both as spice and vegetable crop (Hasan *et al*., 2014). India is the major producer, consumer and exporter of chilli. There are more than 400 different varieties of chillies found all over the world but despite of that continuous effort to increase chilli productivity does not gain any momentum. This could be attributed to a number of limiting factors, of which lack of superior genotypes are of utmost importance. Assessment of genetic diversity among germplasm is a pre requisite for plant breeder in choosing suitable parental lines. Keeping the above point in view, the investigation was undertaken to assess the genetic diversity in eighteen genotypes of chilli to identify suitable genotypes.

The investigation was conducted during 2013 at SKUAST, Jammu. The experimental material comprised of eighteen diverse genotypes collected from different parts of India. These were evaluated of chilli with three replicates. Twenty five to thirty days old seedlings, with 3-4 true leaves, were transplanted in the main field, at an inter row spacing of 60 cm and intra row spacing of 45 cm in a plot size of 3.0 m x 2.25 m. Manures and fertilisers were applied as per recommended dose to raise good crop (Anonymous, 2006). Each genotype was characterized regarding 16 morphological characters in accordance with the descriptor list of the International Plant Genetic Resources Institute in Rome. Five randomly selected plants from the middle row of each entry in each replicate were taken to record fourteen quantitative characters and two quality characters *i.e*., capsaicin and ascorbic acid. Vitamin C was determined by the dichlorophenol indophenol titration procedure (Sadasivam and Theymoli, 1987). The capsaicin content was calculated using a calibration curve against a high purity capsaicin (Sadasivam and Manickam, 1992).

The mean data obtained was subjected to determine the clustering pattern among the genotypes and Mahalanobis (1936) D^2 statistics was employed to measure the genetic distance between genotypes and grouping was done into possible number of groups by Touchers's method as described by Rao (1952).

The differences were significant among the genotypes for all the characters studied indicating considerable amount of genetic variability for all the characters (Table 1). Based on the D^2 statistics, eighteen genotypes of chilli were grouped into five clusters using Tocher's method (Table 2; Figure 1). The perusal of data depicted that cluster II had maximum number of genotypes (5), followed by cluster III and IV with 4 genotypes each. Cluster V (3) comprising of CCH-05-01, LCA-353 and Jammu Local Selection genotypes and cluster I with two genotypes viz. SJPC and SJC-01, similar grouping of genotypes was done by Karad *et al.* (2002), Senapati *et al.* (2003) and Manju and Sreelathakumary (2004) while clustering of diverse chilli lines. Cluster I earned the highest mean value for total number of fruits per plant (135.67), fruit diameter (1.62), number of primary branches per plant (5.95), fruit yield per plant (616.7). Cluster III had the highest mean value for average fruit weight (4.93), fruit length (6.74), stalk length (2.66) and number of seeds per fruit (50.90). Cluster IV gave maximum mean value for capsaicin

Table 1. Analysis of Variance for various characters in chilli (*Capsicum annuum* L)

SoV	Df	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Repl.	2	22.72	29.55	988.84	0.13	0.39	0.01	0.02	184752	0.16	33.02	160.93	0.0004	12.25	10177.50	1017792	221.83
Treat.*	17	587.93	549.85	23705.91	6.99	6.66	0.31	0.50	550503.24	2.17	184.17	454.87	0.015	3610.15	148522.71	14852274	3262.73
Error	34	9.49	14.73	1126.98	0.06	0.12	0.004	0.02	179714.5	0.67	28.51	87.49	0.0002	0.12	11370.26	1137023	249.80
Percent contribution		33.89	17.27	12.17	9.31	7.82	7.31	5.09	3.52	1.70	0.95	0.62	0.25	0.06	0.03	0.00	0.00

1: Days to 50% flowering; 2: Days to fruiting; 3: Total number of fruits plant^{-1}; 4: Average fruit weight (g); 5: Fruit length (cm); 6: Fruit diameter (cm); 7: Stalk length (cm); 8: Plant spread (cm^2); 9: Number of primary branches per plant; 10: Plant height (cm); 11: Number of seeds fruit^{-1}; 12: Capsaicin percentage; 13: Ascorbicacid (mg/100g); 14: Fruit yield plant^{-1} (g); 15: Fruit yield plot^{-1} (g); 16: Fruit yield per ha(q ha^{-1}); * Indicates significant at 5% level of significance

Table 2. Clustering of eighteen genotypes of chilli based on D^2 statistics and their cluster mean for various quantitative and qualitative characters

Cluster (No. of genotypes)	I (2)	II (5)	III (4)	IV (4)	V (3)
Parameters*	SJPC, SJC-01	Punjab Surkh, Selection-1,SJC-02, G-4, LCA-334	Selection-2, Selection-3, LCA-305, LCA-960	DKC-8, Cherry pepper, LCA-206, G-3	CCH-05-01, LCA-353, Jammu Local Selection
1	27.83	49.47	59.33	64.17	48.00
2	29.83	46	58.17	65.58	53.44
3	135.67	55.55	87.13	49.01	255.32
4	4.68	2.00	4.93	1.83	1.86
5	5.06	5.27	6.74	4.36	4.57
6	1.62	1.01	1.50	1.05	1.05
7	2.47	2.30	2.66	2.56	2.13
8	1608.75	1821.16	1708.04	1115.16	2023.12
9	5.95	5.55	5.48	5.40	4.96
10	59.96	59.32	60.82	50.34	64.88
11	18.10	31.50	50.90	36.28	33.85
12	0.07	0.17	0.10	0.20	0.16
13	85.82	87.69	120.39	140.59	91.04
14	616.71	115.28	422.56	98.74	439.43
15	6167.07	1152.83	4225.64	987.39	4394.27
16	91.36	17.02	62.60	14.63	65.10

*As in table 1

percentage (0.20) and ascorbic acid (140.59) and recorded the minimum value for days to 50 % flowering, days to fruiting which is a required character for breeding for earliness, whereas cluster V gave high mean value for total number of fruits per plant (255.32), plant spread (2023.12) and plant height (64.88).

The maximum inter cluster distance (Table 3) was between cluster IV and I (48.889) followed by cluster II and I, V and IV. The crosses between the genotypes belonging to these clusters can be suggested for obtaining hybrids with high yields and can be used in chilli breeding to achieve maximum heterosis. The lowest inter cluster distance was observed between cluster IV and II followed by cluster V and II, indicating close relationship among these three clusters

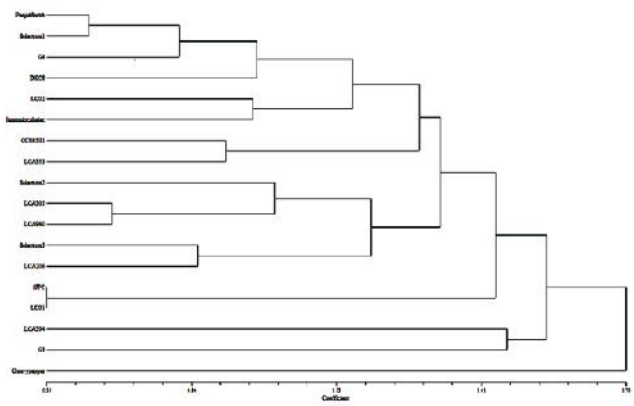

Fig. 1. Dendrogram showing grouping among the genotypes of chilli

Table 3. Average intra (bold) and inter cluster (D^2 Values) distance values

Cluster	I	II	III	IV	V
I	(1.040)	30.130	22.193	48.889	21.902
II		(7.469)	19.088	10.667	13.286
III			(5.683)	22.677	18.430
IV				(9.278)	26.092
V					(4.423)

which can be used for backcrossing. Genotypically distant parents are able to exert high heterosis (Farhad *et al*., 2010, Kumar et al., 2010). The maximum intra cluster distance was recorded for cluster IV i.e. 9.278 followed by cluster II and III revealing sufficient genetic divergence among the genotypes of the cluster. The parents within the cluster can be chosen for hybridization programme. Among the sixteen characters observed, days to 50 % flowering showed highest contribution for divergence followed by days to fruiting and total number of fruits per plant. The first twelve traits contributed for more than 95% towards genetic divergence. Rohit *et al*. (2011), stated that while considering the genetic diversity among the parents to be included in hybridization programme, their field potential should not be ignored. While selecting genotypes from distant cluster the mean values for different trait should be given importance to generate promising breeding material (Hazra *et al*., 2002). From the study, it may be concluded that a wide range of variation for almost all the economically important traits are present in this crop. This implies a great potential for breeding through hybridisation programme or direct use as a variety. Therefore considering group distance, agronomic performance and variability the intergenotypic cross (Table 4) between DKC-8, Cherry pepper, LCA-206, G-3 for total number of fruits per plant, fruit diameter, number of primary branches per plant, fruit yield per plant and SJPC, SJC-01 for days to 50% flowering, days to fruiting, capsaicin percentage, ascorbic acid may be considered as better parent to be used for future hybridization programme.

Table 4. Diverse genotypes identified for various quantitative and qualitative characters in chilli

Cluster	Genotypes	Traits
I	SJPC, SJC-01	• Total number of fruits per plant • Fruit diameter • Number of primary branches per plant • Fruit yield per plant • Fruit yield per plot
III	Selection-2, Selection-3, LCA-305 and LCA-960	• Average fruit weight • Fruit length • Stalk length • Number of seeds/fruit
IV	DKC-8, Cherry pepper, LCA-206 and G-3	• Days to 50% flowering • Days to fruiting • Capsaicin percentage • Ascorbic acid
V	CCH-05-01, LCA-353 and Jammu Local Selection	• Total number of fruits/plant • Plant spread • Plant height

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Received 26 March, 2016; Accepted 26 June, 2016

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Date of Publication 15.09.2016