Sustainable Agricultural Innovations for Resilient Agri-Food Systems

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Title	**Sustainable Agricultural Innovations for Resilient Agri-Food Systems**
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Preface

The Indian Ecological Society is organising an international conference on Sustainable Agricultural Innovations for Resilient Agri-Food Systems from 13-15 October at Jammu, India. The participants will be presenting and learning about the latest multi-disciplinary agricultural research innovations and strategies for sustainable and resilient agri-food systems. To address the issues of sustainability of agri-food systems from an intra and interdisciplinary perspective on wide ranging topics such as genetics innovations**,** biodiversity conservation and management, pest management innovations, public health, food safety and security, sustainable energy services and agriculture production, invasive species rising sharply because of increased trade, and policy issues in light of the United Nations Sustainable Development Goals (SDGs) related to agriculture and development. The international experts from the discipline of plant and animal genetics and plant breeding, entomology, plant pathology, forestry, soil sciences, extension education, resource economics, aquaculture, water; agriculture industry and farmers and resultant availability and quality of food have contributed their research findings and experiences for wider discussion on these topics.

Despite the contrarian school of thought and research, which claims the undesired consequences of agricultural technological innovations overweigh the benefits of the Green Revolution, the modernization of agriculture in the 20^{th} Century saved the world from hunger and malnutrition by increasing yield of food crops thereby making food available at affordable prices.

The question arises whether we continue with the input intensive modernization of agriculture? The answer is yes and no. Yes, because science based innovations in genetics, farm machinery and farm inputs, and public and private sector contributions in research and development has led to produce more food and fiber. No, because overreliance and indiscreet use agro-chemicals, mono-cropping, loss of biodiversity, use of fossil fuels in production of agro-chemical and farm mechanization has had negative impacts on natural resources, humans and climate. So we have to make tradeoff to draw a balance between these two. The desired, direct and functional impacts/ consequences of science based innovations go hand-in-hand with the undesired, indirect and dysfunctional impacts.

Science-based innovations alone can achieve this synergy. And in this science-based advancement towards sustainable and resilient agri-food systems must come from private and public sector research and development. Private sector R&D contributes the technologies that are patentable such as hybrids/ transgenic, farm machinery, drone technology, and agro-chemicals. Public sector R&D is to contribute towards natural resource management technologies namely soil and water conservation, integrated pest management, integrated nutrient management and so on. However, it needs to be emphasized that private and public sector R&D should keep the consumer (farmer) and environmental interest in mind for developing resilient agricultural technologies.

This proceeding is in two parts: the first one compiling the keynote lectures of the eminent scientists from around the world sharing their research into and experiences with sustainable agricultural technologies and the second one compiling contributed original research abstracts of the scientists attending this conference. The keynotes of these proceedings recognise the value of science based technologies that have contributed and will contribute to the growth of agriculture sector and recognise the negative impacts of technologies on environmental quality and human health, and inequalities among small and large farm-holding farmers. In many instances they have suggested the science based solutions for transition towards agricultural systems that are productive and have positive impacts on environment and play a significant role in reversing the climate change crisis.

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Organising Secretary, Indian Ecological Society International Conference: 2022
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India

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Keynote Lectures

The Grand Strategies for Innovation:

An Introduction to the Keynote Lectures

Since the beginning of agriculture—the start of the Neolithic—innovation has been a constant companion of agri-food systems. Periods of rapid change have been interspersed with long stretches of stability, but the ways of producing, processing, and moving food from field to dinner table have changed many times. The pace of change picked up considerably since the 17th century due to the rise of modern science, higher supplies of energy from fossil fuels, more rapid population growth, and vast expansion of trade and travel.

This conference, organized by the Indian Ecological Society, has assembled a diverse range of scientists and scholars dedicated to furthering the long pattern of innovation in agri-food systems broadly conceived, ranging from crop and livestock production, the role of forests in agriculture, the quality of diets of food produced, and the socio-cultural relationships of people working in agri-food systems. Many of the papers focus on the micro-level of individual experiments and studies. These technical papers create knowledge of the materials, energy, and processes in producing food and fiber.

The abstracts that follow, however, present the keynote lectures. These provide the ideas and proposals for the grand strategies of innovation. They provide directions and rationales for needed experiments and studies at the micro-level. They take a step back from laboratory and field to discern the "big picture" of agriculture, perhaps the human endeavor with the most variables and global impacts. Agriculture is also the indispensable foundation for maintaining the lives and activities of humans. Human well-being depends upon the innovative work of this conference's participants to feed and clothe humanity. Perpetually.

The keynote lectures have explored dozens of factors posing the most severe challenges facing agricultural production and agri-food systems in the 21st century. Three major categories capture the breadth of issues addressed.

First, human activities have already changed earth's climates, and with only a few exceptions these changes do not auger well for agricultural production. Since the beginning of agriculture as a substitute for hunting and gathering, about 11,000 to12,000 years ago, the earth has been in a post-glacial climate. The massive ice sheets of the last glacial period retreated as warmer temperatures returned, and agricultural practices, developed within a mostly stable climatic envelop.

This climate showed only minor perturbations—compared to ice ages—from year to year, but the massive exploitation of fossil fuels starting in the 16th century released more carbon dioxide and methane into the atmosphere. These greenhouse gases captured heat from the sun and pushed up the global average temperature. Climates began to change, and the latest report (2022) from the Intergovernmental Panel on Climate Change makes it clear that these warmer climates bring more heatwaves, droughts, floods, stronger cyclones, and wildfires. The climates that farmers and foresters knew and coped with have begun to disappear, and they must learn to cope with new conditions. Climate change demands innovation in the production of crops, livestock, and forests. Forestry must innovate in metods of protecting and using forests. Forestry requires new knowledge and practices to preserve forests and their abilities to capture carbon dioxide from the atmosphere.

Second, the human population has grown rapidly since the advent of intensive uses of fossil fuels, and more people need more food and fiber. Large increases in the production of the world's major cereal crops (rice, wheat, maize) during 20th century provided the metabolic energy to support a population that has reached nearly 8 billion people and still continues to grow. Despite massive increases in production of cereals, diets of many—in both wealthy and lower income countries—suffer from poor diets. Future supplies of food must provide both the metabolic energy plus the micronutrients currently not well supplied. Innovations must improve production of both livestock and crops.

Providing every person—constantly—with adequate food energy and nutrition appeared as a strategic imperative in every keynote lecture, either explicitly or implicitly. Moreover, several lectures emphasized that adequate food supplies involved more than just agronomic practices. Distribution of people on the landscape and rights to land and water profoundly affect the abilities of farmers to produce. Gender and other socio-cultural relationships in agriculture need to change if agri-food systems are to meet the needs of all people. Policies must ensure adequate incomes to farmers to invest in the next cycle of production and to consumers who do not raise their own food. In short, socio-political-economic-cultural factors play powerful roles in agri-food systems. Farming is not just about genetic varieties, soil fertility, and water.

Finally, many of the keynote lectures addressed strategies for research on the physical resources of agri-food systems. Since solving the role of DNA in heredity a half-century ago, genetic manipulations have provided the tools for improving both crops and livestock. Better understanding of meteorology and hydrology opened new ways of ensuring adequate water supplies. Soil fertility can be maintained with fertilizers. These and other tools from the natural sciences give pathways to maintaining and increasing yields. But climate change now demands that the new pathways be powered by energy without fossil fuels and greenhouse gas emissions.

Together, these keynote lectures outline broad strategies on multiple topics. Together with the findings of the technical sessions addressing micro-level topics, agricultural scientists have many new ideas for how best to assist all of humanity in having enough to eat without destroying the earth that provides the bounty.

John H Perkins, PhD
30 September 2022

01 Breeding and Deploying Climate Resilient Maize Varieties in the Tropics*

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Global Maize Program, CIMMYT (International Maize and Wheat Improvement Center) & CGIAR Plant Health Initiative Lead

1. Introduction

Achieving sustainable food and nutritional security, i.e., the basic right of the people to produce and/or purchase the nutritionally balanced food they need, without harming the social and biophysical environment, has to be the funademental goal of any nation. Over the last seven decades, India made immense progress towards food security of the population. Since 1950, the population almost tripled, but foodgrain production had more than quadrupled. India is now among the largest producers of rice, wheat, pulses, fruits, vegetables, milk, cotton, horticultural crops, dairy andpoultry, aquaculture, and spices. Agricultural production in India is valued at US$ 401 billion in 2017, which is more than that of the USA (US$ 279 billion).

Despite this impressive progress, there is no scope for complacency. It is estimated that by 2030, India's population would be 1.52 billion; by 2050, it would be approximately 1.7 billion, which will be the highest in the world and about 400 million more than China, the most populous nation today (Singh, 2019). By 2050, India needs to step up production of all agricultural commoditiesby around 30 per cent in food grains and to more than 300 percentin vegetable oils to meet the needs of increased population and risingliving standards (Singh, 2019).Also, by 2050, to meet the diverse demands of the population, it has been estimated that land productivity has to be increased by 4 times, water productivity by 3 times, and labour productivity by 6 times (Chand, 2012). All this has to be achieved in the context of changing climates, more fargile natural resources, and by staying within the planetary boundaries i.e., without major environmental and ecological footprints. Climate change is for real, and certainly not fiction, as is unfortunately still believed by some in the world! The negative impacts of frequently occuring climatic extremes/variabilities on agricultural production are most often felt by the resource-constrained smallholders in the tropics, be it in Africa, Asia or Latin America. Abiotic stresses, especially drought, heat, flooding/ waterlogging, soil acidity, and combinations of various abiotic stresses have a huge negative impact on the rainfed crop yields. For instance, in South and South East Asia, more than 80 percent of the maize-growing area is rainfed and prone to various climatic extremes/variabilities. While we tend to focus mostly on abiotic stresses in the context of climate change, it is equally important to consider the changing spectrum of pathogens and insect-pests, due to increase in temperature (Deutsch *et al.*, 2018; IPPC Secretariat, 2021; Skendžic *et al.*, 2021).

Building climate resilience in the smallholder farming systems, therefore, requires implementation of an intenisve multi-disciplinary and multi-institutional strategy. This should include extensive awareness creation and widespread adoption of climate-resilient crop varieties and climate-smart agronomic management practices, strengthening of local capacities, and much stronger focus on sustainability. An array of agricultural production technologies and practices, including stress-tolerant improved crop varieties, conservation agriculture practices, and agroforestry systems, that aim to mitigate climate-induced risks and foster resilience have been developed through national and international AR4D initiatives over the past two decades. In addition, institutional interventions that seek to mitigate risk and build resilience through other mechanisms could play a complementary role to climate-smart agricultural production technologies/practices (Hansen *et al.*, 2019).

2. Breeding multiple stress-tolerant improved maize varieties for the tropics

The International Maize and Wheat Improvement Center (CIMMYT) and partners in Africa, Latin America and Asia are intensively engaged in developing and deploying climate-resilient improved maize varieties adapted to the tropics (Cairns and Prasanna, 2018; Prasanna *et al.*, 2021; Chivasa *et al.*, 2021). CIMMYT has used two major approaches for developing sources of abiotic stress tolerance that have been widely used in maize breeding programs in SSA, Asia and Latin America. The first was constitution of drought-tolerant populations for undertaking recurrent selections and derivation of elite inbred lines. The DTP-Y, DTP-W, and La Posta Sequia are examples of such populations. The second approach was full-sib recurrent selection under managed drought stress within elite populations to increase the frequency of drought tolerance alleles in germplasm already adapted to the lowland tropics (e.g., Edmeades *et al.*, 1999; Prasanna *et al.*, 2021a). Both approaches have generated several inbred lines that have become important sources of drought and heat tolerance in maize, especially in the tropics(Cairns *et al.*, 2012). Thus, population formation and improvement have resulted in an increase in the frequency of drought-adaptive alleles and identification of superior sources of drought tolerance (Edmeades *et al.*, 2017).

Besides constitution of appropriate maize populations for implementing recurrent section for improving drought stress tolerance, CIMMYT also has established an extensive phenotyping network for maize breeding in the tropics along with managed stress screening protocols (Prasanna *et al.*, 2021a); identified and used suitable secondary traits (e.g., anthesis-silking interval or ASI); and implemented focused breeding programs to continuously develop products (inbred lines, improved OPVs, and hybrids) that can perform well under both optimal and stressed environments (Cairns and Prasanna, 2018; Prasanna *et al.*, 2021a). CIMMYT's maize product advancement process typically includes not only regional on-station trials of promising pre-commercial hybrids coming out of the breeding pipeline vis-à-vis internal genetic gain checks and commercial checks but also extensive regional on-farm varietal trials to ascertain the performance of the promising pre-commercial hybrids under farmer-managed conditions. This also provides opportunity for the socioeconomics team to assess farmers' product as well as their trait preferences. The best entries coming out of this rigorous process are then announced on the CIMMYT website, and further allocated to interested public/private sector partners for varietal registration, scale-up, and delivery in the target geographies.

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*Keynote lecture at the Indian Ecological Society International Conference (IESIC-2022) at the Sher-e-Kashmir University of Agricultural Sciences & Technology (SKUAST), Jammu, India (October 13-15, 2022).

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3. Accelerating improved varietal development using modern tools/technologies

CIMMYT-Maize Teams in Africa, Asia and Latin America use an array of modern tools/technologies for accelerating improved varietal development and for increasing genetic gain for grain yield in stress-prone tropical environments (Prasanna *et al.*, 2021a). These tools include the doubled haploid (DH) technology (Prasanna *et al.*, 2012; Chaikam *et al.*, 2019), low-cost and high-throughput phenotyping using proximal and remote sensors (e.g., Makanza *et al.*, 2018a,b), genomics-assisted breeding (e.g., Nair *et al.*, 2018), and breeding information management system, including decision-making tools. With the rapid reduction in genotyping costs, new genomic selection technologies have become available in several crops that allow the crop breeding cycle to be greatly reduced, facilitating inclusion of information on genetic effects for multiple stresses in selection decisions (Xu *et al.*, 2017). Through dedicated maize DH facilities in Kenya and Mexico, CIMMYT Global Maize Program produces annually over 100,000 DH lines (up from less than 5000 in 2011) and selects the best out of these lines in breeding pipelines. CIMMYT team has also developed and deployed superior second-generation haploid inducers for tropics using marker-assisted breeding (Chaikam *et al.*, 2018). In December 2021, CIMMYT has established a Maize Doubled Haploid Facility at ARS-Kunigal in Karnataka, India, in partnership with UAS-Bangalore. This facility will provide DH development service not only to CIMMYT maize breeders, but also to those from the NARS and small- and medium-enterprise (SME) seed companies in South Asia.

3.1. Deploying climate-resilient maize varieties in the tropics

An array of elite maize varieties with drought tolerance, disease resistance and other farmer-preferred traits have been developed by CIMMYT and seed companies across sub-Saharan Africa (SSA), Asia and Latin America. Between 2007 and 2021, CIMMYT and partners in SSA released more than 300 climate-resilient maize varieties in 13 African countries. In 2021, more than 171,000 tons of certified seed of CGIAR-dericed multiple stress-tolerant maize varieties were produced and commercialized by over 100 small- and medium-enterprise seed company partners across SSA, covering an estimated 7.2 million hectares, and benefiting about 7 million farm households. Tesfaye *et al.,* (2017, 2018) highlighted the potential benefits of incorporating drought, heat and combined drought and heat tolerance into improved maize varieties in the climate-vulnerable tropical environments. Asia is now beginning to emulate the success story from Africa in terms of extensive deployment of drought-tolerant and drought + Heat-tolerant improved maize varieties through intensive public-private partnerships. Through the USAID-funded Heat Tolerant Maize for Asia (HTMA) project, a large heat-stress phenotyping network, comprising 23 sites in four Asian countries (India, Bangladesh, Nepal and Pakistan) has been established. Several CIMMYT-derived drought-tolerant and heat-tolerant CIMMYT-derived elite maize varieties have been released during 2016-2018 through public and private sector partners in South Asia, and several more are in pipeline.

For new climate-resilient crop varieties to contribute towards smallholders' adaptation to climate variability, it is important to further strengthen the seed systems. Delivering low-cost improved seed to smallholder farmers with limited purchasing capacity and market access requires stronger public-private partnerships, and enhanced support to the committed local seed companies, especially in terms of information on access to new products, adequate and reliable supplies of early-generation (breeder and foundation) seed, and training on quality seed production, quality assurance/quality control (QA/QC),and seed business management. Proactive management of product life cycles by seed companies benefits both the farmers and businesses alike, contributing to improvedfood security and adaptation to the changing climate (Chivasa *et al.*, 2021).

3.2 Protecting Agri-food systems from devastating pathogens and insect pests

Pathogens and insect-pests have severe and cross-cutting negative impacts, particularly affecting farmers' incomes, and livelihoods. Their capacity to rapidly evolve and proliferate pose a huge challenge. There is a significant need for implementation of development and implementation of multi-disciplinary, multi-institutional, and sustainable strategies for devastating crop diseases and pests, to counter the threat to food and nutritional security, and the livelihoods of populations (Prasanna *et al.*, 2022b).

Two most recent examples of transboundary pests/pathogens severely affecting maize smallholders are the maize lethal necrosis (MLN) in Africa, and the fall armyworm (*Spodoptera frugiperda*) in Africa and Asia. MLN is a complex viral disease, emerging as a serious threat to maize production and the livelihoods of smallholders in eastern Africa since 2011, primarily due to the introduction of maize chloroticmottle virus (MCMV). CIMMYT, in close partnership with national and international partners, implemented a multi-disciplinary and multi-institutional strategy tocurb the spread of MLN in sub-Saharan Africa, and mitigate the impact of the disease (Prasanna *et al.*, 2020; Prasanna, 2021).

Fall armyworm (FAW) has been prevalent in the Americas for several decades but was reported for the first time in West Africa in 2016. Within two years, FAW incidence had already been reported in more than 40 countries across Africa, and over 15 countries across the Asia-Pacific (Prasanna *et al.*, 2021b). The pest was reported for the first time in India in mid-2018, and subsequently reported in several other Asian countries. FAW attacks primarily the maize crop and has potential to feed on more than 80 other crops, including sorghum and sugarcane. Indiscriminate and unguided use of toxic synthetic pesticides is reported across Africa and Asia for FAW control, which poses serious threat to environment, animal and human health, besides affecting the natural enemies of the pest. Therefore, it is extremely important to develop, test, and urgently deploy science-based, integrated pest management (IPM) technologies/management practices, including host plant resistance (both native genetic resistance and transgene-based resistance) to FAW (Prasanna *et al.*, 2022), environmentally safer synthetic pesticides, biopesticides and botanicals, besides low-cost cultural control and agro-ecological approaches (Prasanna *et al.*, 2018, 2021b). A set of three first-generation FAW-tolerant CIMMYT maize hybrids have been announced in 2021 for Africa (https://maize.org/cimmyt-announces-fall-armyworm-tolerant-elite-maize-hybrids-for-africa/). While South Sudan has recently released these three hybrids, several more countries are expected to release the FAW-tolerant maize hybrids in 2022-2023. Breeding for native genetic resistance to FAW has also been initiated by CIMMYT and partners in South Asia.

4. Conclusions

We need to collectively address an array of challenges, including adaptation to the changing climates, alleviating extensive malnutrition, improving soil health,and protecting agrifood systems from devastating diseases and insect-pests. Intensive multi-institutional and multi-disciplinary efforts are required to cocreate and deploy innovative and sustainable technologies that can improve crop productivity, reduce production costs, and improve the incomes and livelihoods of smallholder farmers. Building climate resilience warrants effective integration of climate-resilient crop varieties, climate-smart agronomic management practices, and effective implementation of policies to help reduce environmental and ecological footprints of agricultural practices. Scientific institutions must enhance the the pace, precision and efficiency of breeding programs through judicious and effective integration of modern tools/strategies, including high-density genotyping, high throughput and precision phenotyping, speed breeding, molecular marker-assisted and genomic selection-based breeding, and knowledge-led decision-support systems.Seed systems need to be further strengthened to become more market-oriented and dynamic, and for providing smallholders with greater access to affordable climate-resilient and nutritionally enriched improved seed. Understanding the smallholder farmers' constraints for adoption of modern technologies, enhancing affordability and access to quality agricultural inputs, and improving their linkages to the input and output markets should be accorded top priority.

Technologically, we are living in exciting times. Genomics-assisted breeding, genome editing, speed breeding, remote sensors, satellite imagery, drones, artificial intelligence, machine learning, decision support tools, and information and communication technologies, are only a few of the innovations that one can mention that are impacting various spheres of life, including agriculture. Breeding programs should be constantly appraised and revised by incorporating new innovations. Furthermore, the efficiency and effectiveness of the breeding programs should be monitored by employing metrics designed to measure the impacts of breeding outcomes (improved varieties) on the ultimate users–the farmers.

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02. Breeding Wheat for the Future: Opportunities and Challenges

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Keywords: Wheat breeding; genetic gain; genomic selection

1. Introduction

The ever-expanding range of 'omic technologies available presents tremendous opportunity to accelerate plant breeding. In wheat breeding, recent advances in germplasm and genomic resources as well as infrastructure advances such as speed breeding provide the potential to accelerate progress. However, there is an important balance to be struck between retaining existing effective approaches and methods and incorporating new tools into realistically size and resourced breeding programs. This talk will provide an overview of lessons from accelerating spring wheat breeding in the Global Wheat Program of the International Maize and Wheat Improvement Center (CIMMYT). Rapid generation advance and a streamlined trait introgression pipeline are being used to increase gains in the early stages of the breeding program. High-density genotypes, selection indices and intensive pathogen screening provide a means for data-driven decisions for line advancement and parental recycling. These advances are combined with the long-standing requirement for extensive testing and feedback to provide robust breeding material to partners across 100+ countries. Overall, the adoption of new tools and technologies holds exciting opportunities for plant breeding but must be streamlined and optimized to deliver against core breeding and delivery objectives. However, the landscape of global wheat is changing with rising climate threats, a need to reduce inputs and changing geo-politics in wheat supply. All these factors must be considered when developing wheat for the future.

2. Implementing rapid generation advance and trait introgression

CIMMYT has established a speed breeding (SB) facility and a field screenhouse (SH) facility, both at the Toluca experimental station, located in Toluca, Mexico. The purpose of both facilities is to reduce crop cycle time from 4-5 months to 3 months on the average, thereby facilitating 4 generations of crossing/backcrossing or generation advancement per year in spring and durum wheat. Both the SB and SH are important infrastructure underpinning the adoption of faster breeding schemes as part of the "Accelerating Genetic Gains in Maize and Wheat" project. The project aims to accelerate the development and delivery of more productive, climate-resilient, gender-responsive, market-demanded, and nutritious wheat for farmers in sub-Saharan Africa and South Asia.Further details of the overall project aims, progress to date and funder details can be found here: https://www.cimmyt.org/ projects/agg/.

The SB facility is currently being utilized for rapid introgression of marker selectable traits in the trait pipeline. This builds on the evidence for use of speed breeding conditions to rapidly incorporate traits, particularly those with a linked or diagnostic marker, in wheat and other crops (Watson *et al.*, 2018). The focus of the CIMMYT trait pipeline is on the rapid incorporation of new variation for disease resistances into lines that can then provide improved parents. Disease resistance is a key factor in delivering resilient germplasm to farmers in CIMMYT's target regions, and is supported by an established Adult Plant Resistance deployment strategy which is summarized here: https://www.cimmyt.org/content/uploads/2021/06/CIMMYT-Strategy-for-Adult-Plant-Resistance-APR.pdf

The SH facility is being used to shortening the breeding cycle. It allows for the adoption of rapid bulk generation advance (RBGA), saving 1-year from the current 2 generation/year field-based shuttle, allowing a 3-year cycle, as summarized in Figure 1 below.

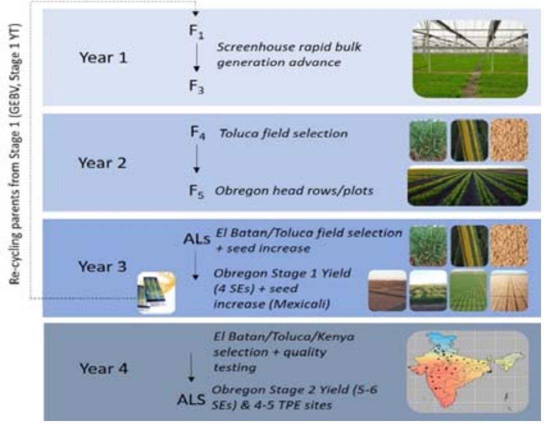

Figure 1: Rapid bulk generation advance using a screen-house facility allows a reduction in breeding cycle time for CIMMYT spring and durum wheat pipelines.

Both facilities are now operational, and over the process of optimization of activities in these facilities several areas were recognized that require further investment to improve functioning. These optimization activities are essential in order to evaluate the true potential of accelerated breeding schemes and infrastructure costs vs. the expected or targeted rates of genetic gains.

Phase I initiation of the RBGA scheme used populations extracted from the existing breeding pipeline to allow optimization of the SH logistics, and the frequency of F4 derived F5 lines/cross with good agronomics, disease resistance & grain characteristics to achieve 10-20 sibs/cross in stage 1 trials (as recommended for improving GEBV). It also enables comparison of germplasm developed from the current shuttle pipeline, RBGA-unselected and RBGA with selection in F4. The expected outcomes from this phase include embedding of generation advance protocols and logistics, optimization of population size and advancement methods and comparison of genetic gain for trait values (including yield) against the current breeding scheme. Further cycles of RBGA have now been initiated.

3. Ensuring accurate multi-trait selection

Because of the number and genetic complexity of traits required in breeding products, selection indices are being tested to add greater depth of information to line advancement and parental selection. Using data from 2019-2020, an eigen selection index method (with the first eigenvector of the multi-trait heritability used as the vector of co-efficients) shows potential for co-selection of Zn and grain yield (69.6% overlap with breeder selections). The

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mainstreaming of high Zinc is a central target for the CIMMYT spring wheat breeding program to ensure the widest reach is achieved via biofortification.Work is ongoing to optimize selection indices, and to create "breeder-friendly" tools for their practical implementation. Genomic selection, based on genomic estimated breeding values (GEBVs) is also being used for for selection of sister lines to progress from Stage 1 testing and selection of parents for recycling from Stage 1 (see Figure 1). Combined, it is envisaged that these approaches will provide a data-driven method to allocate elite parental material to the different breeding pipelines and to improve the multi-trait accuracy of selection for line development.

4. Development of advanced lines targeted to specific geographies and end-users

Recent work (Crespo-Herrera *et al.*, 2021) shows grain yield progress (based on analysis of CIMMYT's international Elite Spring Wheat Yield Trial (ESWYT) trials from 2001 to 2016) over time in India. To further define breeding progress at a target population of environment (TPE; a group of similar production environments) level the study used historical meteorological and soil data, and grain yield information to define three TPEs in India. For each TPE it was possible to estimate correlated response to selection, and the prediction ability of five selection environments (SE) in Obregon and grain yield (GY) progress in each TPE. The analysis shows different rates of gain in each TPE and that some Obregon selection environments (and statistical models) give better predictions for specific TPEs. Further work is ongoing to define TPEs for spring wheat breeding across South Asia, and for Ethiopia, a major wheat producer in sub-Saharan Africa.

5. Summary

The CIMMYT Global Wheat Program has achieved large impact over time in target environments through the provision of improved germplasm. Historical analyses of genetic progress clearly document the upward trend in breeding progress in both on-station selection (Gerard *et al.*, 2020; Mondal *et al.*, 2020) environments and in target regions (Crespo-Herrera *et al.*, 2021). In order to continue to deliver, and to accelerate the rates of breeding gain, new tools and technologies including speed breeding, genomic selection and extensive target environment assessment are being deployed. These approaches need to be optimally implemented in order to deliver wheat breeding gains to farmers. They also need to be integrated within the changing demands of the global wheat and food system to ensure climate change adaptation, reduction in emissions from production and stability in the global wheat market.

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03. Intra-specific Diversity and Adaptation to Climate Variations

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1. Introduction

Humanity relies largely on a small number of crops for its subsistence. A major challenge facing agriculture is adaptation to ongoing climatic change. In natural ecosystem, species diversity led to higher ecosystem productivity and stability (Tilman *et al.,* 2012; Tilman *et al.,* 2014). Study at a global scale have show that cultivated species diversity is also a stabilizing factor to yield under climate variability (Renard and Tilman 2019; Renard and Tilman 2021). More cultivated diversity led to a more stabilized yield to year year variation of climate. Does this impact of diversity is observed at the intra-species level? We will illustrate here how intra-specific diversity had and could be also an asset to future adaptation of crops.

2. Intra-specific diversity and past adaptation to environmental variation

The diversity of crops was shaped at the early steps of their domestication (Purugganan 2009) and later by local selection following the spread of cultivation, including possible introgressions by local wild relatives (Burgarella *et al*., 2018; Burgarella *et al.,* 2019). Wild-cultivated gene flow was a major factor allowing adaptation of crops to environment variability.

One example is the spread of maize to high altitude in Mexico. Maize was domesticated some 9000 year ago in Mexico (Matsuoka *et al.,* 2002), and colonized rapidly south America, and later on North America. Maize is derived from a wild sub-species *Zea mays* ssp *parviglumis (*Vigouroux *et al.,* 2008) adapted to the low altitude in Mexico, altitude ranging roughly from 300 to 1600 m. Early maize consequently had similar set of adaptation, but colonizes rapidly the higher altitude up to 3000 m in Mexico. Evidence pinpoint hybridization between another subspecies of maize *Zea mays* ssp. m*exicana* as a major factor of its adaptation to high altitude (Calfee *et al.,* 2021; Barnes *et al.,* 2022). *Zea mays* ssp *mexicana* is adapted to higher altitude from 1600 up to 3000m (Fustier *et al.,* 2017; Fustier *et al.,* 2019), with key specific adaptation. In a twist in the history of adaptation, we recently showed occurrence of *Zea mays* ssp *mexicana* occurring as a weed in France. This high altitude wild species was adapted to France climate because of hybridization with the cultivated species, *Zea mays* (Le Corre *et al.,* 2020).

Study of pearl millet also shows hybridization with their wild relatives help diffusion and adaptation of the crops. Pearl millet (*Cenchrus americanum*) was domesticated from wild relatives occurring today in Niger and Mauritania (Burgarella *et al.,* 2018). But then, pearl millet cultivation diffused to the West of Africa to Senegal, and the East and South Africa and India (Burgarella *et al.* 2018). Colonization of West and East Africa was associated with gene flow from wild relatives and we pinpointed several key genes strongly associated with adaptation and introgression from wild relatives (Burgarella *et al.,* 2018)[6]. Altogether these two examples illustrate how intra-specific diversity and wild-cultivated hybridization (Burgarella *et al.,* 2019) plays a major role in helping the early diffusion of crops and their adaptation to diverse environment.

Could this intra-specific diversity help adaptation on a short time scale? To answer this question, we studied adaptation of pearl millet in Niger (Vigouroux *et al.,* 2011). Since the early 1970s, Sahel climate experienced long periods of drought. We analyzed samples of pearl millet landraces collected in the same villages in 1976 and 2003. Varieties were studied for their phenological and their morphological differences in the 1976 and 2003 collections in a common garden experiment over three years. We found no major changes in the main cultivated varieties or in their genetic diversity. But, compared to the 1976 samples, samples collected in 2003 displayed a shorter lifecycle, and a reduction in plant and spike size. We also show positive selection for an early flowering allele at the PHYC locus, the early flowering allele increased in frequency between 1976 and 2003. This study suggests that intra-specific diversity was positively selected for adaptation to the recurrent drought. We further demonstrated this selection was partly driven by environmental selection.

3. Intra-specific diversity and adaptation to future climate

Species distribution model (SDMs) were among the first types of models used to assess ecological niches and to perform inference of plant and animal distribution (Aguirre-Liguori *et al.,* 2020; Thuiller *et al.,* 2019) in actual and future climate. SDMs use mainly climate factors and occurrence datasets to define geographical distributions of species and predict change in distribution in future climate (Aguirre-Liguori *et al.,* 2020; Thuiller *et al.,* 2019). However, if these approaches exhibit good power to predict occurrences, they fall short when considering prediction of performances, population fitness or genetic diversity (Lee-Yaw *et al.,* 2022). This claims for better taking into account intra-specific diversity and explicitly include genetic diversity in the predictive models (Aguirre-Liguori *et al.,* 2020). Major efforts have recently been made to develop such models; commonly named genetic offsets (GO). Among them, we can cite Risk of Non Adaptedness (RONA) (Rellstab *et al.,* 2016), Gradient Forests (Bay *et al.,*2018; Fitzpatrick and Keller 2015) (aka Genomic Vulnerability) or Redundancy Analysis (RDA) (Capblancq and Forester 2021). Some recent works have shown the high potentialities of these approaches either using simulated datasets (Láruson *et al.,* 2022) or empirical ones (Aguirre-Liguori *et al.,* 2021; Bay *et al.,* 2018; Láruson *et al.,* 2022; Tournebize *et al.,* 2022) but also raised some concerns (Láruson *et al.,* 2022; Rellstab *et al.,* 2021). This field is currently under intensive development, and some of the initial criticisms, especially regarding the lack of genetic structure consideration in the models are being addressed. If genetic offset analyses were primarily done in an ecological context of natural populations where populations can easily be associated to a given climate, our research (Rhoné *et al.,* 2020) suggest these analyses could also be done on crops notably when we are working with local traditional varieties, locally selected by local farmers and sawn from year to year.

We performed a first experiment using these approaches at a regional scale in pearl millet (Rhoné *et al.,* 2020) using 173 varieties. In this study, we built a map of genetic offset (Figure 1) using the gradient forest approach for pearl millet at the 2050 horizon using 154 climatic variables (temperature, radiation, rainfall pattern, etc). This

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map is based on a consensus over 17 different climate models in 2050 and a CO_2 emission scenario (Representative Concentration Pathway RCP8.5), roughly corresponding to the business-as-usual scenario established by the international panel on climate change (IPCC). The use of different climate models is widely used by IPCC to evaluate scenario variability. Our analysis made it possible to identify northern distribution areas in Niger and Senegal where genomic differences between today and 2050 are highest (in red in Fig. 1). These areas are where the predicted changes will be the strongest. This experiment allowed us to evaluate if we could link the vulnerability indexes with real fitness parameters, and to make a first forecast for pearl millet in West Africa.

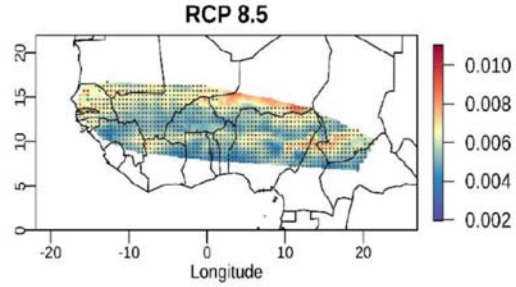

Figure 1: Regional assessment of pearl millet genetic offset to climate change at the 2050 horizon.

Genomic vulnerability measures a mis-adaptation to future climate change. These genomic vulnerabilities were estimated in West Africa based on projections for a scenario of greenhouse gas concentration pathways (Representative Concentration Pathway RCP8.5). Colors refer to the mean value of genomic vulnerability estimated for 17 climate models projections. Figure from Rhone et al., 2020.

To assess relationship between the measure of genomic vulnerability and fitness (yield for crop), we first calculated genomic vulnerability using the spatial contrast between the climate at the site of field experiment and the average climate at the location of origin. We hypothesize spatial contrast could be a first approximation of temporal contrast. The spatially contrasted climate helped us build a genomic vulnerability index of 173 varieties in the average climate conditions of the field experiments. We found significant negative correlations between yield related traits and genomic vulnerability (n=173, r(Pearson)= -0.412, $p < 0.0001$ for 100 seed weight; r(Pearson)=-0.368, $p < 0.0001$ for the mean weight of seeds on the main spike; r(Pearson)= -0.310, $p < 0.0001$ for the weight of seeds per plant). We also performed an analysis taking into account population structure and it increased correlation to R=-0.5. François and Gain (Comm. Pers) began a preliminary assessment using their new latent factors statistics and it led to even better correlation (R=-0.66). A recent article in plants also identify strong non-linear relationship between genetic offset and fitness related traits (Fitzpatrick *et al.* 2021) up to R=-0.81. An opened and barely addressed question following these predictions are the identification of mitigation potentialities. Scenarios of mitigation based on potential migration have been proposed based on the relationship between genetic differentiation (FST) with the contrast of climate (Gougherty *et al.,* 2021) or using gradient forest (Rhoné *et al.,* 2020; Gougherty *et al.* 2021). Goutherthy *et al.,* 2021 considered for any given location in future climate (cell of the model) the genetically closest population (lowest FST) in today's climate ("reverse genetic offset"). We proposed a similar approach to identify varieties that are potentially suitable (Rhoné *et al.,* 2020) to future climate conditions. Goutherthy *et al.,* 2021 extended this analysis to identify present-day varieties that might not find matches in future conditions ("forward genetic offset"), something particularly interesting for crops, raising concerns about the potential loss of locally adapted genetic resources (high forward genetic offset). These two approaches are quite interesting and could identify populations at risk in future climate and scenario of potential migration.

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04. Biofortification of Staple Food Crops as Potential Sustainable Nutrition Intervention

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Keywords: Malnutrition; iron; zinc; provitamin A; nutrition.

Background and approaches

Essential nutrition (vitamins and minerals) is fundamental for well-being. Food production is meant for both food and nutrition security. This has been ignored in recent agricultural research for development manifestos. Modern agriculture has been largely successful in meeting the energy needs of poor populations in developing countries. However, agriculture must now focus on a new paradigm that will not only produce more food but deliver better quality, nutritious, affordable food through crop improvement programs. More than 3 billion people around the world, largely represented by Africa, Asia, and Latin America regions, simply can't afford a diet of nourishing but diverse foods that provide enough essential vitamins and minerals. The agricultural sector gained momentum in producing higher yields through green revolution efforts, but not essential nutrition. Globally, tackling the burden of malnutrition in all its forms remains challenging. According to FAO (2020) estimates, 21% (144.0 million) of children under 5 years of age were stunted, and 7% (47.0 million) were wasted. The highest nutrition priority for eradicating malnutrition and achieving optimum nutrition for all is embedded in the National Nutrition Policy (NNP) adopted by the Government of India in 1993. However, prevalence is also higher in India, according to the national family health survey (NFHS-V, 2021). The HarvestPlus programme of the CGIAR and its global consortium partners enhances three essential nutrition traits, iron (Fe), zinc (Zn), and provitamin A (PVA) in staple crops. Biofortification is a process for increasing the essential minerals and vitamins in the edible parts of crops through genetic selection for the long-term or agronomic intervention for the short term. Biofortification of staple foods targets households most at risk of undernutrition and micronutrient malnutrition, which are mostly rural poor households that produce and consume staple foods. Henceforth, it's a vibrant strategy that ensures the consumption of essential micronutrients cost-effectively. The Biofortification Priority Index (BPI) is a crop-specific index and interactive tool that identifies the country-crop-nutrient combinations for investments in biofortification breeding and product delivery (more details at https://bpi.www.harvestplus.org). Based on the BPI and nutrient targets, HarvetsPlus works with various CGIAR centres and NARS for diverse crop-product development in prioritised countries (Table 1).

At the inception of HarvestPlus-almost 17 years ago as a joint CGIAR program, intending to tackle hidden hunger caused by a lack of vital minerals and vitamins in the diet through biofortification. HarvetsPlus faced many challenges in deliberating this concept and mobilising resources for alliance formation and partnership-based projects. Some of them are: i) is it possible to develop staple food crops with high mineral or vitamin content without reducing crop yields; ii) will consumers adopt it sufficiently to improve their nutritional status; and iii) can farmers scale up adoption? These were gradually addressed with evidence and impact realised on the ground today. So far, more than 400 nutrition-rich varieties have been released across 10 crops in 40 countries (Figure 1), and many more nutrient-rich pipelines and new varieties are being tested in additional countries, adding a total of 60 countries potentially benefiting from biofortification products. Therefore, given the success of the HarvestPlus alliance strategy, products, and scaling up partnerships, the overall CGIAR programme portfolio (from 2020), it is now time to accelerate mainstream nutrition through multidisciplinary approaches. The CGIAR Consortium and its member organisations, the CGIAR crop research centres, are committed to mainstreaming breeding for mineral and vitamin traits into crop improvement programmes through crop product profiles (a blueprint of new variety development by each centre). Therefore, no centre should be on the dilemma of either breeding for yield or nutrition in staple crops; it is for both. Food security without nutrition is incomplete.

To reach more than a billion people by 2030, biofortification must move beyond HarvestPlus efforts, which are prospecting the mainstreaming of essential mineral and vitamin traits in core breeding product pipelines in regionally diversified crops. India declared minimum levels for Fe (42 mg/kg) and Zn (32 mg/kg) in the pearl millet cultivar release policy and such a policy in other crops is expected in 2025. Therefore, this global biofortification effort significantly contributes to ending hidden hunger caused by the lack of essential vitamins and minerals in staple foods. Individual nutritional efficacy studies have proven that consumption of an adequate quantity of biofortified crop varieties will provide a significant amount of target nutrients to an individual, varying from 50–100% of daily requirements for Fe, Zn, and PVA. Other nutrient efficiency will be evaluated. Supporting this national and international nutrition policy is critical to motivating industries. With the available nutrition studies evidence and systematic deliberations, to date, more than 20 nations' implemented publicly available policies and regulations covering biofortification as part of their comprehensive national nutrition strategy (https://www.harvestplus.org).

Way forward for sustainable nutritional security

The world is making progress in addressing nutrition insecurity but is not on track to achieve the 2030 targets for malnutrition burdens. The frequency of supporting unhealthy foods and crops is notably very high with commercial targets. Most developing countries are not on track to achieve the SDGs. There is a need for urgent collective action to reverse these agri-food system-based problems. More than ever, it will not be surprising that the nutritional status of vulnerable groups is likely to depreciate further due to COVID-19 impacts. For addressing hidden hunger, which requires a combination of strategies, ideally, biofortified crops significantly complement them. Biofortification demonstrated its scientific, applied, scalable, and sustainable approach to food-cum-nutritional insecurity.

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The recommendation is to make micronutrient targets a core element of global and national crop research and development just like high yield. CGIAR Centers' initiated mainstreaming of biofortification in global breeding programmes while selected NARS will be supported to strengthen capacity and improve skills and knowledge to mainstream locally and regionally. Unless the government and funding agencies urge the prioritisation of nutrient-rich staple crop research and product development besides higher yields and stress tolerance, it will never be sustainable for public health – no action on this issue will cost much more in years to come. Fixing minimum crop-specific nutrition standards (Eg, Fe and Zn in pearl millet) will guide the organisation for the gradual enhancement of staple crop nutrition over the years. Public and private seed and grain sectors should mobilise these biofortified varieties for public distribution and industrial use. Several studies have confirmed that India is one of the world's most malnourished countries. It is easy to correlate and map the degree of the malnourished population as per the parliamentary constituency of India – which attracts a healthy political and structural investment for public well-being. HarvetsPlus will assist in systematic programming as well as addressing crop research gaps, product development pathways, advocacy, and scaling up food systems strategies for long-term nutritional improvement.

Table 1: Prioritization of staple crops and breeding specific nutrients and lead CGIAR) centres.

Crop Priority	Nutrient Priority	Priority Countries
Wheat	Zinc (Zn)	China, India, Pakistan, Ethiopia
Rice	Zinc (Zn)	Bangladesh, China, India, Colombia
Maize	Provitamin A (PVA)	Brazil, DRCongo, Ghana, Malawi, Mali, Nigeria, Rwanda, Zimbabwe
Maize	Zinc (Zn)	Brazil, DRCongo, Ghana, Malawi, Mali, Nigeria, Rwanda, Zimbabwe
Pearl Millet	Iron (Fe)	Benin, India, Niger, Nigeria, Zimbabwe
Beans	Iron (Fe)	Brazil, DRCongo, Guatemala, Kenya, Malawi, Rwanda, Uganda, Zimbabwe
Cassava	Provitamin A (PVA)	Brazil, DRCongo, Ghana, Malawi, Nigeria,
Sweetpotato	Provitamin A (PVA)	Bangladesh, Brazil, China, Egypt, Ethiopia, Ghana, India, Indonesia, Kenya, Madagascar, Malawi, Mozambique, Nigeria, Rwanda, Tanzania, Uganda, Vietnam, Zambia

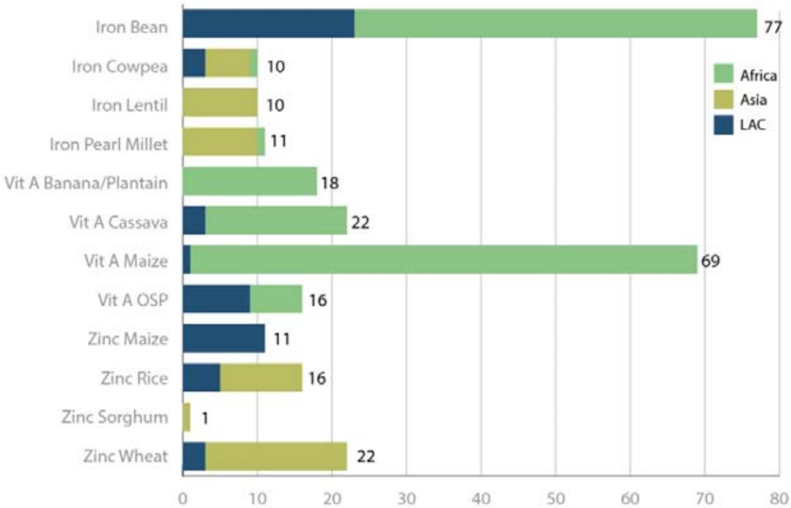

Figure 1: Global biofortified crop cultivars are released for cultivation through a targeted breeding approach.

Summary

The currently available staples of food systems in the developing world and nutrition crises are deeply interconnected. Globally, 3 billion people are suffering from inadequate nutrition. A higher prevalence of malnutrition arises from one or more nutrient deficiencies and is responsible for counterproductive human and national development. Staple crops are key to providing energy and nutrients to vulnerable rural households, particularly in drylands. Biofortification of staple foods can offer a cost-competitive and sustainable way to reach the vulnerable. The first biofortified crop variety was released to farmers in 2004: a vitamin A orange sweet potato variety in Uganda and Mozambique. To date, more than 400 nutrition-rich varieties have been released across 10 crops in 40 countries, demonstrating the mainstreaming of nutrition is possible in the crop improvement program. The HarvestPlus programme of the CGIAR leads the global alliance for the discovery, development, and delivery of nutrient-dense crops across Asia, Africa, and Latin America. Several crop-country-based nutrition efficacy studies have shown that 50–100% of daily requirements are met through biofortified varieties. Integration of nutrition crop improvement for developing nutrient-dense crop varieties with climate resilience and stress tolerance without compromising the farmer's and consumer's preferences is the way forward. Incorporating agronomic biofortification and crop diversification for essential nutrient supply will sustain the crops and nutritional baskets for the farming communities, and surplus can be marketed.

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05. Actual and Potential Effects of New Plant Breeding Technologies

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1. Current realities

Producing enough food for the growing population has always been a daunting task since the beginnings of agriculture and remains a challenge as the world population continues to grow. During the last 100 years, plant breeding, combined with irrigation and agrochemicals, has led to unprecedented yield growth in major cereals such as wheat, rice, and maize. While chronic hunger still exists, the global proportion of hungry people declined from over 50% in the first half of the twentieth century to around 10% today. However, this model of agricultural intensification has also contributed to environmental issues. Moreover, the strong focus on only a few major cereals has slowed down dietary diversification, such that micronutrient deficiencies are now a bigger health concern than calorie deficiencies. And new problems are looming. Climate change is already impacting agriculture in negative ways; the frequency and severity of climate calamities will likely increase in the decades ahead. Poor people in Africa and Asia are particularly vulnerable, as many of them depend on agriculture for their livelihoods. Without new and better technologies, sustainable agriculture and food security cannot become a reality.

New plant breeding technologies (NPBTs), including genetically modified organisms (GMOs) and gene-edited crops, could be a game-changer. They could contribute to higher crop yields, lower use of chemical fertilizers and pesticides, better crop resilience to climate stress, and more diverse and nutritious foods. However, NPBTs are not yet widely used and accepted. Many see GMOs with a lot of skepticism, because anti-biotech groups were very successful in shaping opinions with their fearmongering narratives. Even though 30 years of research have shown that GMOs are safe, there continue to be widespread public concerns about possible negative consequences. These concerns have led to safety regulations and approval procedures for GMOs that are much stricter and more politicized than for any other agricultural technology. In the EU, the GMO regulations also apply to gene-edited crops, which means a quasi-ban. In other words, NPBTs, which could contribute substantially to sustainable development, are sacrificed primarily due to false narratives and public misperceptions.

2. Scientifically credible approaches and challenges

NPBTs are no panacea for making agriculture more sustainable, nor will they completely replace conventional breeding methods. However, NPBTs add precision and speed to plant breeders' efforts of developing desirable crop traits. Through relatively small and targeted changes in the plant genome, scientists have developed and tested a number of interesting crop traits, such as pest and disease resistance, higher nitrogen use efficiency, tolerance to drought, heat, and soil salinity, or higher micronutrient contents. Comprehensive and independent research shows that crops developed with NPBTs are as safe for human health and the environment as conventionally-bred crops. The first transgenic GMOs were commercially approved in the mid-1990s and have been grown by farmers in a large number of countries since then. Most GMOs commercialized so far involve either insect-resistance (IR) or herbicide-tolerance (HT) traits in crops such as maize, soybean, rapeseed, and cotton. IR and HT crops have led to higher harvested yields and income gains for farmers, even though other effects tend to vary by trait. IR crops have helped to reduce insecticide sprays, whereas HT crops have led to increases in the use of chemical herbicides, to substitute for soil tillage. Another difference is that HT crops are primarily used by large, mechanized farms, while IR crops are used by all types of farms, including smallholders. IR cotton in particular has contributed to poverty reduction and improved livelihoods among farmers in China, India, Pakistan, and South Africa. Hence, it is not the breeding method as such, but the specific crop trait that determines technological effects and suitability for different situations.

In spite of the documented benefits of GMOs, there are two broader issues that deserve further discussion. First, the number of commercialized GMO crops and traits is still small and remains far behind initial expectations. Second, almost all available GMO crops were developed and commercialized by large multinational companies, fostering market concentration in some parts of the seed industry. However, both these issues are not inherent to GMO technology but the result of costly overregulation. Regulatory hurdles and politicized approval procedures for GMOs have made the testing and commercialization so expensive and uncertain that only multinationals can afford to do so with a small number of crops and traits that have sufficient commercial potential. Other GMO crops, which are more interesting from a sustainability perspective, were developed and tested by various public and private organizations, but were never approved for commercial use because of unfounded claims of hypothetical risks. Examples include drought-tolerant or fungus- and virus-resistant rice, wheat, potato, or banana. While such applications could be hugely beneficial, politicians often lack the courage to endorse technologies that are widely perceived as risky, even though these technologies were declared safe by researchers and risk assessment authorities. Overly precautious attitudes towards GMOs are not only observed in Europe; European misperceptions and regulatory approaches have also spilled over to other parts of the world, especially to Africa and Asia.

Gene-editing methods are newer and more precise than previous gene-transfer technologies. Many gene-edited crops do not contain foreign DNA, which could help to reduce many of the public concerns related to transgenic GMOs. Gene editing is relatively cheap, which means that also small companies and public labs can use these methods to develop crop varieties with various new traits. Gene editing has been used successfully already in more than 40 different crop species, including cereals, fruits, vegetables, pulses, roots, and tubers. Hence, gene editing could help to increase diversity in agriculture and seed markets. The problem is that many of the potentials may not materialize, as anti-biotech activists continue to use the same narratives for gene-edited crops as for transgenic GMOs. In the EU, gene-edited crops are also regulated in the same way as transgenic GMOs. This does not only affect development and cultivation in the EU. Imports of gene-edited crops and foods also have to be approved and labeled, which can lead

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to serious trade disruptions and technological slowdowns in many other world regions too.

Like any transformative technology, NPBTs can be used to support positive and negative trends. Hence, proper technology policies and management are needed to ensure that desirable outcomes materialize while undesirable ones are avoided. However, especially Europe is far away from science-based policies for NPBTs. Entrenched prejudices have led to a quasi-ban, stifling any meaningful discussion about potentials, limitations, and required policy actions.

3. Evidence-based options and actionable next steps

Plant breeding innovations are crucial for sustainable agricultural development and food security. NPBTs in particular offer large potentials to make farming more productive, environmentally-friendly, and climate-smart. Poor people in developing countries could benefit the most. However, further development and use of NPBTs are obstructed by overregulation and widespread concerns about hypothetical risks.

Harnessing the potentials of NPBTs requires a more evidence-based public and policy debate about technological benefits and risks. Anti-biotech activists must stop spreading fearmongering narratives that ignore the state of science. The mass media must give more weight to scientific evidence and less weight to unsubstantiated claims. EU policymakers should reform the GMO law and regulatory procedures. As a first step, gene-edited crops that do not contain any foreign DNA should be exempted from the law. In a next step, a new law that supersedes the existing GMO law should be developed, regulating the breeding product (new plant variety) instead of the breeding process (method). Breeding products may be associated with certain risks, while there is no indication that breeding methods as such bear any specific risks.

Effective antitrust policies should ensure that market power in biotech and seed industries is avoided. More efficient regulatory and approval procedures will foster market competition, but other factors, such as too strong patents on plant technologies, can also contribute to market concentration and need to be observed and managed.

Public research organizations should ensure that those crop-trait combinations that are particularly useful for sustainability but are not of sufficient commercial interest for the private sector are developed through public research or public-private partnership.

Agricultural policy and development organizations should ensure that suitable breeding innovations and seeds are widely accessible to all farmers at affordable prices, and that these innovations are properly integrated into local production systems, following the rules of good agricultural practice. Breeding innovations must not be seen as substitutes for good agronomy, including crop rotations and integrated pest management.

4. Summary

Plant breeding innovations are crucial for sustainable agricultural development and food security. In the past 100 years, the development and use of new high-yielding crop varieties have helped to increase food production considerably, thus reducing hunger in spite of rapidly rising population numbers. However, past models of agricultural intensification have also contributed to low diversity and various environmental problems. Moreover, climate change poses additional challenges, as climate calamities reduce agricultural yields while increasing production variability. New plant breeding technologies (NPBTs), including genetically modified organisms and gene-edited crops, offer large potentials to make farming more productive, diverse, environmentally-friendly, and resilient. Through targeted changes in the plant genome, scientists have developed and tested a number of interesting crop traits, such as pest and disease resistance, higher nitrogen use efficiency, or tolerance to drought, heat, and soil salinity. Independent research confirms that crops developed with NPBTs are as safe for human health and the environment as conventionally-bred crops. Nevertheless, anti-biotech activists continue to spread narratives about hypothetical risks. These narratives fuel public concerns and lead to unnecessary regulatory hurdles with the result that useful new technologies are not approved for commercial use. Anti-biotech sentiments are largely rooted in Europe, but European attitudes have also spilled over to other parts of the world, especially to Africa and Asia, where improved farming technologies are urgently needed. Harnessing the potentials of NPBTs for sustainable development requires a more science-based public discourse and regulatory procedures.

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06 Climate-smart Push-Pull System: A Resilient, Adaptable Conservation Agriculture for the Future

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1. Introduction

Africa faces serious problems in feeding its population and it is the only continent in which per capita food production is still declining. In sub-Saharan Africa (SSA), land degradation, pests and weeds hamper the efficient production of cereals, particularly maize – the main staple and cash crop. Low and declining yields are affecting food security, nutrition and incomes, trapping farmers in poverty and poor health. The resource-constrained smallholders living in arid and semi-arid regions who practise mixed crop–livestock production is particularly badly affected.In addition to widespread poverty, population pressure on the land is often high, with smallholdings commonly amounting to just one hectare or less. Soils are severely degraded and contain little organic matter as a result of continuous monocropping, lack of investment in soil improvement and the removal of crop residues for livestock fodder. Most fields are heavily infested with parasitic striga weeds, while insect pests – principally stemborers and fall armyworm – devastate cereal crops, frequently causing over half the potential harvest to be lost.

2. Poverty and food security

Many families remain trapped in a cycle of diminishing yields and deepening poverty. Food insecurity is already common, with a critical shortage of cereals in almost 70% of rural households. This is the backdrop to the challenge of intensifying agriculture sustainably to meet the extra demand for food from a growing population. There is an urgent need for a significant and sustainable increase in grain yields and animal production. Sustainability requires ecologically sound ways of managing weeds and pests, and a strong focus on maintaining and conserving soil, crop and water resources.

3. Climate change

Climate change is anticipated to have far-reaching effects in Africa, threatening many of the advances made through efforts to achieve the Sustainable Development Goals (SDGs) by 2030. Ensuring the continuity and sustainability of development in the context of climate change is at the centre of international development agendas.

Studies suggest that, by 2025, growing-season average temperatures will be warmer than those of 1960–2002 for four years in ten for most Africa's maize-growing areas. This is projected to reach nearly nine years in ten by 2050, and nearly ten by 2075. Climate models also suggest that rainfall will become progressively more unpredictable, with falling yearly totals and increasing cases of floods and droughts. These climate trends are likely to exacerbate land degradation, and pest and weed pressure, with more frequent crop failures and worsening food insecurity. To adapt to these adverse conditions, many resource-constrained smallholders will need to modify their farming systems by incorporating drought-tolerant cereal crops, such as sorghum and millet, and replacing dairy cattle with small ruminants.

4. Push-pull farming system

Developing adaptable, productive agricultural systems that are resilient to the risks and shocks associated with long-term climate variability is essential to maintaining food production into the future. But resilience is not enough. Climate-smart agricultural systems also need to protect and enhance natural resources and ecosystem services in ways that mitigate future climate change.

Push–pull (www.push-pull.net) is a conservation agriculture technology developed for smallholder mixed farming systems. The livelihoods of 80% of the population of Sub-Saharan Africa (SSA) depend on these systems. Push–pull farmers establish perennial stands of two fodder crops, one between the rows of their main cereal crop and the other around the field. The natural chemicals produced by these companion plants effectively control insect pests (stemborers and fall armyworm) and parasitic weeds in the genus *Striga*.

When farmers adopt push–pull, as more than 280,000 have done in SSA since 1998, they not only achieve a dramatic and sustainable increase in cereal yields, they also benefit from enhanced soil fertility and obtain year-round fodder crops. This strengthens the foundations of their farming and livelihood systems, making them both more productive and more resilient.

4.1 Climate-smart push-pull

Although farmers have used push–pull successfully since it was first disseminated in 1999-2000 some began reporting in 2008 that the companion plants could not always withstand the long seasonal dry spells that were becoming more frequent. The trap plants and intercrops used in conventional push–pull were developed to suit the average rainfall (>800 mm per year) and moderate temperatures (15-30°C) of western Kenya at the turn of the century. The rising uncertainties of rain-fed agriculture for farmers in this region and those in warmer, drier agro-ecosystems led *icipe* scientists to begin the search for new trap plants and intercrops. Anew research was started in 2011 to develop of a second generation or 'climate-smart' push–pull, with two new drought-tolerant companion plants. Such plants are being identified and tested in an extended range of agro-ecosystems.

The grass selected with farmers, brachiaria 'Mulato II', controls stemborers effectively by supporting a parasitic wasp that feeds on their larvae. Crucially, it can also withstand periods of up to four months with no rainfall, and temperatures in excess of 30°C. In addition, the grass is extremely palatable to livestock.

At the same time, the team worked to identify new species of desmodium that not only had the desirable characteristics of silver leaf desmodium – controlling striga, emitting volatile chemicals to repel stemborers, fixing nitrogen, producing high biomass and spreading on the ground – but were also drought tolerant. Forty-three accessions of 17 species were collected from arid regions across Africa, and green leaf desmodium was selected. In addition to its known ability to control striga and

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stemborers, it fixes more atmospheric nitrogen and produces more fodder than silver leaf desmodium.

Both brachiaria and green leaf desmodium seed are commercially available, which greatly helped rapid dissemination of the climate-smart push–pull package to farmers in new countries. However, green leaf desmodium does not flower or set seed in equatorial or tropical Africa and, while seed is being made available by an increasing number of commercial enterprises, it would be more beneficial if farmers could produce their own to expand their plots and supply their neighbours. *Icipe* has identified *Desmodiumincanum* and *D. ramosissimum*, both collected from Africa and both of which flower and set seed in the target environment.

Moreover, brachiaria 'Mulato II' has succumbed to spider mite *Oligonychus trichardti*, which has become a major pest of the grass. *icipe* has subsequently identified two cultivars of brachiaria that are not only mite resistant, but also more drought tolerant and produce more biomass than 'Mulato II'. Consequently, *Desmodium incanum* and *D. ramosissimum* together with brachiaria (*Brachiaria brizantha*) 'Piatã' (piatã grass) and 'Xaraes' (Xaraes grass) are now being disseminated and promoted as 'third-generation' push–pull options. *icipe* scientists are continuing to work towards developing a better performing third-generation Push–pull technology. The year 2020 has seen the launch of a 'third-generation' push–pull. This builds on the already formidable pest management and soil improvement characteristics of the technology to include its use in much dryer agro-ecosystems and a wide range of cereal crops.

The *icipe* scientists are continuing to analyse the chemistry behind desmodium's ability to suppress striga and control fall armyworm, and the full mechanism of stem borer control in brachiaria grass to ensure future sustainability of the climate-smart push–pull technology. Second-generation and third generation climate-smart push–pull continues to address these problems while also equipping farmers with the increased resilience and adaptability they need to deal with the additional problems associated with climate change. As well as controlling stemborers, fall armyworm and striga, the push–pull companion plants provide high-value animal fodder, which farmers can sell or feed to stall-fed dairy cows and other livestock. The companion plants also increase soil fertility, prevent soil erosion and conserve soil moisture.

4.2 Spreading benefits, increasing impact

Conventional push–pull, usually practised with maize, has had significant impacts on food security, human and animal health, soil fertility, income generation, empowerment of women and conservation of agro-biodiversity. Climate-smart push–pull is spreading these benefits more widely to additional crops and regions with different agro-ecosystems. The trap plants and intercrops of climate-smart push–pull have met farmers' and scientists' expectations. Yields of maize and sorghum have increased significantly, sometimes as much as five-fold when compared with control plots. As well as increasing cereal yields, the new companion plants have provided ample, good-quality livestock fodder, producing enough to allow farmers to make hay for the dry season. For most dairy livestock – cattle and goats, improved and local breeds – a diet of push–pull fodder results in more milk. In all, through the range of benefits it provides, the system gives high economic returns to farmers and results in a range of positive impacts on the livelihoods of farm households.

4.3 Improving food security and health

On-farm research confirms that, thanks to the rapid action of green leaf desmodium in dealing with striga, yield increases from climate-smart push–pull routinely result in cereal harvests more than doubling over the course of a single season. Most push– pull farmers report that since adopting the technology, they are now mainly food-secure. Experience has shown that the yield gains that underpin this increased food security can be maintained over time.In many cases, push–pull farmers say that the diet and therefore the health of their families have improved since adopting the technology, particularly through drinking more milk. *icipe*'s recent research has shown that dietary diversity of push–pull farmers has also increased, with many farmers being in a better position to purchase foods that they cannot produce for themselves.

4.4 Providing nutritious fodder

Livestock have many purposes in the livelihood systems of farming households. They provide milk, meat, manure and draught power. Well-fed, healthy animals play an important part in maintaining soil fertility, providing dietary protein for farm households, and generating income to pay school fees.

Push–pull farmers use their fodder crops to feed goats, sheep, cattle, pigs, poultry and even rabbits. Many farmers report positive changes in the health and productivity of their animals, particularly thanks to the nutritional qualities of desmodium. Because it is rich in protein, desmodium fodder frequently doubles or even triples milk yields. Widespread reports from adopting farmers suggest that the green leaf desmodium of climate-smart push–pull has an even more positive impact than silver leaf desmodium.

4.5 Generating income

There are a number of ways that push–pull generates cash income, including the sale of cereals, milk and fodder. Within the household, this increased income is most often spent on school fees, but also used for improvements to housing and investment in livelihood diversification. There are also many examples of income being used to strengthen the social safety nets that protect vulnerablecommunity members, particularly those affected by HIV/AIDS. These include the construction of primary schools for orphans, and the inclusion of push–pull in the portfolios of income-generating activities conducted by many self-help groups in eastern Africa and beyond.

4.6 Promoting gender equity

Once established, push–pull reduces the drudgery of digging and weeding, tasks most often performed by women, freeing up their time and labour for more productive tasks such as selling milk or starting a poultry enterprise. Diversified farm income means there is more money available to buy medicines, household goods and other essentials. Feeding dairy cattle in stalls also frees women and children from the task of herding cattle to graze.

4.7 More stable and resilient agro-ecosystems

As far as possible, climate-resilient agro-ecosystems maintain the functions and services provided by natural systems. This means integrating instead of segregating, closing water and nutrient cycles, increasing biological and genetic diversity, and regenerating instead of degrading bio-resources. Push–pull technology contributes to stable and climate-resilient agro-ecosystems by providing farmers with a tool for on-farm diversification that is in line with these underlying principles. Farmers have for many years habitually diversified the crops they plant as an insurance strategy against climate uncertainty. Push–pull reinforces this strategy, because it can be equally useful when applied to maize, sorghum, millet and rice. Furthermore, having conventional, climate-smart and third-generation variants widens the range of planting material that farmers can use to tailor their cereal cropping practices to local climatic conditions.

4.8 Intensification of the push–pull system with vegetables

Vegetables are mostly produced, handled and marketed by women. Vegetables are highly profitable (margins per unit area five times those of maize). Moreover, vegetables are important sources of micronutrients, vitamins and minerals – essential components of balanced and healthy diets. Thus, vegetables are a 'win–win–win' (favouring women, increased income, improved nutrition) for rural farming communities. However, vegetables are also attacked by a large number of pests: aphids, cabbage looper, diamondback moth, tomato leaf miner and others. Weeds and various bacterial, fungal and viral diseases are also prevalent in crop fields. Meanwhile, in an already drought-prone region, climate change is increasing the length and severity of dry spells, including during the wet growing seasons, and rising temperatures are also hampering crop production. All ofthese combines to make farming in Africa increasingly difficult and increasingly risky. Increasing food crop production is therefore essential for sub-Saharan Africa. This can be achieved by increasing individual crop yields, but also by intensifying land use to produce more food from the same land.Besides nutrition (people consuming diets traditionally heavy in starchy staples), food safety is another issue. Encouraged by big multinational businesses, many farmers see no solution to the problems of pests and diseases other than spraying (sometimes highly) toxic pesticides on their crops to achieve at least a minimum yield. Illiterate people (who make up about 35% of SSA adults, including smallholder farmers) are unlikely to follow safety instructions on pesticide labels, risking severe contamination of the soil, water resources and the wider environment, in addition to the health risks of pesticide drift during application and residues on crops if they are not handled properly after harvest before consumption.

In 2019, reflecting on the need for sustainable intensification, *icipe* researchers asked an obvious question: will push–pull work for vegetables? Could vegetables be integrated with cereals in a push–pull system or planted between rows of desmodium during a fallow period after cereal harvest when the fields are typically left without any crop? It was quickly shown that desmodium does repel vegetable pests and does attract beneficial arthropods (predators and parasitoids); however, brachiaria and Napier grass do not attract vegetable pests, their sole but vital role being to attract female cereal stemborer moths to lay their eggs on them rather than on the cereal.

There are several benefits for farmers who have integrated vegetables into push–pull system. The first benefit is healthier crops-- the cereals and vegetables are, for the most part, free from pests, and the fields are, for the most part, free from weeds, including striga. Second is improved nutrition and nutritional security: by bringing vegetables into the family diet, farmers are improving their nutritional status and are therefore healthier and stronger. Third is having surplus crop to sell, be it vegetables, cereals or fodder, all contributing to household income and improving family well-being. Fourth is health and safety: push–pull is essentially organic farming – no more pesticides on the farm, which reduces the risk of ill-health from toxic chemicals to a negligible level. Fifth, but by no means last, is that the design of the push–pull field provides everything the farmer needs: staple and vegetables for food, animal fodder from the grass (Napier grass or brachiaria) and desmodium, and the income from the sale of surpluses from all three.

5. Looking ahead

The development of climate-smart and third generation push–pull and their integration with vegetables has made it possible for the technologies to travel to new areas with lower rainfall, and to increase the potential number of farmers who might find it a useful and profitable addition to their livelihood strategies. Climate-smart push–pull is being extended in 18 countries in SSA. Thus, the profile of the technology is rising steadily far beyond its origins in Kenya.

The need for adaptive agricultural practices that can cope with increasingly variable climatic conditions and still produce food for people and livestock has never been greater; neither has the need for development pathways that respect ecological limits and restore ecosystem health. Experiences with push–pull offer important lessons about developing and implementing the kind of climate-smart technologies that are needed to meet these challenging goals

5.1 Push-pull and sustainable development Goals

The Push-pull technology effectively delivers Sustainable Development Goals (SDGs). The technology controls the main biotic constraints to cereal production in Africa, mainly parasitic striga weeds and stemborer insect pests, leading to three-fold increase in staple cereal yields, and significantly improved food security, nutrition and incomes. Secondly it increases quality fodder production and animal health which translates into higher milk production and production of farmyard manure for fertilizing soil. The two impact pathways directly address SDG2 – Zero Hunger, SDG3-Good health and human wellbeing, and SDG1 – No poverty. Increased household income from higher crop and livestock productivity is leading to significantly increase household incomes. Farm communities are investing the increase income into children's quality education (SDG4). Increasing numbers of female children are being enrolled in school, while production of forage seeds, like Desmodium seeds, increase incomes of female farmers (SDG 5- Gender Equality).In another impact pathway the technology fixes atmospheric nitrogen into the soil, reduces soil erosion, conserves soil moisture, naturally improves soil carbon sequestration, biomass and soil biota, all of which improve soil health, the conservation of biodiversity and life on land (SDG 15).The technology has been adapted to mitigate climate change effects which directly addresses SDG 13 – Climate action.

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07. Integrated Pest Management: Innovations, Implementation and Impact in the European Union

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1. Introduction

The pesticide legislation in the European Union (EU) is generally considered to be the among the most rigorous in the world. This statement was recently substantiated by Donley (2019) who reported that 72 pesticides approved for outdoor agricultural use in the United States are banned or in the process of being phased-out in the EU. These pesticides are still widely used in the United States accounting for more than 25% of the total pesticide use. Nonetheless, pesticide authorities in the EU are under constant scrutiny for not providing a sufficient level of human and environmental safety.

Besides regulation setting the criteria for authorization of pesticides in the EU (Regulation (EC) No. 1107/2009), the EU pesticide legislation also includes a directive on the sustainable use of pesticides (Directive 2009/128/EC known as the Sustainable Use Directive (SUD)). The key objectives of the SUD are to reduce risk and impact, promote integrated pest management (IPM) and reduce the reliance on pesticides by promoting alternative approaches and technology. The directive stipulates several obligations for EU countries such as compulsory training for professional users of pesticides, distributors and advisors, regular inspection of spray equipment and raising public awareness. The SUD highlights the importance of IPM to reach the overall goals of the directive and by 1. January 2014 all professional users of pesticides were supposed to follow the eight principles of IPM laid out in Annex 3 of the directive (Barzman *et al.,* 2015). All EU Member States are obliged to draw up National Action Plans to ensure the implementation of the SUD. More specifically, the Member States shall propose goals, targets and indicators to reduce the potential adverse effects on human health and the environment and take initiatives that stimulate the adoption of IPM and the use of alternative methods.

2. Integrated pest management

Bajwa and Kogan (2002) listed 67 definitions of IPM and since 2002 more definitions like 'true' and 'false' IPM reflecting the dependence on pesticides have been introduced (Ehler 2006). It has been argued that the many definitions of IPM focusing on different features of IPM has led to confusion and partly can explain the lack of uptake of IPM (Deguine *et al.,* 2021). The EU has largely adopted the FAO definition with one significant addition namely the word 'ecologically', i.e., the use of pesticides and other forms of intervention should be kept to levels that are economically and ecologically justified' highlighting the increasing emphasis on ecological processes in crop protection (Barzman *et al.,* 2015). The FAO/EU definition does not *per se* consider the hierarchy of different intervention technologies reflected in the 'IPM pyramid' but this is partly amended by the eight IPM principles. The eight principles and their numbering follow the passing of year in the field beginning with preventive and suppressive measures followed by monitoring/forecasting, direct control and ending with evaluation with a view to improve the process (Table 1). Regarding direct interventions, it is clearly stated that non-chemical methods should be preferred to pesticides and that pesticide use, if required, should be kept at a minimum. Nonetheless, they are only principles and not guidelines and for farmers to successfully implement IPM strategies and giving up what most farmers consider to be a cost-effective approach based on a high reliance on pesticides, validated IPM control tactics and strategies are needed. Moreover, IPM emphasises a system approach building on agronomic, mechanical, physical, and ecological principles and only resorting to pesticide use when pests cannot be successfully managed with other tools. IPM is therefore a more knowledge-intensive approach than the traditional pesticide-based approach adopted by most European farmers.

Table 1. IPM principles as laid out in ANNEX III of the SUD

1. The prevention and/or suppression of harmful organisms should be achieved or supported among other options especially by:
   - crop rotation,
   - use of adequate cultivation techniques (e.g., stale seedbed technique, sowing dates and densities, under-sowing, conservation tillage, pruning and direct sowing),
   - use, where appropriate, of resistant/tolerant cultivars and standard/certified seed and planting material,
   - use of balanced fertilisation, liming and irrigation/drainage
   - practices, preventing the spreading of harmful organisms by hygiene measures (e.g., by regular cleansing of machinery and equipment),
   - protection and enhancement of important beneficial organisms, e.g., by adequate plant protection measures or the utilisation of ecological infrastructures inside and outside production sites.
2. Harmful organisms must be monitored by adequate methods and tools, where available. Such adequate tools should include observations in the field as well as scientifically sound warning, forecasting and early diagnosis systems, where feasible, as well as the use of advice from professionally qualified advisors.
3. Based on the results of the monitoring the professional user has to decide whether and when to apply plant protection measures. Robust and scientifically sound threshold values are essential components for decision making. For harmful organisms, threshold levels defined for the region, specific areas, crops and particular climatic conditions must be taken into account before treatments, where feasible.
4. Sustainable biological, physical and other non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control.
5. The pesticides applied shall be as specific as possible for the target and shall have the least side effects on human health, non-target organisms and the environment.
6. The professional user should keep the use of pesticides and other forms of intervention to levels that are necessary, e.g., by reduced doses, reduced application frequency or partial applications, considering that the level of risk in vegetation is acceptable and they do not increase the risk

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for development of resistance in populations of harmful organisms.

7. Where the risk of resistance against a plant protection measure is known and where the level of harmful organisms requires repeated application of pesticides to the crops, available anti-resistance strategies should be applied to maintain the effectiveness of the products. This may include the use of multiple pesticides with different modes of action.
8. Based on the records on the use of pesticides and on the monitoring of harmful organisms the professional user should check the success of the applied plant protection measures.

In recent years the most important drivers for farmers to implement IPM have been the steadily increase in the number of cases of pesticide resistance and, in some crops, also the loss of key pesticides due to stricter regulations. This made many farmers realizing that heavy dependence on a constantly narrower supply of pesticides is not sustainable and led to changes in crop rotation and other farming practices focussing more on prevention and suppression.

Not surprisingly, so far, all evaluations of the adoption of IPM among EU farmers have been negative whether conducted by the EU Commission (European Commission 2017) or third parties (Traon *et al.,* 2018; European Court of Auditors 2020). Studies conducted in individual EU countries add to this picture (Piwowar 2021). In a recent study, Helepciuc and Todor (2021) concluded that the lack of success could be attributed to very different approaches in the EU countries developing National Action Plans and proposing measures and timetables. It should, however, be stressed that because IPM is only defined by the eight principles and not rules, it is difficult to assess the degree of IPM implementation, as Matyjaszczyk (2019), conducting as assessment of IPM implementation in Poland, also concluded.

3. EU and national initiatives to promote the uptake of IPM

At EU country level, many IPM activities were initiated. One initiative has been demonstration farms or farm networks where focus has been on reducing the use of pesticides by adopting IPM approaches and sharing the experiences among farmers. One example is the German project ‘Demonstration Farms Integrated Plant Protection’ which at one point included more than 6o farms covering most parts of Germany. The purpose of the demonstration farms was to demonstrate IPM tactics and strategies and to facilitate this, the farmers were supported by farm advisors and researchers. Another example is the DEPHY network created in France in 2010 now consisting of 3,000 farms who, supported by their advisors, are committed to adopt low pesticide strategies. The network has seen farmers reducing pesticide use (expressed as the Treatment Frequency Index) but rather than adopting IPM this was achieved by substituting pesticides, reducing doses and more efficient pesticide application (Fouillet *et al.,* 2022). The project IPMWORKS was recently supported by the EU. The project builds on the principles of the DEPHY network but rather than building a French farm network, IPMWORKS will establish a pan-European farm network. The ambition is to promote a holistic IPM approach incorporating preventive and non-chemical control methods (‘holistic IPM) (https://ipmworks.net/).

In recent years the EU has supported several IPM related research projects. The objective of many of the projects has been to develop novel IPM tools and assist the implementation of IPM through education and training of farmers and advisors. Earlier, most EU projects were developed and run mainly by researchers from universities and applied research institutes and dissemination and involvement of end-users was a minor activity in the last part of the project. Recently, the EU decided that research projects addressing IPM should adopt a ‘multi-actor approach’, i.e., that all stakeholders should be involved in the planning, execution and evaluation of the research activities thereby promoting a ‘co-innovation’ approach. One of the rationales behind the multi-actor approach is that it is more likely that farmers will adopt IPM tactics that they were involved in developing, adjusting and evaluating than IPM tactics developed and made available to them by researchers. In the following an example of an ongoing multi-actor project will be presented (Kudsk *et al.*, 2020).

4. Case study: IWMPRAISE

IWMPRAISE is addressing integrated weed management (IWM) in a broad range of crops (arable, horticultural and perennial herbaceous and woody crops). In contrast to the crop specificity of most herbicides, IWM tends to be more generic in the sense that IWM control tactics can often be applied in crops with similar growth habit, growing season and/or grown with the same spatial arrangement. This inspired us to adopt a categorical approach with four management scenarios: annually drilled crops in narrow rows (e.g., wheat and oilseed rape), annually drilled crops in wide rows (e.g., maize and field vegetables), perennial herbaceous crops (e.g., grassland and alfalfa) and perennial woody crops (e.g., pomefruit and olive). This allows for extrapolation of the eight IPM principles between regions of Europe with due consideration of differences in climatic and agronomic conditions.

IWMPRAISE adopted the multi-actor approach, i.e., all stakeholders including end-users are involved in all steps of the project from the planning to the execution and evaluation. In each of the eight participating countries, ‘national clusters’ consisting of all stakeholders were formed. The national clusters were involved in the planning, execution and evaluation of the experimental trials. In the case of an unfavourable evaluation, the experimental design was adjusted for the following years. A similar approach was used in the second year prior to the third and last year of experimentation. By adopting this ‘design-assessment-adjustment’ approach it is anticipated that the IPM solutions developed will be more acceptable to the farmers and adopted faster. A range of dissemination activities were conducted to promote the visibility of the IWMPRAISE activities including a website in the local language in each of eight countries.

The IWMPRAISE framework for IWM is built around the life cycle of weeds (Fig. 1). To manage weeds effectively farmers should either: 1) limit weed establishment in the crop from the soil seed bank or subterraneanvegetative organs, 2) limit competition for resources such as light, nutrients and water by removing weeds or manipulating the weed flora to reduce their competitive impact or 3) limit return of seeds or vegetative organs to the soil seed/vegetative organ bank. A sustainable approach should possibly combine control tactics impacting on different steps of the life cycle. Examples of tactics interfering at the three stages of the life cycle are shown in Fig. 1.

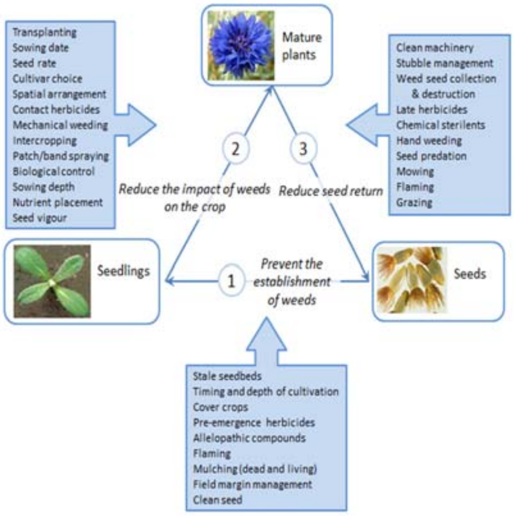

Figure 1: Weed life cycle (From Kudsk *et al.*, 2020)

One of the first activitiesin IWMPRAISE was a mental modelling exercise. Weed experts and various end-users were interviewed to determine the knowledge, beliefs, perceptions and attitudes to IWM. The outcome of these interviews was used to develop an IWM framework. Based on the interviews, it was concluded that in the mindset of weed experts and end-users IPM control tactics could be allocated to one of the following five IPM pillars: 1) diverse cropping systems, 2) cultivar choice and establishment, 3) field/soil management, 4) direct control and 5) monitoring and evaluation. Combining the outcome of the interviews with the concept of categorising control tactics according to what stage of the life cycle they interfere with, led us to develop the general IWM framework shown in Fig. 2 (Riemens *et al.,* 2022). Although the framework was developed in a European context, we believe it can be applied in other parts of the world in other cropping contexts but it may then be necessary to exclude or add control tactics.

The IWM framework is also available as an online version (https://framework.iwmtool.eu/). Using the online version, the first step is to select crop (annual narrow row, annual broad row or perennial) and weed (annual or perennial) groups. When pressing a hexagon, a factsheet will pop up providing further information on the use and experiences with that particular IWM control tactic.

Figure 2: Framework for designing IWM strategies combining individual IWM control tactics from each of the 5 pillars of IWM. Colour codes refer to the weed life cycle shown in Fig. 1 (From Riemens *et al.*, 2022)

5. Discussion

Previous surveys have shown that there are a number of barriers constraining the uptake of IPM by farmers and advisors (Lefebvre *et al*., 2015; Moss, 2019). These barriers are based on both experiences and perceptions. An increased risk of inadequate pest control, higher costs, more labour intensive and investments in new equipment are among the reasons mentioned. Another issue, which is often mentioned, is limited evidence of the efficiency of IPM strategies. Although IPM is not a new invention, the focus on IPM in the EU is of recent date and there is little evidence that IPM strategies are cost-effective and as efficient as pesticide-based strategies.

Another constrain is lack of knowledge among farmers. IPM is more knowledge-intensive (Swanton *et al.,* 2008) and for IPM to be successful, a spatial and temporal scale has to be considered, which is different from the one crop – one pest approach that is currently practiced by many farmers. A spatial scale considering landscape instead of fields may be necessary to control insect pests without or with a minimum use of insecticides and a temporal scale considering, e.g., crop rotation is pivotal to manage weeds due to the close association between the weed flora composition and the crop sequence. Hence, training of farmers and advisors is crucial to ensure that IPM becomes truly integrated pest management and not just 'Integrated Pesticide Management' (Peshin and Zhang, 2014) or 'Intelligent Pesticide Management' (Nicholls and Altieri, 2004). In this context, bringing groups of farmers together in hubs together with an advisor where farmers can share their experiences and receive advise on recent innovations seems to be one of the most promising ways forward. This approach was adopted in the ongoing EU project IPMWORKS and the ambition is that this project can serve as an inspiration in all EU countries. However, the success of this approach depends on the existence of an independent advisory services which is not the case in all European countries.

The development of IPM control tactics has unfortunately been lagging behind the political ambitions of implementing IPM. This is true for both weeds, diseases and insect pests. For example, effective physical weed control methods are not available for all cropping situation but the use of cameras and other sensors for guiding machines will most likely promote the use of these methods. The EU project IWMPRAISE (see above) has provided numerous examples on how physical weed control methods can be part of an IWM strategy. The increased interest among farmers in precision farming including weed mapping may promote the use of integrated weed management approaches (Riemens *et al.*, 2022).

Biologicals have for many years been seen as a key component of IPM strategies (Lamichhane *et al.,* 2016) but the number of products available to European farmers are still limited (Helepciuc and Todor, 2022). This has been attributed to a slow and rigoristic authorisation procedure in the EU (Sundh and Eilenberg, 2020) and it is true that the time to authorise a biological in the EU is much longer than, e.g., in the United States or Canada (Gwynn, https://4458b165-2d60-4788-8442b7e2057eceb6.usrfiles.com/ugd4458b1_bc95f91b705d41b889847504cd647290.pdf.). However, the efficiency of most of the commercially available biologicals is not comparable to that of synthetic pesticides and an increased use of biologicals will require that they are seen as one component of a an IPM strategy rather than a 'stand-alone' product. This change in perception has not been well communicated and the use of biologicals are a good example of how complexity increases when adopting IPM.

MacRae *et al.* (1990) proposed the ESR (Efficiency, Substitution and Redesign) paradigm for describing the transition towards sustainability in farming. The development and implementation of IPM may benefit from leaning on this paradigm. 'Efficiency' is the improvement of the currently used methods such as optimising the application of pesticides thereby improving the performance and possibly allowing for dose reduction. Site-specific application of pesticides is another example. 'Substitution' is replacing the currently used methods by, e.g., environmental more benign methods. Examples are physical weed control methods and biologicals instead of pesticides. As mentioned, compared to pesticides many substitutes are not as effective and should not be regarded as a one-to-one substitution. This is where 'Redesign' comes in. To be successful with IPM and reduce/replace the use of pesticides with non-chemical methods, farmers will often have to apply more than one IPM tactic (referred to as 'the many little hammers' by Liebman and Gallandt (1997)). Often these tactics also involve a change in agronomic practices, i.e., in reality a redesign of the cropping system. Accepting that successful implementation of IPM may require redesign of the cropping system could provide a fresh start for the IPM concept. Recently, Jacquet *et al.* (2022) took it a step further by suggesting that the agricultural research community in Europe need to adopt a pesticide-free paradigm to achieve a significant impact on pesticide use.

In 2020, the EU presented the European Green Deal (https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en). One of the goals of the Green Deal is to create a sustainable food system and to achieve this the EU Commission recently launched the Farm to Fork strategy (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0381&from=EN).

Some EU countries have set targets for pesticide reductions but for the first time, the EU Commission is suggesting a pesticide reduction target of 50% before 2030. This target is also reflected in the proposal of the EU Commission for a new regulation on the sustainable use of plant protection products, intended to replace the SUD. If the new regulation is adopted, all EU countries will in the future have targets for pesticide reductions.

Adoption by all farmers in the EU of 'true' or 'holistic' IPM is the current political goal but, so far, the adoption is progressing very slowly, as reflected in the overall pesticide use in EU which has not gone down since the implementation of the SUD (Buckwell *et al*., 2020). It will require significant investments in research and establishment of independent advisory services in many EU countries to reach the goals of the SUD. Maybe economic incentives such as a restructuring of the EU subsidies to also focus on IPM implementation or pesticide taxes (Kudsk et al, 2018) will be needed too.

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08. Food Systems, Insects and the Sustainable Development Goals

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1. Introduction

On September 25th 2015, the 193 United Nation member states adopted 17 Sustainable Development Goals (SDGs) as part of a new international agenda to address the most fundamental challenges in global sustainability and human development (Nislon *et al.,* 2016). To reduce inequality, limit environmental impact of human activities and secure resilient livelihoods, the scientific research behind SDGs needs to consider not only the ecological integrity of life-supporting systems, but also the underlying socioeconomic stressors that perpetuate their vulnerability in a changing world.

2. Sustainable development goals

Feeding humanity is a key challenge of the SDGs, with the aim to provide people with sustainable diets that have a limited impact on the environment but are also culturally acceptable, affordable, nutritionally adequate and safe. In the aftermath of the Second World War, food was already seen as a global issue with the underlying assumption that any increase in agricultural production would combat hunger. The failure of increased agricultural production to solve the problems of undernourishment and malnutrition gave rise to a new paradigm" Food Security", which evolved again to better integrate the environmental consequences of food production and socio-cultural aspects (Touzard & Fournier, 2014). Agricultural issues are now inseparable from a holistic vision that emphasizes the centrality of "Food Systems", which recognizes the interconnected nature of environmental and social phenomena in agriculture (Rebaï *et al.,* 2016). Insects are a central component of food systems, strongly connected to their environmental and social dimensions (Crespo-Pérez *et al.,* 2015, Rebaudo & Dangles 2015). Since the origin of agriculture, insects found in food systems are mainly perceived as enemies as they are major triggers of socio-economic stressors such as hunger and health crises, thereby representing obstacles to poverty alleviation. With the rise of the ecosystem service concept at the end of the 20th century, insects and other invertebrates have also been recognized as farmer "friends" in food systems as they are vital components of ecological webs and provide key ecosystem services such as pollination, biological control, carbon sequestration and organic matter recycling in soils. More recently, insects have been seen as "solutions" to achieve the SDGs: because insects have important influences on many interlinked SDGs, they have great potential to be used to solve some current global challenges (Dangles and Casas, 2009). Putting insects in the nature-based use of cropland and forests may create additional jobs (pest control, bio-prospection, edible insects) and increases total socioeconomic benefits of ecosystem services.

3. Insect management in food systems

In this talk, I advocate the need for a paradigm shift in insect management in food systems, to achieve increased food production in an ecologically sustainable manner. To attain this goal, agroecology is a promising framework, which is not mere change of farming methods, nor exchange of inputs, but a social-political movement that requires rethink human relationship to nature vis-à-vis food production. To date, the management of insect communities associated with cropping systems has not fully embraced the agroecological approach. It has remained pest-centric instead of adopting a system centric approach, including other component agrosystem biodiversity -such as insects (natural enemies and pollinators) and natural plants – but also the social networks and dynamics of farmers and other stakeholders such as pesticide resellers (Struelens *et al.,* 2022). Also, elevating crop insect management from a plot-based or farmer-level problem to that of the farmers' collective, or even to the community, may lead to a more sustainable goal for the farmers (Parsa *et al.,* 2014). In this context, it is necessary to promote transdisciplinary approaches to better articulate scientific and traditional knowledge on insect ecological functions with farmers' needs (Cardenas *et al.,* 2022). Moreover, participatory methods for improving entomological literacy (Campo & Dangles, 2020), learning, discussion, experimentation, monitoring and evaluation allows for local knowledge to be shared, mobilize the farmers and related stakeholders to work together in lowering pests populations and protecting pollinators, and put political pressure on the government to promote and support agroecology. Overall, making a place for insects in the research and innovation agenda of food system requires transforming existing academic entomological knowledge into applications-driven science and socioeconomic relevance, which are key to attain the SDGs.

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09. Climate Change and its Impact on Agricultural Pests

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Keywords: Climate change; agriculture; insect pests; risks;impacts; adaptation and mitigation

1. Introduction

Agricultural production has undergone many major changes -agricultural revolution which have influenced by the development of civilization, technology, and general human advancement. The exceptional population growth in the last 100 years has had many undesirable consequences which along with changes in environmental conditions impacted the security of the food supply. The growing world population has rising demands for crop production and accordingly, by 2050, global agricultural production will very likely need to be doubled to meet that kind of increasing demand (Tilman *et al.,* 2011)

Climate change is a worldwide threat that is unavoidable and immediate which encompasses a combination of natural and anthropogenic changes in the environment. Worldwide attention has been attracted by recent changes in global climate phenomena and consequent losses. Climate change, according to the Intergovernmental Panel on Climate Change (IPCC), is described as "any change in climate over time, whether due to natural variability or as a result of human activity." Human activities are responsible for much of the warming that has been observed over the last 50 years.

According to Intergovernmental Panel on Climate Change (IPCC) projections, the global annual temperature will increase by 1°C by 2025 and it may increase up to 3°C by the end of the next century and CO_2 is expected to increase up to 445-640 ppm by 2050 due to increase in greenhouse gas emissions(Kumar *et al.,* 2020).

Human activities are responsible for much of the warming that has been observed over the last 50 years. In the next 100 years, if temperatures increase by around 2°C, the detrimental global warming effects will begin to spread in much of the world's region (IPCC. Climate change, 2001) In addition, CO_2 levels rose from 280 ppm to 401 ppm during 2015 (Mauna Loa Observatory: Hawaii).

Insects constitute over half of the estimated 1.5 million organism species of the biodiversity identified so far on the planet and are fundamental to the structure and function of ecosystems. At the same time insects are among the most susceptible groups of organisms to climate change as they are ectothermic, so thermal changes have strong direct effect upon their growth,reproduction and existence (Bale *et al.,* 2002). The effects of climate change on insect pests are of greater significance because insects are involved in many biotic interactions, such as plants, natural enemies, pollinators and other organisms, which play a major role in the ecological functioning of insect pests (Moore *et al.,* 2008).Nowadays, more attention is focussed on abiotic factors which have the tendency to reduce yield loss due to such conditions increases.

Temperature rise directly affects pest's reproduction, survival, spread and population dynamics as well as the relationships between pests, the environment, and natural enemies (Prakash *et al.,* 2014). This paper will review the impact of some of the predicted climate changes, especially increasing temperatures, atmospheric carbon dioxide concentrations and changeable precipitation pattern effects on the biology and ecology of harmful insects.

Potential solutions for the current issues in plant production will be presented, mostly in the form of modified integrated pest management (IPM) strategies, which include IPM and the production of healthy food in an environmentally friendly way.

2. Indian scenario of climate change

The footprint of climate change can already be seen in every corner of the planet. Erratic weather patterns, rising sea levels and melting glaciers due to climate change, are reshaping societies across the globe. India is one of the world's most climate vulnerable countries. In India, climate change is already affecting human health, wildlife, food production, clean water access and the economy at large. The country's average temperature is expected to rise by 4.4 degree Celsius by the end of the year 2100 (Blog on climate change 17.5.2022).

The warming may be more pronounced in the northern parts of India. The extremes in maximum and minimum temperatures are expected to increase under changing climate, few places are expected to get more rain while some may remain dry. Number of rainy days may come down but the intensity is expected to rise at most of the parts of India. Gross per capita water availability in India will decline from 1820 m^3/ year in 2001 to as low as 1140 m^3/ year in 2050. Over 50% of India's forests are likely to experience shift in forest types, adversely impacting associated biodiversity, regional climate dynamics as well as livelihoods based on forest products. Even in a relatively short span of about 50 years, most of the forest biomass in India seems to be highly vulnerable to the projected change in climate (Mahato, 2014).

Being a tropical country, India is more challenged with impacts of looming climate change (Chahal *et al.*, 2008). Productivity of Indian agriculture is limited by its high dependency on monsoon rainfall which is most often erratic and inadequate in its distribution (Chand and Raju, 2009). Country is experiencing declining trend of agricultural productivity due to fluctuating temperatures (Aggarwal, 2008), frequently occurring droughts and floods, problem soils, and increased outbreaks of insect pests (Srikanth 2007; Dhawan *et al.,* 2007; IARI News 2008; IRRI News 2009) and diseases. These problems are likely to be aggravated further by changing climate which put forth major challenge to attain a goal of food security.

2.1 Risks

Climate-related risks are higher for global warming of 1.5°C compared to the current risks, but the risks are significantly more severe if the global warming reaches 2°C. Risks depend on the degree and pace of warming, geographical location, levels of regional and local development and vulnerability, and realized adaptation and mitigation activities. Global food and fibre production, plant protection and plant biosecurity, which include all strategies to assess and manage the risks posed by infectious diseases, quarantine regulated pests, invasive alien species and living modified organisms in natural and managed ecosystems, will also be adversely impacted (IPCC 2018).

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2.2 Impacts

Climate-change impacts are already emerging for natural and human systems, including changes in water quantity and quality, and shifts in geographical ranges, seasonal activities, migration patterns, species abundance and interactions for many with more negative than positive impacts on the yields of most crops (Porter *et al.,* 2019). There is evidence that climate change is affecting biological systems at multiple scales, from genes to ecosystems (Sutherst e*t al.,* 2011). According to Scheffers *et al.* (2016), anthropogenic climate change has impaired 82 percent of 94 core ecological processes recognized by biologists, from genetic diversity to ecosystem function.

According to IPCC (2018) if temperatures rise by about 2°C over the next 100 years, negative effects of global warming would begin to extend to most regions of the world and directly affect most of the organisms on the earth. Climatic variability, together with increase in atmospheric temperature and carbon dioxide, change in precipitation pattern, extended period of drought does have lot of implication in agriculture sector. Climatic changes also profoundly affect the population dynamics and the status of insect pests (Woiwod, 1997). These effects could either be direct, through the influence of weather on the insects physiology and behaviour (Samways 2005), or may be mediated by host plants, competitors or natural enemies (Harrington *et al.*, 2001 and Bale *et al.*, 2002). In addition, the impacts include changes in phenology, distribution and community composition of ecosystem that finally leads to extinction of species (Walther *et al.,* 2002).

For species to survive in the changing climates, they must either adapt *in situ* to new conditions or shift their distributions in pursuit of more favourable ones. Many insects have large population sizes and short generation times, and their phenology, fecundity, survival, selection, and habitat use can respond rapidly to the climate change. These changes to insect life-history may in turn produce rapid changes in their abundance and distribution. Increased temperature will cause insect pests to be more abundant and almost all insects will be affected by changes in temperature (Bale *et al.,* 2002). In-season effects of warming include the potential for increased levels of feeding and growth, including the possibility of additional generations in a given year (Cannon, 1998). This will alter the crop yield, and also influence the effectiveness of insect-pest management practices. Increased global temperature will also influence the phenology of insects including early arrival of insect pests in their agricultural habitats and emergence time of a range of insect pests (Dewar and Watt 1992; Whittaker and Tribe, 1998), which in turn requires early and more frequent application of insecticides to reduce the pest damage. Increased temperatures will also increase the pest population, and water stressed plants at times may result in increased insect populations and pest outbreaks. This will affect the crop yield and availability of food grains and threaten food security.

Climate change will also result in increased problems of insect transmitted diseases. These changes will have major implications for crop protection and food security, particularly in the developing countries, where the need to increase and sustain food production is most urgent. Long-term monitoring of population levels and insect behaviour, particularly in identifiably sensitive regions, may provide some of the first indications of a biological response to climate change. The impact of climate change will vary across regions, crops and species. Many models and protocols have been designed to measure the effects of climate change for different species and in different disciplines.

3. Impact of rising temperature

Temperature is one of the dominant abiotic factors affecting directly the insects. temperature can affect the insect species in several complex ways. Species which cannot adapt and thrive in increased temperature tend to have hard times maintaining its population while others may thrive and multiply rapidly. Temperature has roles in metabolism, metamorphosis, mobility, host availability etc. which determines the possibility of change in insect pest population and dynamics.

Laboratory and modeling experiments support the notion that the biology of insect pests are likely to respond to increased temperatures (Cammell and Knight 1991). With every degree rise in global temperature, the life cycle of insect will get shorter. The quicker the life cycle, the higher will be the population of pests. In temperate regions, most insects have their growth period during the warmer part of the year because of which, species whose niche space is defined by climatic regime, will respond more predictably to climate change while those in which the niche is limited by other abiotic or biotic factors will be less predictable (Bale *et al.,* 2002). In the first case, the general prediction is that if global temperatures increase, the species will shift their geographical ranges closer to the poles or to higher elevations and increase their population size (Samways, 2005).

From the distribution and behaviour of contemporary insects, it can be hypothesized that rising temperatures should be accompanied by increased herbivory(DeLucia *et al.,* 2008) Given the distribution and behaviour of insect pests, it can be hypothesised that an increase in temperature should be associated with increased herbivory as well as changes in the growth rate of insect populations (Deutsch *et al.,* 2018). Thus, insect populations in tropical zones are predicted to experience a decrease in growth rate as a result of climate warming due to the current temperature level, which is already close to the optimum for pest development and growth, while insects in temperate zones are expected to experience an increase in growth rate. The same authors confirmed this theory by estimating changes in the growth of pest populations in the production of the world's three major grain crops (wheat, rice and maize) under different climate change scenarios. According to the study wheat, which is normally grown in temperate climates, warming will accelerate the growth of pest populations. For rice grown in tropical zones, they predict a decrease in the growth of pest populations, and for maize grown in both temperate and tropical regions. Effects of increased temperatures are greater for aboveground insects than for those that spend most of their life cycle in the soil, because soil is a thermally insulating medium that can buffer temperature changes and thus reduce their impact (Bale *et al.,* 2002).

Future changes in insect population dynamics depend on the level of global temperature increase in coming years. Climate models predict that the average temperature of the globe will increase by 1.8–4°C by the end of the current century (Karl and Trenberth, 2003).

The increase in temperature associated with climatic change, would impact crop pest insect populations in several complex ways like (a) extension of geographical range (b) increased over-wintering (c) changes in population growth rate (d) increased number of generations (e) extension of development season (f) changes in crop pest synchrony (g) changes in interspecific interactions (h) increased risks of invasions by migrant pests and (i) introduction of alternative hosts and over-wintering hosts.

3.1 Response of insect pests to increased CO_2 concentration

Elevated concentrations of atmospheric CO_2 can affect the distribution, abundance, and performance of herbivorous insects. Such increases can affect consumption rates, growth rates, fecundity, and population densities of insect pests. Currently available data suggest that the effect of elevated atmospheric CO_2 on herbivory is not only highly specific to individual insect species, but also to insect pest–host plant systems. The effects of increasing CO_2 levels on insect pests are highly dependent on their host plants. Increased CO_2 levels would have a greater impact on C_3 crops (wheat, rice, cotton, etc.) than on C_4 crops (corn, sorghum, etc.). Therefore, these differential effects of elevated atmospheric CO_2 on C_3 and C_4 plants may result in asymmetric effects on herbivory, and the response of insects feeding on C_4 plants may differ from that of C_3 plants. C_3 plants are likely to be positively affected by elevated CO_2 and negatively affected by insect response, whereas C_4 plants are less responsive to elevated CO_2 and therefore less likely to be affected by changes in insect feeding behaviour (Skendžic *et al.,* 2021).

3.2 Impact of precipitation on insects

Distribution and frequency of rainfall may also affect the incidence of pests directly as well as through changes in humidity levels. It is predicted that under the climate change, frequency of rainfall would decline while its intensity would increase, which would lead to heavy showers and floods on one hand and drought spells on the other. Under such situations, incidence of small pests such as aphids, leafhoppers, whiteflies, mites, etc. on crops may be reduced as these get washed away by the heavy rains (Pathak *et al.,* 2012). The deviation of rainfall during monsoon and November and its relationship with level of *Helicoverpa armigera* (Hub.) damage severity showed higher November rainfall favoured higher infestation. Average rainfall is predicted to decrease in several regions and the occurrence of summer droughts is likely to increase. Lever (1969) analysed the relationship between outbreaks of armyworm, *Mythimna separata* (Walker) and to a lesser extent *Spodoptera mauritia* (Boisd.) and rainfall from 1938 to 1965 and observed that all but three outbreaks occurred when rainfall exceeded the average 89 cm. The effect of rainfall on pests can be studied by simulating various rainfall intensities through sprinklers(Karuppaiah and Sujayanad, 2012).

3.3 Invasive insect pests

Many authors in recent studies predict expanded geographic range and increased population densities and voltinism under predicted climate change scenarios, which could soon lead to potentially severe consequences for sustainable agricultural production (Ziska *et al.,* 2011). However, it is important to state that climate change is not the predominant driver of biological invasion. To become invasive, alien insects must successfully arrive in a new habitat, survive the given conditions, and thrive. Climate change could positively or negatively influence the components of this invasive pathway. The process of insect invasion involves a chain of events that include the transport, introduction, establishment, and dispersal of invasive alien insects (Ricciardi, 2013). Once a new species arrives in a new habitat, the other stages of the invasion process could be positively or negatively influenced by existing climate and climate change. Climate change can directly affect the transport and introduction of invasive insects. Extreme climate events (storms, high winds, hurricanes, currents and swells) could shift pests to new geographic areas where they may find environmental conditions favourable for establishment (Food and Agriculture Organization, 2020). Since 1889, a total of 24 insect species have been reported to invade India (Naveena *et al.,* 2020).

In recent times many exotic pests invaded India, such as Papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink (Muniappan *et al.*, 2008); cotton mealybug, *Phenacoccus solenopsis* Tinsley; tomato leaf miner *Tuta absoluta* (Meyrick), fall armyworm, *Spodoptera frugiperda* (J.E.Smith) and rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin established very successfully in different parts of India. The reason behind this may due to climate change, where congenial environment has developed for their survival and reproduction (Vinod Kumar *et al.,* 2020).

3.4 Impact on pest population dynamics and outbreaks

Abiotic environment resulting due to climate change will affect significantly the diversity and abundance of insect-pests through geographic range expansion, increased overwintering survival and more number of generations per year, thereby increasing the extent of crop losses. It may result in upsetting ecological balance because of unpredictable changes in the population of insect-pests along with their existing and potential natural enemies (IPCC, 2007).

Changes in climatic variables have led to increased frequency and intensity of outbreaks of insect-pests viz., sugarcane woolly aphid *Ceratovacuna lanigera* Zehntner in Karnataka and Maharashtra states during 2002-03 (Srikanth, 2007) Rice plant hoppers *Nilparvata lugens* (Stal) and *Sogatella furcifera* (Horvath) on Rice in North (IARI News 2008; IRRI News, 2009) Mealybug, *Phenacoccus solenopsis* Tinsley in Cotton growing belt of the country (Dhawan *et al.,* 2007) Papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink on Papaya in Tamil Nadu, Karnataka, Maharashtra (Tanwar *et al*., 2010).

3.5 Impact of climate change on pollinators and pollination

Climate change is reported to impact insect pollinators at various levels, including their pollination efficiency. According to Millennium Ecosystem Assessment report 2005, pollination is one of the 15 major ecosystem services currently under threat from mounting pressures exerted by growing population, depleting natural resource base and global climate change (Costanza *et al.,* 1987; Sachs 2008). Earlier studies have clearly shown that the population abundance, geographic range and pollination activities of important pollinator species like bees, moths and butterflies are declining considerably with changing climate (FAO, 2008). The climatic factors like temperature and water availability have been found to affect profoundly the critical events like flowering, pollination and fruiting in the life cycle of plants (Cleland *et al.,* 2007). The quality and the quantity of pollination have multiple implications for food security, species diversity, ecosystem stability and resilience to climate change (FAO, 2008). The pollination services and associated risks are not addressed properly in determining the actions needed for conserving pollinators.

3.6 Impact of climate change on agricultural chemicals

Agricultural chemicals are basically chemical compounds and thus their properties may vary based on change in climate, i.e. temperature, atmospheric moisture, wind velocity, rainfall pattern, etc. Generally, after spraying, a pesticide undergoes degradation or persists in the environment for a longer time. Degradation of pesticide molecule depends upon the chemical structure, its formulation type and the intensity of factors responsible for its degradation. Major factors which contribute to degradation of a pesticide molecule are sunlight and temperature. Temperature plays a role in breaking the pesticide molecule by increasing the heat around the molecule, thus, the molecule breaks down into either a toxic or a non-toxic molecule. Breakdown molecules or the metabolites may persist longer than the parent molecule, and It may possess more leaching potential than other metabolites or parents too. Sometimes pesticide toxicity increases due to synergistic effect from the presence of environmental contamination. Thus, the potential of pesticides in managing the pests' decreases. Dosage of the pesticide formulation will have to be changed as it may become effective at a lower dose due to enhanced temperature and vice-versa. Sometimes due to increase in temperature penetration of pesticide molecule into the insects and crops becomes faster as compared to low temperature (Vinod Kumar *et al.,* 2020)

Temperature is a major factor affecting insecticide toxicity either positive or negative and, thus, efficacy. The response relationship between temperature and efficacy has been found to vary depending on the mode of action of an insecticide, target species, method of application and quantity of insecticide ingested or contacted. Increased temperature will increase the activity of some of the insecticides. Natural plant products, entomopathogenic viruses, fungi, bacteria, nematodes, and synthetic pesticides are highly sensitive to the environment (Pareek *et al.,* 2017)

3.7 Effectiveness of biological control agents/ natural enemies

Climate change is likely to have severe impacts on the abundance, distribution, and seasonal timing of pests and their natural enemies, which will alter the degree of success of biological control programs (Thomson *et al.,* 2010). Phytophagous insect species are naturally controlled by top-down (natural enemies) and bottom-up (host plant availability and quality) mechanisms. These mechanisms interact to influence insect population dynamics, performance, behaviour and are affected by climate change (Jamieson *et al.,* 2012). Temperature changes can affect the biology of host and natural enemy differently, destabilizing their population dynamics (Hance *et al.,* 2007)) and causing temporal desynchronization. Natural enemies, being at the third trophic level, are expected to be significantly affected by climate change (Furlong and Zalucki, 2017). If trophically connected species respond variously to climate change, the trophic interaction between them could be perturbed, resulting in decoupling of the synchronized dynamics between insect pests and their natural enemies and potentially negatively affecting the performance of biological control (Welch and Harwood, 2014). All these species are affected by the effects of global warming and could respond differently to temperature changes (Harington *et al.*1999). Hance *et al.*(2007) reported that if a natural enemy starts to develop at a slightly lower temperature than the prey and develops faster than the prey when the temperature rises, a too early and warm spring leads to its early emergence and a high probability of death from lack of prey. If this phenomenon is repeated over several years, it may lead to the extinction of the natural enemy.

4. Adaptation and mitigation strategies for pest management

Climate change adaptation can be viewed as an ongoing process of implementing existing risk management strategies and reducing the potential risk from climate change impacts (Howden *et al.,* 2007). Climate change is widely expected to make pest infestations more unpredictable and increase their geographic range. Coupled with the uncertainty of how climate change will directly affect crop yields, the interactions between insects and plants in ecosystems remain unclear (Gregory *et al.*2009). The adaptive capacity of agricultural production systems will depend on several biological, economic, and sociological factors. The ability of local communities to adapt their pest management practices will depend on their physical, social, and financial resources (Sutherst *et al.,* 2011). With climate change and the acceleration of global trade, uncertainties, and frequency of occurrence of existing and new pests will increase. Increasing the ability to adapt rapidly to disturbances and climatic changes will therefore become all the more important (Barzman *et al.,* 2015). Potential adaptation strategies have been identified by many scientists to reduce the risks of spreading new pests and diseases, and to mitigate the negative impacts of existing pests. Most commonly mentioned strategies are modified integrated pest management (IPM) practices, monitoring climate and insect pest populations and the use of modelling predictions tools (Skendžic et *al.*, 2021).

5. Conclusions

Climate change now a day is globally acknowledged fact. Different aspects of climate change that are relevant to insect pests include small-scale climate variability such as temperature increase, increase in atmospheric CO_2, changing precipitation patterns, relative humidity, and other factors. It has serious impacts on diversity, distribution, incidence, reproduction, growth, development, voltisim and phenology of insect pests. Climate changes also affect the activity of plant defence and resistance, biopesticides, synthetic chemicals, invasive insect species, expression of Bt toxins in transgenic crops. Considering such declining production efficiency due to depleting natural resource base, serious consequences of climate change on diversity and abundance of insect-pests and the extent of crop losses, food security for 21st century is the major challenge for human kind in years to come. Being a tropical country, India is more challenged with impacts of looming climate change. In India, pest damage varies in different agro-climatic regions across the country mainly due to differential impacts of abiotic factors such as temperature, humidity and rainfall. This entails the intensification of yield losses due to potential changes in crop diversity and increased incidence of insect-pests due to changing climate. It will have serious environmental and socio-economic impacts on rural farmers whose livelihoods depend directly on the agriculture and other climate sensitive sectors. Dealing with the climate change is really tedious task owing to its complexity, uncertainty, unpredictability and differential impacts over time and place. Understanding abiotic stress responses in crop plants, insect-pests and their natural enemies is an important and challenge ahead in agricultural research. Impacts of climate change on crop production mediated through changes in populations of serious insect-pests need to be given careful attention for planning and devising adaptation and mitigation strategies for future pest management programmes. Using different pest models for forecasting the insect outbreaks, creating farmers network, pest diagnosis, pest surveillance and pest management services in real time using ICT tools critical for insect pest management in the climate change scenario is the need of the hour. Therefore, there is a need to have a concerted look at the likely effects of climate change on crop protection, and devise appropriate measures to mitigate the effects of climate change on food security.

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10. Herbicide Tolerant Full Page ® Rice for Sustainable Rice Cultivation under Direct Seeded Rice (DSR) System

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Keywords: Direct seeded rice; weeds; Herbicide tolerant; Full Page®

1. Introduction

Rice is the staple food for more than half of the world's population. It is one of the most important food crops in the world. Rice production occupies a very important position in agriculture, particularly in Asian countries.

Rice is the most important cereal food crop of India. It occupies about 23.3% of gross cropped area of the country. It plays vital role in the national food grain supply. Rice contributes 43% of total food grain production and 46% of the total cereal production of the country.

Among the rice growing countries in the world, India has the largest area under rice crop and ranks second in production next to China. The productivity of rice in India is higher than Thailand, Pakistan, Bangladesh, and Nepal but much below the productivity in Japan, China, Korea, U.S.A., and Indonesia. Average rice productivity in India during 1999-2000 was 1986 kg/ha, which is about 23% below the world average productivity of 2563 kg/ha during the same year (Anonymous, 2016).

Weed is an important factor affecting rice production (Ehsanullah *et al.,* 2011). Weeds compete with rice for nutrients, water, sunlight, and space. The presence of weeds also increases the occurrence of diseases and insect pests. These problems lead to varying degrees of reduction in rice yield and grain quality. It was reported that the rice yield can be reduced by more than 40% due to weed damages (Burgos *et al.,* 2014).

Sustainability from both ecological and economic point of view is important aspects for increasing rice productivity in different eco-systems

Direct-seeded rice (DSR) supported by conservation agriculture (CA)-based crop management practices is perceived to address the challenge of producing more rice grain with less water. DSR is endowed with multiple benefits/advantages over transplanted puddled rice (TPR) through savings in labour (40-45%), water (30-40%), fuel/energy (60-70%), and reductions in greenhouse gas emissions. It can be an economic alternative to TPR, (Ali *et al.*2018). In another study to evaluate the DSR and TPR it was found that (DSR) has a ~10% yield advantage compared with mechanically transplanted rice. The results also indicated that DSR technology has the potential to protect against up to 70% of crop lodging in adverse climatic conditions. Apart from this the DSR also helps in advancing the planting dates of succeeding rabi crops, by at least 7-10 days, by saving the land preparation time. (Jat *et al.,* 2022)

DSR has emerged as an efficient, economically viable, and environmentally promising alternative to puddled transplanted rice (PTR) in Asia. Due to Covid-19, there was a paradigm shift towards DSR in Punjab India. Because of its cultivation method that saves resources which are becoming increasingly scarce, such as labour and water, and the costs of cultivation DSR has been accepted. DSR offers both mitigation of climate change (in terms of reducing GHG emissions) and adaptation to its effects (i.e., water shortage, as well as weak and variable monsoon conditions).

As a result of its benefits, DSR is widely practiced in many Southeast Asian countries (e.g., Malaysia, Cambodia, Vietnam, Philippines, and Thailand), as well as Sri Lanka in South Asia. China and other South Asian countries (e.g., India, Pakistan, Nepal, and Bangladesh) are also transitioning from PTR to DSR. Despite its many benefits, there are some risks associated with DSR which limit its wide-scale adoption and the possibility of attaining optimal grain yields using this method. These risks include poor crop establishment and higher weed infestation, which can lead to high yield losses. (Kaur and Singh, 2017)

2. Constraints associated with DSR

Weed management is the major challenge in DSR (Rao *et al.*2007, Singh *et al.,* 2007; Singh *et al.,* 2021). DSR systems are subject to much higher weed pressure than PTR system (Rao *et al.,* 2007). The weeds pose to be more problematic in DSR than in puddled transplanting because (a) The emerging weeds are more competitive as compared to the simultaneously emerging DSR seedlings and (b) lack of water layer in Wet- and Dry-DSR make these crops more prone to initial weed infestation which lacks otherwise in case of transplanting. The research has shown that, in the absence of effective weed control options, yield losses are greater in DSR than in transplanted rice. The reported range of such yield losses in DSR in India is 20-85 % (Kaur & Singh, 2017).

There were several experiments to work on the herbicide options to control of weeds in the DSR system with combination of various post and pre-emergent weedicides. However, they were effective only to control to the extent of 75% (Singh *et al.,* 2016). The current recommended practice of weed control in DSR based on the field experiments conducted at research farm of PAU, Ludhiana, is that the pre-emergence spray of pendimethalin 0.75 kg /ha followed by post-emergence spray of bispyribac 0.025 kg /ha provided excellent control of weeds, as compared to either pre-emergence spray of pendimethalin 0.75 kg /ha or post-emergence spray of bispyribac 0.025 kg /ha alone (Anonymous, 2010)

3. Herbicide tolerant rice

Traditional measures to control weeds in rice fields include combination of tillage, irrigation, and hand-weeding, which require extensive labours and other resources. Rational utilization of herbicides is the most effective way in weed control. However, most of the herbicides that kill weeds in rice field also cause certain damages to the rice. Particularly, there is no chemical that can effectively control weedy rice, a notorious and widely occurring weed that is very similar to cultivated rice in taxonomy and physiology, without damaging the cultivated rice (Burgos *et al.,* 2014)

To solve the weed problem in DSR, the Louisiana State University Agricultural Centre (LSU Ag Center) introduced imidazolinone-resistant cultivated rice varieties, known as Clearfield® rice in the year 2002. Clearfield® rice offered

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an opportunity to selectively control weedy rice with imidazolinone (IMI) herbicides (Croughan, 2003). The IMI technology is a very valuable tool in rice weed management because the imidazolinones, i.e., imazethapyr, has soil and foliar activity. Combined with other herbicides, imazethapyr can provide season-long weed control in rice production. In the southern U.S., imazethapyr is used as the base component of various site-specific, pre-, and post-emergence weed management programs, which includes several herbicide modes of action such as clomazone, quinclorac, pendimethalin, thiobencarb, propanil, bensulfuron, cyhalofop, and others (Scott *et al.,* 2012).

A few major herbicides and their corresponding target gene are (a) Glyphosate and EPSPS, (b) Glufosinate and glutamine synthetase, (c) Acetolactate synthase (ALS) inhibitor herbicides and ALS, (d) Acetyl-CoA carboxylase (ACCase) inhibitor herbicides and ACCase, (e) Hydroxyphenylpyruvate dioxygenase (HPPD) inhibitor herbicides and HPPD, (f) Dinitroaniline herbicides and tubulin genes (Jin *et al.,* 2022). Although the IMI rice technology was readily accepted in the Americas, it was slow to gain foothold in Asia and Europe where weedy rice is also a major problem. As of 2012, only Malaysia, Vietnam, and Italy have expressed interest in developing and commercializing IMI rice. Malaysia and Italy have released IMI rice cultivars and are currently promoting the production.

In India, the discovery of Robin mutant by Mohapatra and others (Mohapatra *et al.,* 2014) for the herbicide tolerance paved the way for release of two basmati herbicide tolerant varieties (Grover *et al.,* 2020) PB1979 and PB1985 which are suitable for DSR also in September 2021 by the Prime Minister Narendra Modi. The genotypes IET 28812 and IET 28813 with no or low phytotoxicity to imazethapyr have contributed to higher crop growth and grain yield with standard pre and post-emergence application of pendimethalin, bispyribac-sodium (Anonymous, 2019).

4. Development of full page® system

Full Page™ is a new generation IMI tolerant rice developed by Rice Tec Inc USA by identifying a specific gene/mutant in rice and back crossing that gene in commercial lines of rice to provide resistance for a specific group of herbicides called IMIDAZOLES (IMI). This allows the rice plant with the gene to survive after the application of herbicide whereas other plants of rice not having gene and most of weeds are killed because of herbicide application. This technology is also called IMI Herbicide Tolerant (HT) Technology.

Savannah has strong collaboration with Rice Tec group and is engaged in research and commercial activities in India and other Asian countries. Savannah has access to Rice Tec's Full Page technology and is also working on introgression of HT trait in commercial hybrids being sold in India. Initial sponsored trials for two years by Adama India Pvt Ltd. at IGKVV Raipur, BCKV West Bengal, GKVK Bangalore and ICAR DWR Jabalpur have proved the effectiveness of this technology in the Indian conditions. The conclusion of the study indicates that Imazethapyr 10% SL fb Imazethapyr 10% SL @ 1000 fb 1000 ml/ha can be recommended for effective control of all types of weeds in dry direct seeded herbicide tolerant rice SAVA 134 FULL PAGE® as post-emergence application (Table 1 and Table 2) (Chaudhary 2022). The results of this study are submitted to Central Insecticide Board for recommendation to use on Full Page.

Table 1 Weed density (no/m^2) before application of herbicide in dry direct seeded rice (DDSR)

Treatment	Dose (g/ha)	*Dinebra retroflexa*	*Echinochloa colona*	*Digitaria sanguinalis*	*Cyperus iria*	*Alternanthera sessilis*	*Ludwigia parviflora*	Other weeds
T1 Imazethapyr 10% SL	100	6.39 (40.7)	4.42 (19.3)	4.54 (20.7)	4.68 (22)	1.00 (0.7)	2.67 (6.7)	4.45 (19.5)
T2 Imazethapyr 10% SL	125	5.49 (30.4)	3.58 (12.4)	3.78 (14)	4.24 (18.1)	1.00 (0.7)	2.53 (6)	3.86 (14.7)
T3 Imazethapyr 10% SL	200	4.83 (23.3)	2.95 (8.3)	2.80 (7.3)	3.66 (13.3)	1.00 (.7)	2.46 (6)	2.89 (9.3)
T4 Imazethapyr 10% SL fb Imazethapyr 10% SL	75fb75	2.25 (4.7)	2.42 (5.3)	3.30 (11.3)	3.43 (11.3)	0.71 (0)	2.41 (5.3)	2.58 (6.7)
T5 Imazethapyr 10% SL fb Imazethapyr 10% SL	100 fb 100	0.71 (0)	1 (0.7)	2.26 (4.7)	3.20 (10)	0.71 (0)	2.67 (6.7)	2.91 (8.7)
T6 Imazethapyr 10% SL fb Imazethapyr 10% SL	125 fb 125	0.71 (0)	0.71 (0)	2.23 (4.7)	3.88 (14.7)	0.71 (0)	2.67 (6.7)	2.29 (6)
T7 Imazethapyr 10% SL fb Imazethapyr 10% SL	200 fb 200	0.71 (0)	0.71 (0)	1.61 (2.7)	3.51 (12)	0.71 (0)	2.63 (6.7)	3.04 (8.9)
T8 Bispyribac-sodium 10% SC	25	10.30 (106)	5.12 (26)	5.48 (30)	4.42 (19.3)	5.62 (31.3)	2.64 (6.7)	6.59 (44)
T9 Two hand weeding	-	2.10 (4.9)	2.46 (6)	2.64 (6.7)	3.84 (14.7)	1.18 (1.3)	0.71 (0)	2.03 (4)
T10 Untreated control (Weedy check)	-	11.30 (127.7)	7.72 (59.3)	8.12 (66)	6.46 (42)	8.77 (76.7)	2.76 (7.3)	9.37 (87.4)
S. Em (+)		0.4	0.31	0.47	0.46	0.24	0.27	0.52
CD at 5%		1.3	0.91	1.41	1.37	0.72	0.79	1.72

*Data in the parenthesis are original value. **Square root transformed value of (X+0.5) was used for statistical analysis. (Chaudhary 2022).

Table 2 Weed density (no/m^2) at 60 days after application of herbicide in dry direct seeded rice (DDSR)

Treatment	Dose (g/ha)	*Dinebra retroflexa*	*Echinochloa colona*	*Digitaria sanguinalis*	*Cyperus iria*	*Alternanathera sessilis*	*Ludwigia parviflora*	Other weeds
T1 Imazethapyr 10%SL	100	9.42** (88.7) *	6.13 (37.3)	2.49 (6.0)	3.55 (12.7)	5.92 (34.7)	1.47 (2.0)	2.99 (10.0)
T2 Imazethapyr 10%SL	125	9.87 (97.3)	6.03 (36.0)	2.64 (7.3)	3.75 (14.0)	5.61 (32.7)	1.47 (2.7)	3.4 (11.3)
T3 Imazethapyr 10%SL	200	9.68(94.0)	6.40 (40.7)	2.82 (8.0)	3.47 (12.0)	4.87 (24.7)	2.33 (2.0)	3.40 (11.3)
T4 Imazethapyr 10%SL fb Imazethapyr 10%SL	75fb75	9.80 (96.0)	5.86 (34.0)	2.48 (7.3)	3.84 (14.7)	5.57 (31.3)	1.65 (2.7)	3.20 (10.7)
T5 Imazethapyr 10%SL fb Imazethapyr 10%SL	100 fb 100	9.61 (92.7)	6.34 (40.0)	2.90 (8.0)	3.78 (14.0)	5.73 (33.3)	1.32 (2.0)	3.30 (10.7)
T6 Imazethapyr 10%SL fb Imazethapyr 10%SL	125 fb 125	9.32 (86.7)	6.46 (41.3)	2.65 (7.3)	3.70 (14.0)	5.29 (28.7)	1.55 (3.3)	3.11 (10.0)
T7 Imazethapyr 10%SL fb Imazethapyr 10%SL	200 fb 200	9.90 (98.0)	6.14 (37.3)	2.64 (6.7)	4.21 (17.3)	5.48 (31.3)	1.76 (2.7)	3.13 (9.3)
T8 Bispyribac-sodium 10%SC	25	9.57 (91.3)	6.19 (38.0)	2.59 (6.7)	3.55 (12.7)	5.46 (30.0)	1.47 (2.0)	3.30 (11.3)
T9 Two hand weeding	-	9.74 (94.7)	6.79 (46.0)	2.64 (6.7)	3.86 (15.3)	5.61 (32.7)	1.32 (2.0)	3.41 (11.3)
T10 Untreated control (Weedy check)	-	10.10 (102.7)	6.46 (41.3)	2.03 (4.6)	4.15 (17.3)	6.15 (38.0)	1.47 (2.7)	3.44 (11.3)
S.Em(+)		0.466	0.302	0.771	0.573	0.517	0.621	0.577
CD at 5%		ns	ns	ns	ns	ns	ns	ns

*Data in the parenthesis are original value. **Square root transformed value of (X+0.5) was used for statistical analysis (Chaudhary, 2022).

5. Benefits of full-page technology

The benefits of Full-Page technology are almost comparable to the direct seeded rice. The water energy and fuel savings have been studied for the DSR. Farmers of Punjab where rice- wheat cropping system is present have saved about Rs 3000 - 4000 per hectare in labour cost and irrigation water (less by 7 irrigations). Saving in water was up to 25%, saving in energy up to 27% of diesel as pumping energy is saved for field preparation, nursery raising, puddling and reduced frequency of applying irrigation water, saving of 35-to-40-man days / ha (Anonymus, 2020)

Full page Technology can also be one of the options, to reduce CH_4 emission because it uses less water during initial cropping as the seed is direct seeded. Few studies have observed the effect of DSR to GHG emission. A field experiment at IAERI research station Indonesia, during rainy season showed that the direct seeded reduced GHG emission approximately around 46.4% and without any yield loss compared to transplanted rice. The direct seeded could be a feasible option to transplanted rice for mitigating and adapting to climate change.
(Susilawati *et al.,* 2019)

Global warming potential was 76.2 % lower for dry direct-seeded rice and 60.4 % lower for wet direct-seeded rice than for transplanted rice (Tao *et al.,* 2016). This technology offers a broad spectrum weed control including all key grasses, broadleaved weeds and sedges appearing in rice fields. The herbicide also offers a broader window of application to offer convenience and comfort to the farmers.

6. Conclusions

The cultivation of rice in USA and South American countries like Brazil, Argentina and in Europe is being done through DSR. The rice growing methods have evolved over time in these countries and now the current yield levels are significantly high in average productivity than many key rice growing countries including India. One of the key differentiations between Indian DSR and DSR in Americas is the weed control method. India has limited chemical weed control options for DSR. Whereas in Americas major weed control in rice is achieved through use of Herbicide Tolerant rice varieties and hybrids.

The DSR cultivation in India is expanding post COVID pandemic with the support of the Government. The direct benefits of DSR such as labour saving, water saving, fuel and energy saving, cost saving are attractive to farmers to adopt. The indirect benefits such as lower greenhouse gas emissions, better soil physical conditions, avoiding puddling and timely sowing are important. However, the major issue of weed control is limiting the expansion of DSR. The current weed control chemicals used in DSR can provide only 75% of weed control. Considering the benefits and challenges of DSR practice, and to overcome the problem of weed control Savannah seeds Pvt limited initiated the introduction of FULL-PAGE integrated cropping solution for weed control in DSR. The bioefficasy trials have been conducted for two years and the results are submitted to Central Insecticide Board for approval for use on rice. Based on above experience, it is evident that Full Page™ technology shall be helpful to Indian farmers in adopting DSR planting method with all its benefits and overcoming the challenges in adoption of DSR technology.

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11. The Role of Biologicals in Sustainable Agriculture and Soil Health

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1. Pre-innovation of agrochemical era

In this era when there was no technological development in agriculture, there were no breeder seeds / Varieties farmers were using their own procured seeds from their own fields which he is growing year by year. No mechanization, the tillage is carried out with bullock drew plough there was no farm machinery to take leverage on farming practices.

Farmers mainly rely on some Cattle for milk production and their waste was used as manure after proper decomposition, this was the only fertilizer in the form of Compost / Farm Yard Manure (FYM) made from cattle dung /waste after the decomposition process which takes around 5-6 months. There was no chemical fertilizer/ pesticide available for crop development and protection

A pair of bullocks cultivate approximately 10 acres of land in a cropping season and the farmer can apply FYM in this cultivated area only. FYM was also available in limited quantities. They were no assured source of irrigation i.e. - Canal or tube well etc. The crops were mainly rain-fed depending on rains and yields were very low. We have to import food grain to meet our requirements. The only fertilizer or other inputs were FYM and their seeds.

2. P**ost innovation of agrochemical era**

The innovation of Agrochemicals was taken place e.g. 1920 - Innovation of Urea by (Dr. Haber & Dr. Bosch) First Chemical Nitrogenous Fertilizer. Which even today is made with Haber &Bosch process in the whole world. Hay got a noble prize for this invention.

1939- Invented of first 1st chemical insecticide named DDT (Dr. Paul Muller) it was used initially in public hygiene and agriculture it was used for locust control in locust breading areas.

1958- Invented first contact fungicide- Mancozeb by DuPont scientist.

1966- First systemic fungicide Carbendazim was invented and follows many more fungicides in this segment.

Thereafter a lot of new inventions took Place in the Agrochemical field- a lot of insecticides i.e. chlorinated Hydrocarbons (CHC), Organophosphorus compounds, Carbamates, SYNTHETIC pyrethroids, biological and various other groups of Contact and Systemic pesticides like Pyrrole, etc. In a similar way lot of contact and systemic fungicides were available, but still, there are outbreaks of insect pests, white fly, pink bollworm, and Heliothus in Cotton, Fusarium wilt diseases in many crop plants, and downy mildew diseases in cucurbits &Grapes. Heliopeltis (Tea mosquito bug in Tea)phytophthora in citrus, etc. There are many more numerous insect pests and diseases that damage our crops and sometimes they destroy our crops.

There is a need to understand the problems and their remedy. In pre innovation Period we were Managing all these problems without any of these Chemical Fertilizers, Insecticide & Fungicide, Let us understand from this situation, Farmer was using only well-decomposed FYM in soil and they maintain the soil pH neutral or slightly acidic, and a secret certain organic acid which breaks down the Complexes and provides all 16 essential Element to plant and plant growth is natural/normal with balance nutrient and give yield year after years without any insecticides and fungicides and there is no residue of toxic chemical in food is called a Natural Farming.

As we required more food grain to meet our growing demand. We introduced high-yielding Dwarf Varieties which require more nitrogenous fertilizer and mechanization has taken Place, In Place of Bullocks drawn plough was taken over by trackers and the cultivation area has been increased to 100 more acres means 10 to 15 times than in the pre-innovation era. To get a good yield, and to meet the nutritional requirement of new high-yielding varieties we required nitrogenous chemical fertilizers. We need to apply approximately 15-20 kg of urea /Ammonium-Sulphate per acre and our yield doubled. This continued year after year and dependency on FYM has reduced as it is and was a limited factor Farmers cannot cover the large area with this and no Biofertilizers were available during this period. Farmers keep on using chemical fertilizers more and more to sustain their crops.

Became of continuous and discriminate use of chemicals fertilizers at the double or triple dosage or much more dosages, we reached a situation where the dosage of chemical fertilizer is reached 10 to 15 times but the yield is Stagnant and there is a lot of disease and insect attacks which require additional insecticides and fungicides application but we cannot manage the crops, this is an alarming situation needs to be addressed.

The main reason for this indiscriminate use of chemical fertilizer dosage is, that the crop plants are not responding to the fertilization at the initial stages of crops and farmers keep on increasing the application of the fertilizer, they are only dependent on fertilizer but in some cases also use PGPR, Triacontanol, Hydrolyse protein, Amino acids, and seaweed extract to boost the initial vegetative growth of crop plants. This PGPR is very common in Tea plantations as planters require more leaves to increase productivity.

By doing this, they make plants weak and susceptible to insect pests and diseases, due to this, there is an outbreak of insect pests and diseases in many crops.

The main cause of the initial stunted growth is soil health (this is mainly soil pH, and Soil salinity) the plant is unable to take up essential elements for their growth as high pH makes complexes and they are insoluble in water, hence not taken or up by plant root System, the plant becomes stunted and weak and prone to insect attack, diseases and cannot compete with weeds having C_4 cycle.

To overcome this situation we need Biologicals - Bio fertilizers which when applied in the soil field secrets organic acids -Keto Gluctarticnic acid, Fumaric and, Tartaric acid, Acetic acid which Break down the Complexes and make essential Element available to plants and also reduces the Soil to 6.5-7.5 which facilitate the movement of essential Element in plant system as shown in pH chart. It also increases grain straw ratio and plants develop resistance to various diseases.

If soil pH is more than 8.5 then only two elements i.e. potash and sulphur can take up by the plant's rest of the 14 essential elements are not available to the plants and this situation needs to be addressed.

The solution lies, in the integration of biologicals

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(Biofertilizer) rather than PGPR, which makes the plant grow normally and strong as it takes up all the essential (16) elements required for its normal growth. This also avoids the problem of only vegetative growth and not reproductive growth which more often happened when given more nitrogenous fertilizers and PGPR in any form.

Moreover, the present-day requirement is safe, healthy, and nutritious food which Can only be achieved by the integration or Use of biological Pesticides, as residue in food plays a very important role in our present-day farm economy, lot of Consignments are being rejected because of this, resulted in total loss and we also lose creditability in the market place which, affect the farm economy directly In addition to this, there are lot of crop disease which are not successfully controlled by the Chemical fungicides even the latest inventions but biological (Bio fungicides) Can easily control these devastating diseases of the Crop without, any toxic residues.

Organic farming, GAP cultivation natural farming is only achieved by the use of biological which is a Sustainable Solution, No resistance, no pesticide residue, good crop yield and maintain Good Soil-health. It also produces good quality farm produce without any toxic residues. These biologicals also are a sustainable solution as they are not developing resistance against any pest and diseases and can be used for a longer period of time, unlike chemical pesticides. It is high time to integrate natural farming for the development of the farm economy and rural development.

12. Invasive Alien Species and their Management

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1. Introduction

Invasive alien species, including plants, algae, fungi, microbes, and animals, are spreading in an accelerated rate due to globalization, resulting in increased human mobilization, trade, and transport. Further,due to population growth, shrinking farm acreage, intensive agriculture, and climate change, long distance transportation has become essential for availability of commodities year-round, which has increased the risk of spreading invasive species.Several factors contribute to successful invasion by exotic species, including climatic and environmental similaritiesbetween the nativeand new habitat of the invasive species. The congressional Office of Technology Assessment (OTA) in the U.S. reported 4,500 non-native species, of which 15% to cause severe harm. India has more than 2,000 alien species, of which 330 (173 plants and 157 animals) species are declared invasive and out of these, 10 invasive alien species alone cost the Indian economy $127.3 billion.India is in second place after the U.S. in terms of bearing costs from invasive species. The yearly loss related to agriculture alone by invasive insects is $16.8 billion *(Bang, 2022). Globally, it has been estimated that invasive species to cost $1.288 trillion over the past 50 years (Zenni et al., 2021). This paperhighlightsa few of the invasive plants and insects, management actions available to be taken, and their current status, on a global scale, for sustained agricultural production, and enhanced human and environmental health.*

2. Invasive alien species

Documents on introduction of most invasive alien species into India exist. In the 18th century, the invasive plant *Opuntia monacantha* (Wildenow) Haworth (Cactaceae) was introduced to India from the Americas for production of cochineal dye. However, because of the mismatch of the host plants and the dye-producing cochineal insects, the cactusbecame invasive and occupied a vast area stretching from Punjab to Assam in northern India. In the late 19th century and early 20th century, another cactus, *Opuntia stricta* (Haw.) (Cactaceae), introduced for the same purpose, became invasive in southern India (Muniappan 2018). It has introduced to Australia, and Africa. Several plants were intentionally introduced as ornamentals, such as water hyacinth (*Pontederia* (*Eichhornia*) *crassipes* Mart.) (Pontederiaceae), lantana (*Lantana camara* L.) (Verbinaceae), and Siam weed (*Chromolaena odorata* (L.) King and Robinson) (Asteraceae). Some plants, such as giant sensitive plant (*Mimosa diplotricha* C. Wright ex Sauvalle) (Mimosaceae), mesquite(*Prosopis juliflora*(Sw.) DC) (Fabaceae), and subabul (*Leucaena leucocephala* (Lam.) De Wit) (Fabaceae), were introduced for other economic reasons,and some were accidentally introduced, such as parthenium (*Parthenium hysterophorus* L.) (Asteraceae) and Spanish needle (*Bidens pilosa* L.) (Asteraceae), andhave become invasive.Most of the invasive insects such as papaya mealy bug (*Paracoccus marginatus* Williams and Granara de Willink) (Hemiptera: Pseudococcidae), South American tomato leaf miner (*Phthorimaea* (*Tuta*) *absoluta* (Meyrick)) (Lepidoptera: Gelechiidae), banana leaf roller (*Erionota torus* Evans) (Lepidoptera: Hesperidae), coconut eriophyid mite (*Aceria guerreronis* Keifer) (Acari: Eriophyidae),and rugose spiraling whitefly (*Aleurodicus rugioperculatus* Martin) (Hemiptera: Aleyrodidae) were introduced accidentally.The fall armyworm (*Spodoptera frugiperda* (J.E. Smith)) (Lepidoptera: Noctuidae) was introduced as a stowaway or by air currents. The desert locust (*Schistocerca gregaria* Forskål) (Orthoptera: Acrididae) periodically invaded Northwestern India due to natural range expansion when its population built up in the region of Iran, Afghanistan, and Pakistan; however, its occurrence has been recorded only since 1812 (Government of India 2013). All of them, except the desert locust are New-World species introduced to the Old-World. Some examples of Old-World species becoming invasive in the New World are Chinese tallow tree, tree of heaven, kudzu, Japanese knotweed, purple loose stripe and others in plants and spotted lanternfly, Asian long-horned beetle, spongy moth to mention a few.

3. Management

Prevention: Prevention is better than a cure.Quarantine regulations need to be amended, instituted, and promulgated when an impending danger of pest or disease invasion from neighboring countries is observed. In general, quarantine regulations do not prevent introduction of an invasive species, however, it can delay the process. Countries like Australia, New Zealand and U.S.A. have invested heavily in the quarantine regulations and enforcement.

Monitoring and early detection: Establishing an early detection and rapid response (EDRR) would detect unexpected invasions.A monitoring system with pheromone lure traps, light traps, and field surveys leads to early detection to institute appropriate action plans.In California, the killer alga (*Caulerpa taxifolia* Agardh (Chlorophyta: Caulerpaceae)) was recognized early and led to successful eradication (Simberloff, 2013). In August 2008, a papaya field was found infested with papaya mealybug in Coimbatore, India, and it was immediately communicated to the Indian Council of Agricultural Research and other government agencies. By 2009, it has spread to most of the states in Southern India, affecting papaya, cassava, mulberry, and other crops. Even though there was a some bureaucratic delay in taking actions, in collaboration with theU.S. Agency for International Development (USAID) mission in India, USDA-APHIS, IPM Innovation Lab, and government agencies in India, the parasitoids *Acerophagus papaya* Noyes and Schauff (Hymenoptera: Encyrtidae), *Anagyrus loecki* Noyes and Menezes (Hymenoptera: Encyrtidae), and *Pseudleptomastix mexicana* Noyes and Schauff (Hymenoptera: Encyrtidae) were imported from the Puerto Rico laboratory to National Bureau of Agricultural Insect Resources in Bengaluru in mid-2010. Subsequently, field releases were made in Tamil Nadu in 2011. By early 2012, the parasitoids, especially *A. papayae* suppressed the mealy bug population below its economic threshold level (Sharma and Muniappan, 2021).In the case of South American tomato leaf miner, when communities prepared themselves by using pheromone lures well ahead of its invasion, the pest was detected as soon as it reached Pune in 2016.

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Awareness raising: The Feed the Future Innovation Lab for Integrated Pest Management (IPM Innovation Lab) at Virginia Tech conducted several regional and in-country awareness workshops in West Africa, East Africa, South Asia, and Southeast Asia, and prepared authorities in the government and the public before the invasion of the South American tomato leaf miner and fall armyworm (FAW). In fact, one of the participants from India who attended the South American tomato leaf miner awareness workshop conducted in Ethiopia in 2014 began producing tomato leaf miner lures in her company, and distributed them when the pest reached India in 2016, thus taking diagnostic and remedial measures immediately after invasion of this pest.

Eradication:It is possible to eradicate invasive species only if the invasion has been detected before buildup of a large population. It is expensive and requires collaboration and coordinationof various agencies involved and trained personnel to execute. The introductions of the Mediterranean fruit fly (*Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae)) in California, and Oriental fruit fly (*Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae)) in Florida were recognized early and eradicated. The pink bollworm (*Pectino sphora gossypiella* (Saunders) (Lepidoptera: Gelechiidae)) in the U.S. was eradicated after a long and sustained effort.

Maintenance management:

***Mechanical or Physical*:** Hand picking/weeding, slashing, ploughing,digging,and application of ash and sand are practiced for managing insect pests, diseases, and weeds, especially in crop lands. In 2019, when FAW became a serious problem in Ethiopia, school children were recruited to hand pick caterpillars from maize plants. Ash and sand were applied in whorls of maize to control the pest in some southern African countries. Additionally, the invasive parthenium weed is pulled by hand mostly by women farmers/laborers in crop lands. Slashing is also practiced to remove shrubby perennial weeds like lantana and Siam weed. Ploughing is done to remove annual weeds and also kill insect pupae in cultivated lands. Banana bunchy top-infected hills are dug out and disposed of from the field to prevent it from servicing as a source of virus inoculum. Some perennial weeds like lantana and *Ageratina adenophora* (Sprengel) King and Robinson (Asteraceae) were dug out and removed in a few instances without much long-term consequence. Water hyacinth and water lettuce are mechanically removed from lakes with similar effect.

***Chemical control*:** The use of chemical insecticides, herbicides, rodenticides, molluscicides, and piscicides provide long time management of establishing and established invasive species. However, it requires repeated applications and it is controversial because of possible nontarget impacts on human health and the environment. Additionally, it has two generic problems: resistance development and expense (Simberloff 2013). Many insect pests, including the recent global invaders FAW and the South American tomato leaf miner, are known to have developed resistance to many insecticides. Most of the recently developed pesticide molecules are too expensive for small-scale farmers. Use of pesticides is augmentative and requires repeated applications.

Biological control: Classical biological control offers aneffective and economical method of managing exotic pests and weeds.In this method,biological control agents from their native geographical range are imported and introduced to provide long-term control (Heimpel and Mills2017). Some of the successful cases include control of papaya mealybug in India, cassava mealybug in Africa and Southeast Asia, and *Salvinia molesta* D.S. Mitchell (Salviniaceae) in India (ICAR 2021). Augmentative biological control includes release of laboratory-reared parasitoids or predators through an inoculative or an inundative process. Seed treatment with *Trichoderma* sp. for control of soil borne fungal diseases, release of *Trichogramma* sp. (Hymenoptera: Trichogrammatidae) for control of *P.* (*Tuta*) *absoluta*in green houses, and repeated applications of biopesticides for control of insect pests are examples.

Mating disruption: Use of sex pheromone lure traps for monitoring insect pests before and after invasion has become a common technology in recent years.Use of pheromones in mating disruption technology is practiced in North America against codling moth spongy moth, medfly, and others. Its adoption in small-scale farming conditions in developing countries is in its infancy – cost is major factor; however, some avenues are actively explored to reduce the production cost and efficient delivery system (Stokstad 2022).

***Integrated Pest Management*:** The nontarget effects of chemical pesticides, resistance development, resurgence of pests, and expense led to the development of Integrated Pest Management (IPM). It is a universally accepted concept for pest management; however, there are some misconceptions surrounding IPM that continue to linger with many scientists. IPM books written by entomologists tend to only address problems caused by arthropod pests and how to manage them, not mentioning diseases or weeds. Similarly, books written by plant pathologists address only plant diseases and not insect pests and weeds. There are also publications titled "IPM for *Tutaabsoluta*" (Desneux *et al.,* 2021) or "IPM for Fall Armyworm" (Prasanna *et al.,* 2021) and a conference titled "IPM for FAW 2022" (ICRAF 2022). IPM is intended, however, for a crop and not for a particular a pest, disease, orweed. Management practices developed for a pest or a disease need to be integrated in the IPM package developed for the crop on which it is a pest, disease, or weed. These management practices should not interfere with the technologies already developed for management of other pests and diseases of the crop.

4. Case studies

***Cacti*:** In the 18th century, *Opuntia monacantha* (Willd.) Haw. (Cactaceae) was introduced to India from the Americas for cochineal dye production. However, because of the mismatch between the host plant and the dye-producing cochineal insects, the cactus became invasive and occupied a vast area covering Punjab to Assam in northern India. In 1795, *Dactylopius ceylonicus*(Green) (Hemiptera: Dactylopiidae) was introduced from Brazil for cochineal dyeproduction, which did not contribute much to the cochineal dye, but killed the cactus and effectively cleared it from the infested area. Even though it was not a deliberate attempt to control a weed, it brought the potential of classical biological control of weeds tolight. Around 1865, *D. ceylonicus*was deliberately introduced to Sri Lanka for control of *O. monacantha*. In the search for the correct cactus and the cochineal insect for quality dye production, another cactus, *Opuntia stricta,* was introduced to southern India and it too became invasive in the states of Tamil Nadu and Karnataka. In 1926, *Dactylopius opuntiae* (Cockerell) (Hemiptera: Dactylopiidae) was introduced from Sri Lanka to India, which effectively suppressed this cactus (Muniappan, 2018).

Papaya mealy bug: *Paracoccus marginatus* (Hemiptera: Pseudococcidae). It is a native of Mexico and it started to spread in the Caribbean in 1995 and in 2008 it was reported from southern part of India (Muniappan *et al.,* 2008). It is highly polyphagous and plants from 50 families reported to be its hosts.

Three parasitoids (*A. papayae*, *P. mexicana*, and *A. loecki*) were imported to India from Puerto Rico and released in Tamil Nadu, India in 2010. They established in the field and in five months they regulated the population of *P. marginatus*. *Acerophagus papaya* played a major role in managing populations of *P. marginatus* in India (Sharma and Muniappan 2021) and it has fortuitously established in most countries in the South and Southeast Asia, except in Sri Lanka where it was introduced in 2009. International organizations, FAO, IITA and CABI have been introducing this parasitoid in African countries for control of the invading mealybug. The benefit to India for controlling papaya mealybug was estimated to range from $524 million to $1.34 billion (Myrick *et al.,* 2014).

***Lantana*:** In1807, *Lantana camara* (Verbinaceae) was introduced to Royal Botanic Garden in Calcutta (now known as Acharya Jagadish Chandra Bose Indian Botanic Garden, Kolkata),a plant that turned out to be an aggressive invader throughout India. In 1906, Y. Ramachandra Rao was deputed to conduct a survey of natural enemies of lantana in India and he came up with a list of 148 insects, two pathogenic fungi and a parasitic weed, associated with it (Rao, 1920). Since then, several natural enemies were imported and introduced with little or no impact on the population of lantana. Lantana is a problem in Australia, Africa and Asia, of these Australia and South Africa are having active biocontrol programs.

Siam weed: In 1837, *Chromolaena odorata* (L.) King and Robinson (*Eupatorium odoratum*) (Asteraceae) was introduced to Acharya Jagadish Chandra Bose Indian Botanic Garden, Kolkata, which then spread widely in Northeast India and Burma (Rao, 1920). After World War II, it established in Southwestern India from the seeds that came from contaminated clothing of soldiers. The natural enemy, a leaf feeding caterpillar *Pareuchaete spseudoinsulata* Rego Barros (Lepidoptera: Erebidae), was released from the mid-1970s to early 2000s and established in Sri Lanka, India, Malaysia, the Philippines, Micronesia, Papua New Guinea, Indonesia, and Ghana, resulting in minimal damage in the continental areas but fair to good control in islands (Zachariades *et al.,* 2009).Another natural enemy, a stem galling fly *Cecidochares connexa* Macquart (Diptera: Tephritidae), was released and established in Indonesia in 1995, Papua New Guinea in 2005, Micronesian Islands 2002 to 2007, and India in 2007 (Zachariades *et al.,* 2009; Rabindra and Bhumannavar, 2009). Even though *C. connexa* has been established in southern India and it is yet to be introduced to Northeastern India where *C. odorata* is serious problem.

5. Conclusion

Globalization that led to increase in travel and transportation has increased movement of alien invasive species. Invasive species cause phenomenal economic loss by affecting crop, human, and environmental health. They are not constrained by political boundaries and their sustained management requires national, regional and international initiatives and collaboration for prevention, eradication, forecasting, and sustainable management.

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13. Distribution Mapping of Invasive Weeds Using Satellite Imageries

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1. Introduction

About one-fifth of the earth's surface is at risk of biological invasion with the probability of greater increment impact by new invasive species by 2050 (IPBES 2019, Seebans *et al.,* 2021). There are 938 and countinginvasive plant species distributed globally (Turbelin *et al.,* 2017) and 37 plants in the International Union for Conservation of Nature (IUCN) list of the 100 worst invasive alien species in the world (Lowe *et al.,* 2000). Increased trade and transport, climate change, and socio-economic changes are considered to significantly affect the further distribution and impact of invasive species on biodiversity and agro-ecosystems (Essl *et al.,* 2020). Numerous studies in different countries have revealed that risks from plant invasion will continue to increase due to climate change, particularly due to increasing climatically suitable area for invasive plant species (Bradley *et al.,* 2010; Maharjan *et al.,* 2019, Poudel *et al.,* 2020). Almost every country in the world, including Nepal, is facing problems caused by invasive alien plant species (IAPS), which have serious impacts on biodiversity conservation, ecosystem services, and agriculture. Therefore, mapping the distribution of invasive plant species and identifying the areas potentially at risk of invasion is a growing need for effective IAPS management planning.

There are different approaches and methods to mapping the distribution of species. Initially, the distribution or range maps of species were done by producing outline, dot, or contour maps. The maps used to be prepared withfield surveys. Currently, there are several alternative approaches available, including remotely sensed information, species distribution modelling, and use of artificial intelligence. Not only the past and present distribution of species, but also mapping the future distribution of species has become possible. Kate *et al.* (2015) believe that existing and emerging remote sensing technologies also meet the challenges of Species Distribution Modelling (SDM), e.g., spatial biases in existing occurrence data and variables to fully capture habitat characteristics of species.

The problems caused by invasive species are major impediments to achieving several sustainable development goals. Preparing accurate species distribution maps help in detecting distribution and movement pathways, monitoring, and mitigation. Application of remote sensing has become an important approach for large-scale ecological studies in the last four decades. This approach was successfully employed in mapping vegetation and tree and large shrub species, but very rarely used for the mapping of small shrubs and herbaceous invasive plant species. Use of remote sensing tools was not commonly used to study alien invasive plants until the mid-1990s (Filzpatrick *et al.,* 1990, Huang and Asner, 2009). The availability and coverage of satellite data increased after 2010 and thereafter the use of the approach to assess invasive species using satellite images also increased (Kosaka *et al.,* 2010; He *et al.,* 2015; Rocchini *et al.,* 2015; Dube *et al.,* 2017; Gyawali, 2021; Maharjan, 2021; Poudel, 2021). In south Asia, Kimothi and Darsai (2010) evaluated the utility of different Indian remote sensing sensors for detection, mapping, and patch size estimation of the invasive *Lantana camara.* In Nepal, through the U.S. Agency for International Development-funded IPM Innovation Lab project, Tribhuvan University commenced he assessment of the distribution of invasive plant species using satellite imageries in 2018. This team assessed the distribution pattern and change in area of invaded species (*Ageratina adenophora*, *Chromolaena odorata*, *Parthenium hysterophorus*) between 1990 and 2018 in Chitwan-Annapurna Landscape (CHAL), Nepal, with the help of Multispectral scanners of LANDSAT (30 m x 30 m pixel size) and high resolution WorldView-2 (2 m x2 m pixel size) imageries following Knowledge-based image classification technique by integrating knowledge engineering, including other collateral information i.e. physiography, climate, plant phenology, and land use information.

2. Invasive weeds

The purpose of this presentation is to demonstrate (i) the possibility of mapping of herbaceous or small shrub invasive weeds, (ii) accuracy of the results, and (iii) challenges in distribution mapping of invasive plant species using remote sensing. The presentation is mainly focused from the perspective of a botanist realizing the limitation of remote sensing understanding. There are several steps to map the distribution of invasive species using satellite images and we followed the following steps to map the invasive plant species in the mountainous area of CHAL, Nepal.

Data sources and software in use: (i) Occurrence data, (ii) Secondary data, (III) software used (ArcGIS 10.3 and ERDAS IMAGIN 2014)

Data collection and compilation: LANDSAT Image download, WorldView-2 image purchase, topographical, climate and land use data collected from different authorized sources

Image Processing: subset, rectification, filtering

Image Classification: (i) Unsupervised classification, (ii) Supervised Classification, (III) Knowledge-based Classification

Accuracy Assessment: (i) Overall Accuracy, (ii) Kappa Coefficient, (iii) Field Validation

To determine the distribution of invasive species, presence and absence points of species are of prime importance. The satellite images of LANDSAT were freely downloaded from the archives and high-resolution multispectral satellite imageries of WorldView-2 was procured from authentic sources. Unsupervised (machine-based spectral value segregation and clustering software algorithm), supervised (training sample or signature-based classification algorithm)and knowledge-based classification were performed by employing seven variables (elevation,

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land use, normalized difference vegetation index (NDVI), digital number, maximum temperature, minimum temperature and rainfall) within the software-embedded knowledge engineering approach.

Furthermore, the spatial distribution of these weeds was assessed in small areas of interests viz. Mahadevbesi (Dhading district), Sarangkot (Kaski district) and Ghasikuwa (Tanahun district) for *A. adenophora*; Rampur (Chitwan district), Dumkibas (Nawalparasi district), Mahadevbesi (Dhading district), Dhulegauda (Tanahun district), and Hetauda (Makwanpur district) for *C. odorata;* and Ghasikuwa (Tanahun district), Hetauda (Makwanpur district), Majimtar (Dhading district) and Rampur (Chitwan district) for *P. hysterophorus* using both low spatial and spectral resolution (LANDSAT) and high spatial and spectral resolution (WorldView-2) images to find more accurate results.

I would like to share our results and observations on the spatio-temporal distribution of three IAPS in CHAL, Nepal. The spatio-temporal distribution pattern showed an expansion of *A. adenophora*, *C. odorata,* and *P. hysterophorus* from 1990 to 2018. The area invaded by these three species increased from 0.22% in 1990 to 4.55 % in 2018, 0.6% in 1990 to 1.3% in 2018, and 0.02% in 1990 to 1.26% in 2018, respectively (Figure 1). Comparison of area covered by these three weeds in different areas of interest (AOI) showed that there is more area coverage in LANDSAT images than in WorldView-2 (Table 1, Figure 2). Our results showed that the area occupied by the invasive weeds increased since 1990.It is obvious that multispectral images with high spectral and spatial resolution are better in detection of the weed in comparison to low resolution images. However, the high resolution multispectral scanners were available only after 2002. The satellite sensing history began in 1971 with low-to-coarse resolution and the multispectral LANDSAT scenes are available in archives with free download only after 1990s. Therefore, the current study used the LANDSAT data with two purposes (i.e. firstly, as far as possible for available starting time to determine he species distribution time period, and secondly, the affordability of project costs to use the satellite imageries due to its availability). Though multispectral sensors showed better predictions of distribution, freely available LANDSAT images can help in determining invasion history. Multispectral sensors, i.e., World View-2 images had higher accuracy in comparison to LANDSAT images in the case of these weeds and provided a better scenario of species distribution. Our study helps in determining the pattern of invasion with the help of LANDSAT satellite images. In addition, detection and mapping of invasive plant species using the remote sensing technique enables the quick, precise, and efficient monitoring of species at regional and global scales.

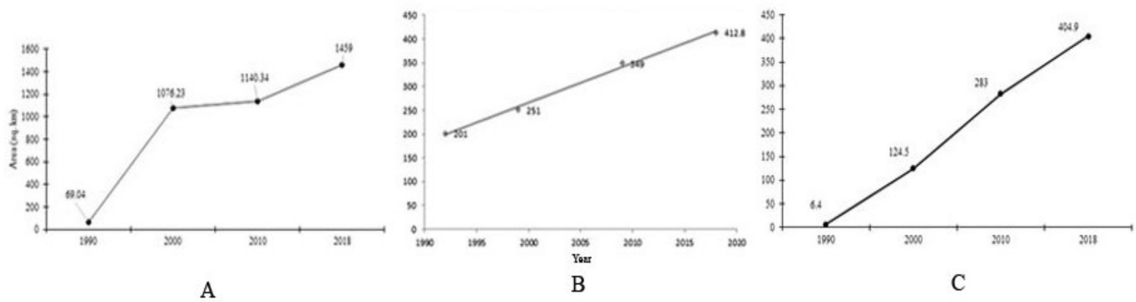

Figure 1: Trend line showing the distribution of A. adenophora (A), C. odorata (B)and P. hysterophorus(C) from 1990-2018 in CHAL

Table 1 Comparison of distribution of invasive species in LANDSAT and WorldView-2 imageries

District	Area of interests	Area coverage by *A. adenophora* (Km^2)		Area coverage by *C. odorata* (Km^2)		Area coverage by *P. hysterophorus* (Km^2)	
		WorldView-2	LANDSAT	WorldView-2	LANDSAT	WorldView-2	LANDSAT
Chitwan	Rampur	0.93	1.53	4.6	3.1	5.61	15.94
Nawalparasi	Dhumkibas	1.97	2.88	-	-	-	-
Dhading	Mahadevbesi	3.31	4.49	-	-	-	-
Makwanpur	Hetauda	1.30	3.28	-	-	2.68	6.41
Kaski	Sarangkot	-	-	3.3	5.7	-	-
Tanahu	Ghasikuwa	-	-	5.11	10.1	0.49	1.35
Tanahun	Dhulegauda	0.56	3.01	-	-	-	-
Dhading	Majimtar	-	-	-	-	0.25	0.62

Table 2 Comparison of overall accuracy and Kappa value of LANDSATand WorldView-2 images for three different IAPS

Species	Area of interests	WorldView-2		LANDSAT	
		Accuracy (%)	Kappa Value	Accuracy (%)	Kappa Value
A. adenophora	CHAL	-	-	62.0	0.35
	Tanahu (Ghasikuwa)	72.4	0.50	38.8	0.40
P. hysterophorus	CHAL	-	-	68.8	0.40
	Tanahu (Ghasikuwa)	78.1	0.52	44.8	0.50
C.odorata	CHAL	-	-	72.0	0.45
	Tanahu (Dhuegauda)	87.6	0.52	73.0	0.46

Results (Table 2) reveal that overall accuracy for CHAL using Landsat images was in the range of 62 to 73% and kappa value 0.35 to 0.45.For smaller areas of interest, overall accuracy and kappa value ranged between 38.8-73.4 % and 0.40-0.45 for Landsat images, and 72.4-87.6% and 0.50-0.52 for WorldView-2,respectively.The range of difference in the overall accuracy in WorldView-2 images was less than in the LANDSAT images. One of the reasons for difference in overall accuracy is habitat and phenology. Field verification showed around 80% accuracy. Based on the results and our observations, the following challenges of distribution mapping using satellite images may be faced by researchers:

- Biologists as well as remote sensing experts should understand the specific characteristics of plants as well as satellite images.
- Phenological changes might create confusion in recording reflectance or spectral signature or Digital Number (DN) value of targeted species. Distinct flowering period may ease the job.
- Visual- and photo-interpretation and digital image processing (DIP) are labor and time intensive, and the quality of results may be highly dependent upon the skills and experience of the interpreter. Similarly, both these techniques require intensive field knowledge and adequate ground realities.
- High resolution images are required for IAPS mapping but expensive to acquire. Student level research is almost impossible without research support grants.
- Observations of small patches may not give accurate results.
- Reflectance value or DN value of targeted species may have large range because of different phonological phases.
- The satellite images for mountain areas are often hindered by shadow, cloud, fog, haze, and mist.
- The regular satellite images for desired dates or season may not be available and requires special order for dates but it is costly and historical archives limit available scene.

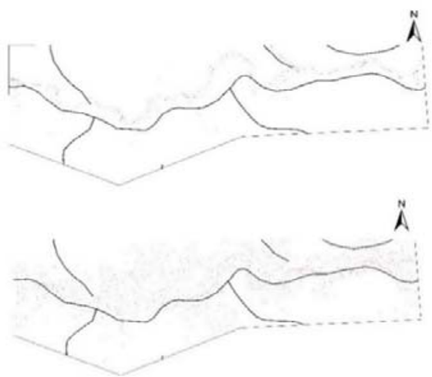

Figure 2: *P. hysterophorus* distribution in WorldView-2 images of Dhading district (Majhimtar) in 2008 and 2018

3. Conclusion

It can be said that use of satellite images for long-term monitoring of IAPS is feasible and recommendable. High resolution multispectral images like WorldView-2 and high resolution imageries give precise assessment of the distribution of species whereas LANDSAT gives approximation. However, it is more affordable for low budget research.

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14. Agri-food Systems as Energy Systems: An Innovation for New Insights on Transformation to Sustainability

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1. Agri-food systems and calls for change

Agri-food systems, indispensable but flawed institutions of the modern world, have partiallyac complished their primary purpose: producing and delivering enough food and fiber to feed and clothe people who do not farm for their livelihood or do not havesufficient land to produce enough.Despite agri-food systems supporting 7.9 billion people—a numberthat is still growing—multiple criticisms have surrounded them for over half a century. Flaws with these systems include (1)insufficient quantities and qualities of food or (2) threats to perpetual functioning. Poverty usually contributes tothe first set of flaws, a social-economic-political-cultural issue, not a physical absence of food and fiber.

A wide range of physical-chemical-biological problems cause the second set of concerns. For example, chemicals used to increase yields (fertilizers, pesticides, and others) unfortunately contaminate the environment and threaten the health of humans and other species.In the years after 1900, many scientists and social reformers began a systematic critique of industrial agriculture and its many hazards to health and sustainability.

Most importantly for agri-food systems, atmospheric changes caused by emissions of greenhouse gases have raised global temperatures, which have altered climatic factors, especiallytemperatures, precipitation, and storms. Such changes disrupt the physiology of crop plants and livestock, alter occurrences of pest populations and beneficial insects, reduce irrigation water, increase the frequency of "100-year" floods, and destroy farm infrastructure. Moreover, the processes of agri-food systems themselves contribute about one-third of the greenhouse gases causing climate change.

Even so, the modern world depends uponagri-food systems for security and well-being. As a result, the systems must deliver enoughfood *to every person*, especially enough calories and nutrients to support metabolic energy needs, sound nutrition, and health. Agri-food systems must also be resilient, i.e., able to withstand and recover from disruptions such as heat waves. Finally, agri-food systems must deliver food and fiber in perpetuity. The needs for metabolic energy and adequate supplies of nutrients will never end, so agri-food systems must function *forever*.

Sustainability of agri-food systems, in other words, rests heavily on the need to produce and deliver calories and nutrients "forever," a very demanding criterion.For agricultural scientists, cultivating sustainable agri-food systems requires research, development, and innovation. New agricultural science, technology, and knowledge can contribute to resolving both socio-cultural and bio-physical problems of agri-food systems.

But what exactly is an agrifood system? This paper first highlights the origins of agri-food systems as a concept for scientific study. Definitions and diagrams from multiple perspectives have captured many of the components, processes, and outcomes of these systems.The paper then presents a new perspective based on seeing agri-food systems as part of energy systems. This innovation leads to revised definitions and diagrams of agri-food systems, new ways of understanding needed changes, and new possibilities and justifications for research so that agri-food systems will bebetter able to achieve their missionfor many years to come.

2. Agri-food systems: a concept for scientific study

Traditionally, before modern transportation and manufacturing, local farmers supplied their regions with the foodstuffs needed to sustain them. Energy intensive agriculture, based on cheap nitrogen fertilizer, irrigation, and mechanization, prompted development of larger farms worked by fewer people.Food production instead of being local increasingly became far removed from population centers, dependent on well-functioning agri-food systems. The historical record clearlypoints to a longstanding interest in the inabilities of "modern" agriculture—i.e., developments since the early 1900s—to resolve deficiencies in food supplies, social inequities and injustices among people working in agri-food systems, and environmental degradation threatening future food and fiber production.

Global recognition of the failures of agri-food systems came in 2002 at the Rio +10 Summit on Sustainable Development, which ledthe World Bankand the UN Food and Agriculture Organization to launch the International Assessment of Agricultural Knowledge, Science, and Technology for Development (IAASTD).The effort grew into a wholistic assessment of the abilities of agricultural science and technology to reduce hunger and poverty, improve rural livelihoods, and facilitate sustainable development.

The broad scopeof IAASTD's assessment suggests that, in 2009, the assessors saw agriculture as a system with multiple components interacting to produce a wide variety of outcomes, some beneficial and some not. Nevertheless, expliciteuse of agri-food systems as a conceptappears to have played little role in the 2009 assessment.

In the decade following IAASTD's report, however, the concept of agri-food systems began to appear frequently and signaled recognition of a flawed, unsustainable system that, at a bare minimum, needed incremental change. Some agricultural scientists, both natural and social, called fortransformational innovations, a far more ambitious target.Calls for transformative changes grew rapidlyafter 2015. Adoption by the United Nations General Assembly of seventeen Sustainable Development Goals in 2015 galvanized action, especially by international organizations. After adoption of the Sustainable Development Goals in 2015, researchers developed a theory of change by identifying eight specific objectives for transformative research.

In 2020, some participants from the original IAASTD assessment reviewed developments since the 2009 report. They highlighted "*... how a new food system narrative has been firmly established since 2008, which is distinctly different from the post-war chemical narrative that still dominates mainstream farming*." This report emphasized the need for a "paradigm shift" in agricultural science and

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technology, a transformation of scientific knowledge by completely new concepts and methods, i.e., a radical shift indeed.

The themes of the 2020 report have been frequently echoed. Participants in the 5th Global Conference on Climate Smart Agriculture in Indonesia in 2019 acceptedthe need for innovation to preserve and improve functioning of agri-food systems in the face of climate change. Already, the theme of Climate Smart Agriculture has attracted significant support, about $56 billion per year.A survey of participants in the Conference measuredsentiments, and respondents identified 629 issues needing research. Top priority for the largest group of respondents (34 percent) was “climate-resilient and low emission practices and technologies,” a clear indication that climate change was the top priority among those surveyed.

But what exactly are the agri-food systems now the focus of global concern and scientific study?Unfortunately, precise definitions of them have not yet stabilized, which complicates efforts to produce useful innovations. Many useful textual and diagrammatic definitions have been proposed, and each emphasizes useful points for discussion.They complement each other, but no definition can capture every dimension of these systems. Many include energy, but none make energy a key feature of the definition. Given that modern agriculture depends upon intensive uses of energy, it is important to develop a definition allowing closer examination of energy's role in agri-food systems. The major point of this paper portrays agri-food systems as a special kind of energy system.

3. Agri-food systems as an energy system: a new perspective

Figure 1 portraysan agri-food system based on an energy system (ERIC-AFS)to emphasize that production of food and feed provides an “energy service:”metabolic energy for people and their livestock. Production of food and feed operates cyclically and perpetuallyif the requisite investment streams persist. As with energy systems in general, transformation of agri-food systems requires redirecting perpetual streams of investment.

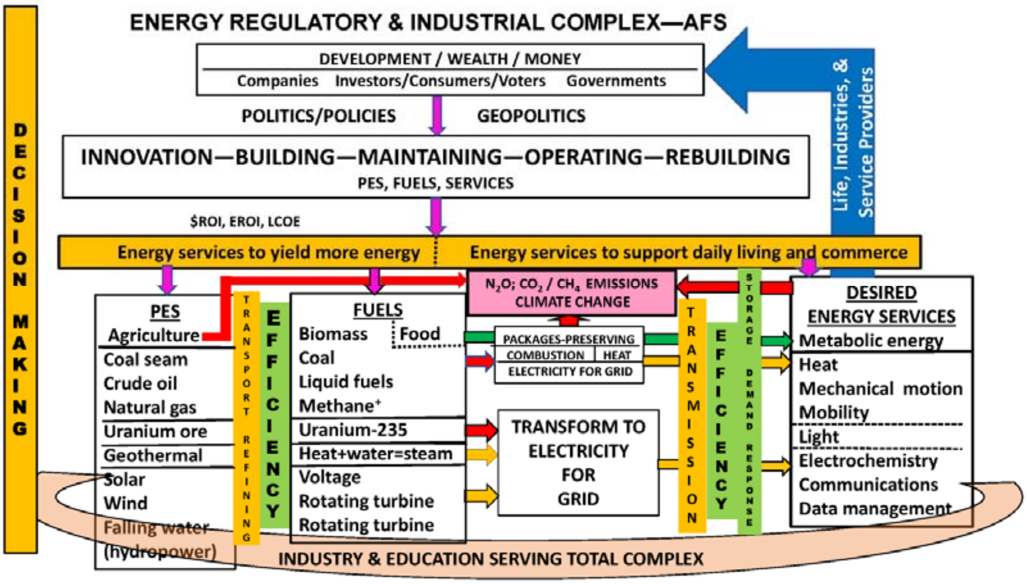

Figure 1: ERIC-AFS shows acyclic agri-food system in which metabolic energy services enable human activities in modern societies leading to development and wealth. In a perpetual cycle, some of this wealth must be invested to renew supplies of energy sources, one of which is agriculture, so that food and feed can again support metabolic energy essential to life.

Key to this new perspective is recognition that “biomass” is a primary energy source (PES), i.e., one of the nine natural resourcesthat yield energy services. Ordinarily, biomass yields energy when combusted (e.g., firewood) or fermented (e.g., grain or sugar cane into ethanol). Food and feed, special forms of biomass,are sources of life-sustaining metabolic energy. Food and feed come from agri-ecosystems, and ERIC-AFS shows “Agriculture” instead of the more generic “biomass” as one of the nine PES.

In Figure 1, ENERGY SERVICES produce DEVELOPMENT/WEALTH/MONEY controlled variously by companies, individuals, and governments. DECISION MAKING, in turn perpetually invests some of this money into INNOVATION-BUILDING-MAINTAINING-OPERATING-REBUILDING infrastructure needed to produce PES, FUELS, and ENERGY SERVICES, to again produce DEVELOPMENT-WEALTH-MONEY and thus continue the investment cycle.

CLIMATE CHANGE is the inevitable by-product of the world’s current energy systems, based on production and use of fossil fuels, which emit the largest share of greenhouse gases. Fossil fuels (coal, oil, natural gas), the most widely used PES, provide about 80 percent of the world’s energy services, and historically they created modern societies, energy intensive agriculture,and modern agri-food systems.Production and use of fossil fuels release the two most important greenhouse gases, CO_2 and CH_4. Warmer temperatures and climate changehave already damaged agricultural yields, due to physiological harm to crops and livestock and to changes in precipitation: more floods and more droughts.Loss of yield has already damaged human health and ultimately will destroy the benefits from high-yielding agriculture.

Agriculture not only is damaged by climate change, but it also contributes to climate change by increasing emissions of three greenhouse gases (N_2O, CO_2, and CH_4).Dangers to agricultural yields from climate change created the Central Dilemma: if humanity stops using fossil fuels to mitigate climate change, yields decline, and agri-food systems collapse.If fossil fuels continue in use and continue driving climate change, yields also decline and agri-food systems collapse. The Central Dilemmapowerfully supports placing agriculture in a diagram of an energy system, clearly illustrating agriculture's role, along with the fossil fuels, as the source of an essential energy service and as a cause of climate change.

ERIC-AFS suggests a new definition of agrifood systems, designed to emphasize that they are energy systems.

Agri-food systems are arrangements of components promoting multiple, perpetual, cyclical flows of physical materials, energy, decisions, and investments, all designed to promote agricultural production of biomass, one of the nine primary energy sources. In turn, harvested biomass undergoes refining, processing, packaging, and transport to produce and deliverfood and feed, the fuels providing metabolic energy, existentially important for humans and their livestock. In collaboration with other primary energy sources providing other energy services, food and feed support the continuity of developed economies, which of necessity must allocate a perpetual flow of investments to promote continued agricultural productionto provide perpetual flows of food and feedto support metabolic energy.

ERIC-AFS and its associated definitionemphasize several important points. Figure 1explicitly indicates a key feature of all agri-food systems: financial investments required to produce food and feed, the fuels providing metabolic energy.Not only are investmentscyclic and perpetual, theyaim carefully at supporting specific production practices. To put innovations into practice, the investment targets must change. For the investment targets to change, decision making by investors must change, and such changes frequently generate controversy.The Central Dilemma calls for two separate lines of research: one to make the systems more resilient to climate change and the other to reduce the emissions of greenhouse gases from the systems.

The value of portraying agri-food systems as an energy systembrings out yet more perspectives and components of these systems.Combining the energy lens with the sense that history matters points to the need for agricultural scientists working in the traditional disciplines to pay close attention to the energy connections embedded in modern agri-food systems.They should support efforts to transition away from fossil fuels to renewable energy without carbon emissions. This awareness must translate into supportive agricultural practices that work well with energy from renewable sources.

15. Agroforestry for Sustainable Livelihoods, Food & Nutritional Security and Environmental Protection

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Keywords: Agroforestry, benefits, prospects, potentials, future strategies.

1. Background

An increase in unchecked population, rise in average income, continued urbanization and industrialization are causing unprecedented pressure on natural resources and a marked decline in per capita availability of arable land and fewer water resources. This, coupled with unscientific management practices, have resulted in low productivity, deceleration of factor productivity, unabated land degradation & impairment of soil health, and environmental deterioration. These are some of the global problems, especially in the developing countries like India, which are plagued with extreme (absolute) poverty.

Ironically, the same forces have created opportunities for agroforestry practitioners to produce a range of high-value products, support watershed protection, biodiversity conservation and mitigate climate change effects. Agroforestry systems have been known to offer opportunities to harness the use of natural resources for high end economic, social, and environmental gains on a sustainable basis. In short, they contribute to entire gamut of livelihoods, and food & nutrition and environmental security.

2. Sustainable agriculture

Sustainable agriculture can be defined as the management and conservation of the natural resource base, and the technology and policy support to ensure achieving satisfaction of human needs for present and future generations. Such sustainable development in agriculture, forestry, and fisheries sectors conserves land, water, plant, and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable, equitable, and socially acceptable (FAO, 1995). Agricultural intensification has been generally associated with an increase in the productivity of existing land and water resources along with increased use of external inputs in the production of food and cash crops, livestock, forestry, and aquaculture (FAO, 2004, Singh and Nayak, 2013 a). Intensification is now defined as the more efficient use of production inputs. Although intensification of production systems is an important goal, these systems need to be sustainable to provide for current needs without compromising the ability of future generations to meet their needs.

3. Current status of agroforestry

Trees were once considered as a hindrance to agriculture, particularly in intensive irrigated areas. It was felt that they occupied productive land, and competed with crops and pastures for soil moisture, as well as made machinery operation more difficult. Well planned tree planting is now widely recognized as a partial means of restoring an environmental balance, especially when used along with other land management techniques.

Tree crops are any edible fruit, nut or legume that can serve as food for humans, livestock, or wildlife. Trees produce high quality food on marginal as well as prime agricultural land. They also can produce crops on land that is too steep for field crops (Smith, 1950). Having trees in the field, soils are not exposed to erosion because there is no plowing needed for growing them. Only pits are dug and filled with soil- manure mixture for growing trees. Tree crop systems also do not require the same level of fossil fuel inputs as is needed by other crop systems for plowing, cultivating and pest management.

Agroforestry is a specialized way of farming trees with the field crops out side the forests in a variety of designs, configurations and combinations. Herein, the choice of tree and field crop combination varies by local preference, market demand and experience and resources of the producers to invest on. Agroforestry is a traditional system in India, locally known as "Kheti Badi", and is recognized as an optimal multifunctional land use system, which provides a variety of important benefits.

Agroforestry systems provide numerous benefits, ranging from timber in the north- western India, Kerala Home Gardens, multipurpose tree, 'Khejari' in the semiarid/arid regions of western parts, mangos in northern, eastern, and central India, and tamarind in Tamil Nadu, and Karnataka, and so on.

In general, agroforestry systems are ecology specific and natural resource domain bound. Examples of some of the globally prominent agroforestry systems include, paulownia and bamboo in China, pine, oak and poplars in North America, macadamia nut and maize, and Calliandra fodder in eastern Africa (Kenya and Tanzania), *Dacrodilis idulis* and maize in Cameroon, and the shea butter and pearl millet in western Africa (Mali and Senegal).

These systems have been documented to contribute to sustainable livelihoods, sound economy and environmental safety in the respective domain areas.

There is whole range of benefits that accrue from the agroforestry systems. The following list includes some of them.

- Sustainable and diversified land use.
- Numerous products, e.g. food, fodder, fertilizer, fiber, fuel, fruits, fitness, timber, mulch, edible pods, spices, etc.
- Products of high economic value viz-a-viz; pulp, resin, gum, tannin, oils, and items having medicinal, aromatic, natural dye and antiseptic properties.
- Increased use efficiency of different inputs, reduced production costs, higher profitability, regular flow of income, asset building, poverty alleviation, and wealth accumulation.
- Greater employment opportunities, livelihood and nutritional security.
- Soil health enhancement, nutrient cycling, N- fixation, waste utilization, organic carbon addition to soil.
- Amelioration of degraded lands, economic use of waste lands, such as rocky areas, waterlogged tracts, sand dunes, saline, sodic lands, etc.

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- Biodiversity conservation, minimization of water runoff loss, favored hydrologic regime, ground water recharge, and prevention of nutrient loss and productive topsoil.
- Continued support for proper maintenance and husbandry of livestock, which contribute significantly to agricultural GDP growth.
- Vast scope for agribusiness enterprises.
- Renewable energy from dendro-thermal power, in the form of liquid fuels and electricity.
- Environmental protection; CO_2 - emission reduction, clean air, climatic moderation, buffer against extreme temperature fluctuations, mitigation of impact of climate change.
- Efficient use of byproducts of different components; better utilization of resources.
- Insulation against risks and disasters.

The precise global extent of Agroforestry has been variously reported, including in India. The global estimates show about a billion ha to 1.6 billion ha, with roughly greater coverage ($4/5^{th}$) in the tropics and the remaining ($1/5^{th}$) in the temperate regions (Nair, *et al.* 2021. In India the reports indicate agroforestry extent between 13.5 million ha to 15 million ha, including trees outside forests.

4. Some examples of significant contributions of agroforestry systems in India

- Timber production and employment: There are a number of successful examples of highly significant contributions of agroforestry systems, which have and are continuing to impact a large constituency in the country. For example, the timber based on –farm systems are meeting more than 60 % of the country's timber demand, saving a substantial amount of foreign currency otherwise needed for the imports. In addition, they are generating significant amount of revenue for the State and are fully supporting the livelihoods of tens of thousands of skilled and unskilled labors engaged in various operations in this venture and allied services in the industry.
- As an example, (Bhojvaid and Singh, 2005) has indicated that in one of the markets in Yamuna Nagar town, Haryana State, 15,000 tons of poplar wood from small holder agroforestry systems is auctioned daily, valued at $ one million. In this market, the transport industry earns $ 100,000 daily and the State Gov. makes $ one million each month in revenues. Each ha land under agroforestry generates employment for 450 labors annually, 15,000 labor daily for logging and 60,000 labor daily for plywood manufacturing.

  Agroforestry can be practiced in many combinations and designs, viz a viz crops in the main field and trees on field boundaries, or both in the main field together or in rotation, etc. (Singh, 2007).

Agroforestry practice on an average can provide a net supplementary income at least equal to the income from main field crop, depending on the tree species, density of tree planting, and market price (Bhojvaid and Singh, 2005). As has been said above, planting fast growing tree species for timber production can be another source of income. Some species can also be grown for their non-wood value. At times when the returns from other enterprises are down, a tree crop could provide a much needed cash income. The timing of the harvest can also be very flexible. To make sure that there is a regular source of income from the plantation, the trees should be planted and harvested on a rotational basis, particularly if they are being grown for wood products. This would provide a number of plantations at different stages of growth. Singh, et al, 2016 from the field data have indicated the following possibilities:

- Trees on field boundaries (60-80 trees per ha on a boundary length of 400 meters length) can provide, INR 10,000 to 12,500 per year in addition to the regular income from the main field crops.
- In agri-hort-silvi- system, the supplementary income from fruits and medicinal shrubs / trees could be 3-4 times greater than only the pure field crop(s),
- If the agroforestry system is practiced in the main field (field crops and trees together) + boundary is planted with trees, the supplementary income could easily be 6-8 times than that from the field crop only, which is INR 60,000-80,000 per year.
- Integration of livestock in the system can further boost the supplementary income.

- **Fruit based systems:** Fruit based systems, particularly the mango, guava, tamarind, sapodilla, pomegranate, etc. are impacting in similar ways and scales, in the respective eco-regions throughout the country. As an example, only from Lucknow City in Uttar Pradesh, one Boeing plane load of mangoes is daily brought to Europe and Middle East during the season (personal observation, and Puspakumara, et al, 2012). Similar is the situation about the pomegranate grown in Maharashtra, *ziziphus mauritiana* (ber) grown in Rajasthan, and *Syzygium cumini* (jamun) grown in Gujarat.
- **Nut based systems:** Nut trees, such as the almonds, walnut, and pistachio, produce high protein foods with low levels of saturated fat that can substitute for meat and other animal products, thereby reducing the demand on land-based production systems for livestock. There is also a high potential for integration of livestock and field crop production systems.
- **Multipurpose trees:** Multipurpose trees like jackfruit, gliricidia and moringa are the futuristic trees, enhancing the livelihood and income of the farmers. Again, as an example, if the flights coming from India to Singapore, carrying daily loads of moringa leaves and pods are delayed, the price of these items in the Singapore market doubles. I personally know several farmers in Tamil Nadu and Andhra Pradesh who are engaged in cultivating moringa.
- **Fodder based systems:** Both, the dry and green fodder are in short supply in India. Wheat straw is sold almost at the same price as wheat grain. Tree fodder crops can be grown that will provide nutritional benefit to livestock. Examples of this are Prosopis, Acasia, Salvadora, Mahua *(Bassia latifolia),* Neem, *Ailanthus excellsa,* Leucaena, Indian fig, Oak, and many others (Nayak and Singh,2013, Singh and Nayak 2013b). Throughout in Rajasthan State and nearby surrounding areas, many farmers have been observed to grow *Prosopis cineraria* for livestock fodder (Singh, 2014), and each tree is auctioned for lopping at an average of Rs 400/tree plus one day halting of the livestock herd in farmers' field (Trees of Change, 2012). Such examples abound in other states also, especially in their hilly regions.
- **Arresting soil erosion:** Another good example would be the gradual replacement of the slash and burn system with settled agriculture in the north-eastern region (Singh *et al.*, 2022), resulting in the halting of the soil erosion and in the conservation of other natural

resources, while continuing to provide livelihoods to the local population on a sustained basis (Singh, et al, 2018 a). Eliminating soil loss enhances land productivity and water quality. By stopping sediment from entering streams, the water resources will be cleaner and therefore, are more suitable for fish and other aquatic species. There are reports that show a drastic reduction with agroforestry fields than without it, in terms of soil loss due to erosion (from 140 t per ha/per year to 15 t per ha/per year).

- **Sequestering carbon:** All trees sequester carbon. The reports indicate that agroforestry systems sequester same amount of carbon in below ground biomass as in well managed forests and higher than in pastures, field crop lands and grasslands (Verchot and Singh 2009, Zomer *et al.*, 2016, Minang *et al.*, 2014). They reduce emissions (Rao *et al.*, 2015, Achten *et al.*, 2013) and some of them also produce high quality saw logs, raw material for plywood, particle board, paper and pulp, etc.
- **Reactivation of traditional watersheds and rehabilitation of degraded lands:** This may include re-using drainage water to irrigate a tree plantation, and rehabilitation of degraded lands, etc. (Singh *et al.*, 2018b). Trees can use substantial amounts of water, up to 300 liters/tree/day. The actual amount of water that each tree uses depends on climatic conditions, their stage of growth and planted species (Zomer *et al*., 2007). Of course, if the drainage water seeps through the soil to the water table, it will contribute to recharge the soil profile. Where areas are already badly degraded due to erosion, salinity, or other factors, trees and other vegetation can be used in conjunction with other techniques to slowly return them to productive use. There are large scale examples from Madhya Pradesh, Rajasthan, Haryana and Uttar Pradesh, and Odisha, where rehabilitation of degraded lands has taken place through agroforestry (Singh, *et al*., 2018a).
- **Providing shade and shelter:** Windbreaks and shelters during high-speed winds and very hot summers can protect pasture and crops from heat stress, thereby improving the productivity (Mohotti *et al.*, 2020). I have personally observed four-degree lower temperature under shade than without it. Likewise, during winter season, they can also protect the animals and plants from the weather and let them use their energy to growth rather than to just staying alive.
- **Improving the general environmental conditions:** Trees are known to provide cleaner air, water, and natural biodiversity, (both terrestrial and aquatic), and act as a noise barrier. Also, by planting local tree species, some of the natural characteristics of the landscape is retained. This helps to maintain the level of diversity of wildlife. One of the benefits that may result from doing this is the preservation of viable populations of insect-eating birds to protect crops and pastures. Natural vegetation areas can be more effective if they are linked, using corridors of trees of suitable width as they provide pathways for the wildlife.
- **Increasing property's aesthetic values:** Trees improve the working environment, and generally make the property more pleasant to live on. Tree crops screen the air and serve as a noise barrier. Moreover, most people enjoy the natural beauty only a tree or a forest can provide. Trees can improve a property's appearance, making it more attractive to a potential purchaser.

The field crops and trees can be of any species, their complementary combination is the science in it. The field crop and tree phenology, rooting pattern, canopy structure, etc. are to be studied (Singh *et al.*, 2014). For example, any field crop, such as rice, wheat, millets, potato, oil seeds, forages and trees for timber, fruits, fodder, herbals & medicinal, multipurpose, have different phenology, rooting pattern, canopy structure, etc.

4.1 Prominent agroforestry systems in India

There are several agroforestry systems in different agro-ecological zones of the country. The prominent ones are the following.

- Plantation crops and fruit orchards in all ecologies.
- Home gardens, primarily in Kerala and Tamil Nadu.
- Trees in the shifting cultivation and slash & burn systems in the north-east.
- Taungya system, mainly in the eastern and north-eastern regions.
- Large cardamom and alder plantations in Sikkim and Nagaland, respectively.
- Inter-spread trees on the farmland throughout India.
- Trees on farm boundaries throughout India.
- Wood lots/ park lands throughout India.
- Shelter belts and Mangroves in coastal regions.
- Shrubs and tress on the range lands, mostly in arid and semi-arid region.
- Aqua- forestry in and around fishponds.
- Apiculture in fruit orchards and flowering field crops, such as mustard.
- Shade Coffee and Tea plantations with trees in South and Eastern India.
- Tree spices system in Karnataka, Kerala, and Tamil Nadu.
- Sacred grooves in all ecologies.

4.2 Prospects and constraints for harnessing the full potential of agroforestry in India

Obviously, there are enormous prospects for practicing agroforestry throughout in all the ecological conditions and socio-economic settings, including the land holding sizes in the country (Nayak *et al.*, 2014). Not only this, but agroforestry systems also offer greater opportunities for the landless, women and resource poor populations than most of the other on-farm and off-farm employment prospects, especially for the unskilled labor force. Additionally, these systems contribute greatly to the food and nutritional security at the rural house hold level and thereby ensure health aspects of the societies (Nayak *et al.*, 2013 a). Needless to say, agroforestry systems offer a range of benefits and in quantities incomparable to other agricultural systems. These systems, however, are suitable in specific niches, and they need to be mapped and their recommendation domains delineated (Mahato *et al.*, 2016). Recommendations on validated and specific agroforestry models according to the landholding sizes in different ecological conditions are expected to accelerate the adoption of these systems significantly (Sahoo *et al.*, 2022). There are other technical, support and policy constraints, which also need to be addressed in the scaling up efforts (Neufeldt *et al.*, 2016, Singh *et al.*, 2016).

4.3 Future strategies and policies for promoting agroforestry in India

In context of the land holding size, the small and marginal farmers constitute a majority of the farmers in the country, one of the important strategies could be to motivate and provide support to these farmers (Singh, et al, 2016). Not only for the promotion of agroforestry, they are also relevant for agriculture in general. Some of the motivation and support items are listed below.

- Developing and promoting small scale farm machinery for planting and harvesting, especially for fruit trees, and providing food processing units for fruits. Imagine, as to date, we don't have any decent fruit and vegetable desiccator, let alone the complete processing unit in the country.
- In private investment schemes, the farmer should be made at the center during the negotiations at different levels, and it should become a Public-Farmer-Private partnership program.
- Bringing uniformity in Research and Extension Services / Strengthening of Research and Extension Agencies. As of now we have three models in India. In some States, for example, Punjab and Haryana, the research and extension are with the agricultural universities. In West Bengal, research is with the universities and extension is with the Department of Agriculture (DA). In rest of the country, research is with the agricultural universities, and the subject matter specialists (SMS) from universities only provide technical inputs to the DAs.
- Farmers neither need only research nor extension, they need technology packages, which they can adopt and apply. But, we don't have any department in any state for technology synthesis, which can put together the research findings and suggest extension methods, except agriculture technology management authority (ATMA) at the district level.
- Evaluating and promoting new novel products being produced from agroforestry systems. Such products may include biochar as soil amendment to improve soil organic carbon and soil health.

Likewise, the small and marginal farmers may be supported by:

- Encouraging them to grow high value crops as per the market demand. In this context, one of the guiding principles could be the 'High Value-Low Volume' system concept.
- Providing opportunities for integrating livestock in farming systems. The livestock could be a large frame or small frame animal, or a foul, depending on family preference and other resources at farmer's hand.
- Planting high value trees / shrubs /herbs on the field boundary. For example, in Chhatish Garh state, the field bunds are generally broad and occupy about 28,000 km linear length, which is four times the Global circumference, but farmers grow mostly babool *(Acaia nilotica)* on them. *Acacia nilotica* can be replaced with high value crops, such as Custard apple, which is non-browsable and drought tolerant as well as efficient extractor of soil fixed phosphorus.
- Reducing dependence on external inputs. Many of the farm inputs can safely and reliably be produced on the farm; if not all inputs in full quantities, at least some of them in partial amounts. The seeds and other planting materials, bio-fertilizers and manures, including green manure, Bio-pesticides, etc. can be produced on the farm. Examples of Bio fertilizers include, *Sesbania rostrata, Sesbania aculeata, Sesbania grandiflora,* Azolla, and Crotalaria. Examples of plants with pesticidal properties include, Neem, Pongamia, Aak (*Calotropis gigantean*), Chilli (fruit), Lemon grass, Basil (various kinds), and Marigold.
- Enhance the scope of the incentivized schemes, such as for example, linking them with the birth of female child to encourage farmer's plant more trees and harvesting the trees when the girl attains adolescence and becomes of marriageable age. Farmers could also plant trees not only in their own fields, but also on the community landscape.

Agroforestry, in the current context of needs in India, has to be broadened in its definition and has to be taken as a specialized form of agriculture, wherein multi-strata farming is used as the basis for designing the production and management systems, not only for economic gains but also for the nutritional, health and environmental benefits (Mahato, *et al.,* 2016). Such cultivation systems may take various forms. They may involve growing of combinations of field crops and trees together in the same field, in rotation, in blocks, or in separate parcels of land in the same farm. Similarly, the field crop may be grown in the main field, and the trees may be grown on the field boundary, etc.

In addition to the 'high value-low volume system concept' to guide the agroforestry efforts in India, the other important aspect is the post-harvest handling, value addition, packaging and marketing. These aspects are to be made as an integral part of the system as a whole, a broadened approach from just production, as has been in the past. Another important consideration is the recognition of the fact that agroforestry systems also provide environmental services (which are often overlooked) in favor of the economic gains and other contributions. Incorporation of trees in the farming may be one of the ways to mitigate some of the climate change effects (Sahoo *et al.*, 2016). It is worth mentioning here that agroforestry systems are probably the only means for getting the desired tree cover in the country, especially in states that have limited area under forests.

In order to have a large-scale impact in the country, agroforestry efforts at the national level therefore, should strategically focus on tackling poverty, food security and environment through four channels. These channels are: a) overcoming natural resource degradation in intensive irrigated systems, b) arresting land degradation in smallholder farms in sub humid and semi arid areas, c) searching for alternatives to slash and burn in tropical humid areas, and d) providing shelter belts in the coastal areas.

All the above issues can be addressed through the following approaches:

- By seeking to understand the basis for sound land management, and then quantifying the long term consequences of agroforestry practices on small scale agriculture so as to develop locally relevant land management options. Thereby, it should provide innovations that built a sustainable platform for achieving food security and income.
- By delivering approaches, strategies and methods for product development, tree domestication, diversification of cultivation systems, and broadening of the germplasm base & better planting material supply systems in response to farmers needs. Agroforestry efforts at the national level would, therefore, be able to provide innovations that enable farmers to diversify their enterprise to capture market opportunities and provide nutritional and health benefits.
- By examining the role of agroforestry and landscape mosaics in generating environmental services and aiming to improve related institutions and incentive systems. This way, one should be able to open up broader market linkages between farms and society's needs for a better environment and facilitate

appropriate recognition of social cost and benefits.

- By strengthening of agroforestry research, education and development (R, E and D) institutions, one should be able to build institutional capacity in generating and applying innovations.

In addition, the following interventions/actions at the national level are expected to make a significant impact on the development and large-scale adoption of agroforestry systems in the country.

- Direct and indirect impact assessment of agroforestry systems.
- Easy availability of high-quality seeds and other planting materials.
- Mass awareness about agroforestry benefits among stakeholders.
- Infra-structural and institutional development; agribusiness, post-harvest processing, value addition, packaging, branding, marketing, storage, and transport, etc.
- Establishing multi-institutional collaboration, both with the national and international agencies.

5. Conclusions

Agroforestry practices offer an enormous scope for optimizing the use of natural resources and for designing of the eco-friendly land use systems, which have been documented to provide a number of economic, social, and environmental benefits on sustainable basis. In addition, there are clear indications that these systems are also helpful in enhancing the natural resource base, minimizing the effects of climatic change, and in creating added opportunities for employment, value addition and extra income to the practitioners. However, concerted efforts are needed to highlight these benefits and to promote the adoption of these systems through continued research and development support and commensurate policies at different levels. There is limited new land and water resources that can be brought into production to satisfy the demand. The expected ecological impacts from doubling food production using past production strategies may result in production systems becoming unsustainable. Agricultural systems must therefore intensify existing land and water resources using more sustainable methods, and by changing current production systems and diversifying them into new and more productive enterprises.

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16. Artificial Intelligence for Food and Environment Sustainability

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Keywords: Agriculture; Sustainability; Food Security; Artificial Intelligence; Monitoring; Decision making; Automation; Digital India; AgriStack

1. Introduction

With agriculture providing the largest source of livelihood to the people, India is a global agricultural powerhouse. It stands 4th among the top agricultural counties of the world. Agriculture contributes 23% to the National GDP (FAO, 2022). 58% population of the Nation is engaged with agriculture (FAO, 2022) with 70% of rural households depending on agriculture. Despite all this, food insecurity prevails with 43 crore people affected by it in 2019 which is 31.6% of the population. The global COVID-19 pandemic aggravated the situation further by increasing this number to 52 crores (38.4%) in 2021 (FAO *et al.*, 2021). One-quarter of the world's hungry people live in India (von Grebmer *et al.*, 2013) despite it having nearly 120 million tons of grain in storage. India has greater than 190 million undernourished people. As per the global food security index, the country stands 76th (among 113 countries) and as per the global hunger index, India stands103rd (among 119 countries).

This situation is expected to get even worse in the coming years. This may be projected from the fact that the land resources have already degraded significantly from94.53 million hectares in 2003-05 to 97.85 million hectares in 2018-19. Almost 30% of the land area in India is already under desertification and among the degraded land area, about 60% is farmland or forest land (ISRO, 2019). This, along with many other factors, is contributing to the shrinkage of land area in India. It is expected that the total land area may shrink from the current 180.88 million hectares to 179.86 million hectares by 2050. This projection, however, does not account for unpreceded disasters like droughts, floods, etc. which may accelerate this loss due to their increased frequency due to climate change. Environment degradation is yet another issue that needs to be combated at its earliest. Nearly 20% of global greenhouse emissions come from agriculture (Yale School of Environment, 2018). Inefficient burning of fuels leads to indoor pollution as well which is a great health hazard, especially for women (Mousavi-Avval *et al.*, 2018).

2. Developed countries v/s India

Developed countries are achieving food security and environmental sustainability in a much more efficient way than India. As an example, Israel; a tropical arid desert with a meager cultivated land area of 10 lac ha is emerging as one of the top countries in terms of agricultural efficiency. This country is 14,885% smaller than India and despite this, it has seen a 16-fold agricultural growth since 1984. It produces 262 tons/ha of citrus fruits and 300 tons/ha of tomatoes. A single cow in Israel produces 33l of milk per day. It has less than 2 percent post-harvest losses and its drip irrigation is extensive. India, on the other hand, produces 25 tons/ hectare of tomato and only 10 tons/ hectare of citrus fruits. A cow in India only produces about 7.5 l of milk/ day. Its post-harvest losses sometimes go up to a whopping 40% (Hegazy, 2016).

2.1 Main reasons for the difference

Several reasons are responsible for this vast difference between the agricultural systems of Israel and India. The main ones include India's agriculture being resource-intensive and regionally biased. Due to inefficient utilization, there is increased stress on water resources, desertification, and land degradation. Uncertainty and risks are always high, and the agricultural system is increasing in complexity to the rise of industry and urbanization. Poor market discovery, lack of open agriculture data & standards, poor access to credit and information, poor mechanization of farms, decreased soil fertility, pest infestation and diseases, changing crop patterns, wastage in the supply chain and exploitation of farmers by intermediaries are some other factors (UNO, 2022). Additionally, 82% of farmers are small and marginal with an average land hold of 1.2 hectares. 20% of farmers are landless (HLPE, 2013). To top it all, India is the second-most populous country in the world and will continue to be so in 2050 with the population rising from 1.3 to 1.64 billion (UNO, 2019).

3. A potential way forward

Food and environment sustainability can be achieved by ensuring affordability, availability, quality, and safety of food as well as sensitivity towards the environment. There is a dire need for the intensification of agriculture so that there is efficient and optimum resource utilization and loss minimization.

However, the challenges faced by agriculture are outliving the existing solutions because they are outdated or ineffective alone. A potential solution to such challenges in agriculture is the use of artificial intelligence (AI)for precision agriculture to attain food security and environmental sustainability.

4. Artificial intelligence in agriculture

AI is expected to tackle challenges in agriculture through its ability to monitor, analyze, predict, and automate agriculture and its allied sectors (Talaviya *et al.*, 2020).

Monitoring: Artificial intelligence can be used for crop/soil monitoring, animal health and production (Neethirajan, 2020), farm profits and losses, farm surveillance, and ecosystem monitoring. The applications of various sensors in animals are given in figure 1. The application of AI for plant monitoring is given in figure 2.

Predictive analysis: Accurate forecasts and predictions are crucial for any successful venture. Up until now, farmers had to rely on intuition and luck for any decision-making. Now AI can perform predictions and forecasts for various aspects of farming (Liakos *et al.*, 2018) including, wildlife migratory patterns, yield, and production, genetic merits, demand and supply of renewable energy, market changes, future prices, outbreaks, pests, and diseases, plant and animal requirement as well as environmental degradation. For example, google is developing algorithms to predict floods and other major disasters with a high degree of accuracy.

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Decision making: Based on the analysis of big data AI enables farmers to make decisions established on scientific analysis and data mining. This allows the farming decisions to be more futuristic and accurate. AI-based decisions range from trade route and shipping optimization, irrigation optimization, feed, and fodder optimization, soil nutrition level optimization, the establishment of sowing time, the establishment of artificial insemination, selection decisions, and culling decisions as well as decisions for sale, and procurement. Today, there are apps available that give precise information about the food on our plates, their freshness as well as calorie values. These lead to conservation and optimization of resources and prevent wastage of energy.

Automation: Farm automation has proved to be a game-changer for developed countries. It can therefore transform the agricultural sector to provide food security in a big way (Saiful *et al.*, 2020) by eliminating drudgery, making the farms labor-free, and hyper-efficient. Robots and other smart appliances are fast, accurate, hygienic, and resource effectively. This amalgamation with the internet of things can make farming, sustainable, easy, and profitable (Adetunji *et al.*, 2022). The various tasks that can be performed by robots in agriculture include remote control, harvesting, weed control, mowing, seeding, spraying, sorting and packaging, livestock tracking and monitoring, irrigation, health scanning, and surgeries on animals. They help to optimize energy and effective resource utilization.

4.1 Potential as a change agent

AI has been transforming all sectors, it can therefore bring about several positive changes to ensure food and environmental sustainability. As per a paper published in Nature, AI can help achieve 79% of UN-sustainable development goals (Vinuesa *et al.*, 2020). It can help reduce greenhouse gas emissions by 1.5-4.0% and also 2.2% reduce energy usage by 2030.Artificial intelligence alone can increase the yield by thirty percent and reduce post-harvest losses by 30-40% (Mishra and Panday, 2021).

Self-driving tractors have been shown to increase the speed of farm work by 50%. AI also has the potential to increase India's income by 2035 by 15%. By 2023, the global dairy farming industryis going to see growth from $1.9 to $8 billion industry. The AI market is also expected to grow from $1.0 in 2020 to $4.0 billion in 2026 (Markets and Markets Research, 2021).

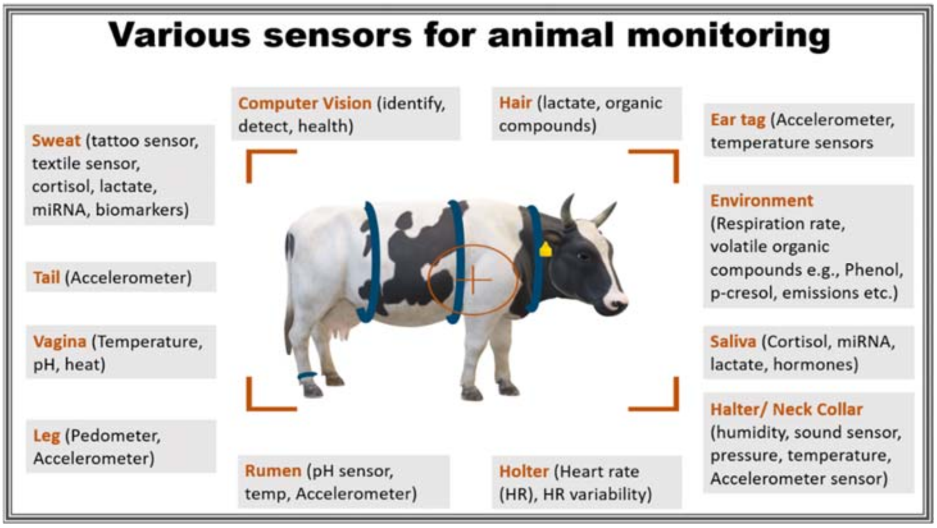

Figure 1: Application of various sensors in animals

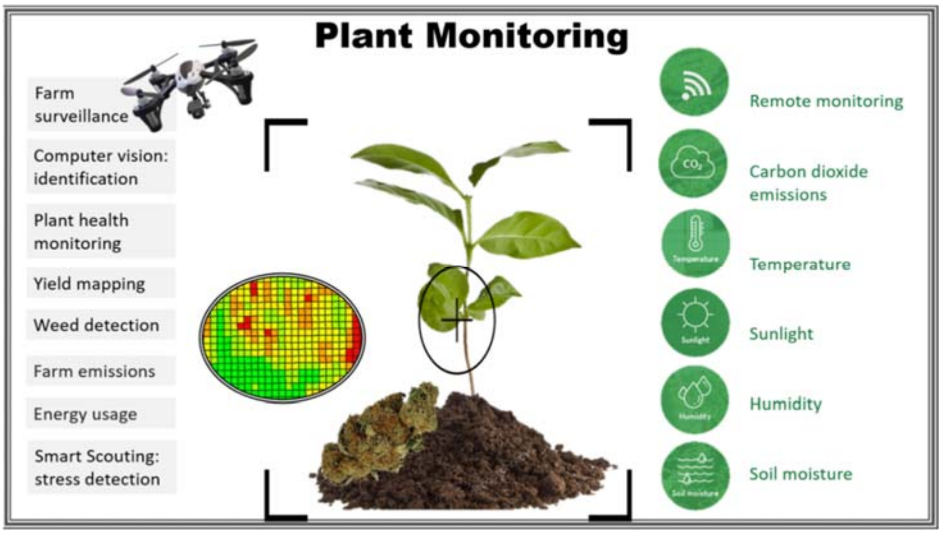

Figure 2: Application of AI for plant monitoring

4.3 Popularizing AI in India

With the reduction in data rates over the past decade and the penetration of smartphones to even the remotest corners of the world, AI has a vast scope for popularization in India. As per the KANTAR IMRB I-Cube Report (2017,2018), the number of active internet users in India is steadily increasing. Therefore,smartphones and the internet can be potential tools to popularize AI among rural and marginalized farmers. However,the development of low-cost technologies is essential for the early adoption of new technologies in the Country.

5. Major areas of technology application in India

Technology dissemination is happening in India at a very fast pace. This technology can also be utilized for harnessing the power of AI in agriculture as well. The major areas of technology dissemination include data-backed credit risk assessment, personalized mobile-based decision support systems, tech-enabled agri-extension workers, precision farming using IoT & remote sensing data, promotion of innovations, technology infrastructure, e-price discovery & e-marketing, track & trace through the supply chain.

5.1 Blockchain for AI in India

Blockchain technology offers a lot of promise in agriculture to provide more consistency, especially in a massive country like India. Some important use cases include overseeing farm inventory, enhancing agricultural supply chains, modernizing farm management software, agri-tech IoT optimization, fair pricing, oversight and payment of agricultural subsidies, community-sponsored agriculture, mobile remittance for small farmers, incentivizing sustainable practices, and greater accountability for multinationals (FAO, 2019).

5.2 NITI AAYOG'S national strategy on AI

The National Institution for Transforming India; NITI Aayog formulated a national strategy forAI in India which includes agriculture as a core area. Under this strategy, the following have been laid out (Mahindru, 2019):

- **Promotion of applied research:** Focus on the creation of products that can be commercialized (COREs and ICTAIs)
- **Guiding innovation:** Provision of the 'Moonshot Challenges' to guide research and start-up ecosystems to solve the most pressing government concerns
- **Facilitate application:** Skilling and education of the workforce cloud-based AI hardware infrastructure (AIRAWAT)

Other initiatives and policies of the NITI Aayog in this direction include:

- Mobile-based recommender systems and expert systems
- AI-based automatic grading & sorting for vegetables and fruits
- AI auto-translation to Indian languages

It also envisions the development of computing infrastructure for nationalized domain-specific annotated data sets and improved access to existing data. A need for developing domain-specific expertise to design solutions is also felt. In this regard, the AIRAWAT cloud computing platform for developers to train algorithms and host large data sets has been developed.

Application-focused research institutes for inter-sectoral linkages are also being envisioned. Some other important endeavors by the government in this direction include:

- National-level schemes for data digitization
- Pradhan Mantri Fasal Bima Yojana: using remote sensing imagery, AI, and modeling tools to reduce claim settlement times which covers some 20 million farmers

In 2018 NITI Aayog, India's leading think tank devised a National Strategy for Artificial Intelligence that discusses how AI can enhance farmers' income, increase farm productivity, and reduce wastage.

5.3 Idea for digital agriculture

Building on the idea thatdata is the oxygen for innovation, the India Digital Ecosystem of Agriculture (IDEA) has been envisioned. This is to be implemented for agriculture under the Digital Agriculture Mission and therefore, the Government of India is planning a nationwide implementation of 'AgriStack' which is a collection of technology-based interventions in agriculture (IBEF, 2022). The IT architectures for agriculture would span beyond organizational boundaries and enable the delivery of holistic and integrated services in agriculture. The future adoption of digital agriculture in India would be implementedin the Public-Private Partnership (PPP) mode.

The IDEA ecosystem shall help in effective planning towards increasing farmers' income and improving the efficiency of all processes in the agriculture sector. The government of India is undertaking pilot projects in collaboration with leading technology companies and Agtechs (Beriya, 2022).

In this regard, the government is collaborating with technological giants to build a digital infrastructure for agriculture in India. It has already signed MOUs with Microsoft,ISCO, Ninjacart, Jio Platforms Limited, ITC Limited, NCDEX e-markets Limited (NeML), Star Agribazaar, Patanjali Organic Research Institute for agricultural management and services, Amazon Internet Services, and Esri India for different operations under AgriStack.

The Digital Agriculture Mission 2021–2025 aims to support and accelerate projects based on new technologies, like AI, blockchain, GIS technology, drones and robots. These include 'farmer data sanitization', land profiling, crop estimation using remote sensing, mobile applications for advising farmers on soil nutrition, accurate quantification of farmer crop and yield, fertilizer recommendations, and farmer trainings.Additionally, the "National Agri Data Stack" can potentially serve as the primary data layer on which "agri-focussed solutions". This way a 'stack' of agricultural datasets, with their core as land records would be built to provide farmers a "Unified Farmer Service Interface" through its cloud computing services, raising troubling questions about informational privacy.

The establishment of a 'national agriculture geo hub' to provide GIS tools and technologies and create and collate farmer and other agriculture data services on the GIS platform is also envisioned under the policy.It would also provide 'Site Specific Crop Advisory' services for crops reared under the Indian agricultural system.All this would eventually help increase farmers' income and improve the efficiency of the agricultural sector.

The need to provide end-to-end services, adopting the methods of digital transformation, agile development methods, disruptive business models, and above all, the as-yet unfathomable opportunities offered by emerging technologies like AI, ML, IoT, and DLT are strong forces pushing the limits towards the evolution of digital ecosystems.

This digital architecture would be adopted at three different levels.

- Ministries of GOI
- States/ UT as per their priorities and resources in a phased manner.
- Departments intending to produce "quick wins" on their own.

Under National e-Governance Plan in Agriculture guideline, funds would be released to the States/Union Territories for the projects involving the use of modern information technologies and for customization of web and mobile applications. J&K is oneof the forerunners in making digital agriculture successful in the UT. The implementation in J&K is also underway and a steering committee has been formed.

5.4 ICRISAT-Microsoft partnership for ai in agriculture

One of the collaborations that developed out of the Digital Agriculture Mission is with Microsoft. They are developing an AI-based sowing application; Sowing App, for farmers having a personalized advisory dashboard for Andhra Pradesh, has been developed and initial results showed a 30% higher average in yield per hectare. A good harvest and subsequently, better financial returns have been reported. The apphas been developed to assist farmers in achieving optimal harvests by recommending the best times to sow based on an analysis of weather, soil, and other indicators. This app has been developed through a partnership between Microsoft, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the Andhra Pradesh government.

6. Applications of digital agriculture

Technological interventions permit farmers to gather, visualize and assess crop and soil health conditions at all stages of production, in a convenient and cost-effective approach. They can act as an early indicator to identify potential challenges and provide options to deal with them promptly by generating real-time actionable insights to help improve crop yield, control pests, assist in soil screening, provide actionable data for farmers, and reduce their workload. Blockchain technology offers tamper-proof and precise data about farms, inventories, quick and secure transactions, and food tracking. Thus, farmers don't have to be dependent on paperwork or files to record and store important data.

6.1 Implementation of digital agriculture in india

As discussed earlier, several challenges are unique to Indian Agriculture. These include the prominence of segregated small-holder farms in the country, limited penetration of mechanization tools, and frequent natural calamities, like droughts, floods, and excessive monsoon rains. All this may complicate data gathering. Thus, a customized approach would be needed to implement digital agriculture in India.

The following measures could be critical for the successful implementation of digital agriculture success in India:

- Low-cost technology would be critical for ensuring adoption.
- Portable hardware would ensure adoption in typical Indian farms which are small and scattered.
- Renting and sharing platforms for agriculture equipment and machinery would ensure a more widespread use.
- Academic support from agricultural organizations and academic institutes regularly would improve digital literacy among farmers.

6.2 SKUAST Kashmir innovations

SKUAST Kashmir is taking a lead in building innovative and hi-tech solutions to our problems in agriculture. It is rapidly transforming into India's first innovation-driven University. In this direction, anAI and IoT-based farm management information & decision support system; Smart Sheep Breeder (SSB) was developed for sheep breeding farms as well as all stakeholders of the sheep husbandry sector (Hamadani and Ganai, 2021). SSB is India's first and only tool for catering to all aspects of sheep husbandry (Figure 3). It uses complex algorithms of animal breeding, biometrical genetics, and machine learning to single out the genetically most superior sheep and for e-linking all farms for germplasm dissemination. SSB is capable of automatic data capture and generates custom-tailored reports and graphs on all aspects of each farm & has inbuilt AI algorithms. It is an e-governance tool, an e-commerce portal, e-veterinarian (real-time sheep healthcare), smart farm manager, e-entrepreneur for helping new entrepreneurs get started, and more. It supports automatic animal monitoring and performance recording through IoT-based devices.

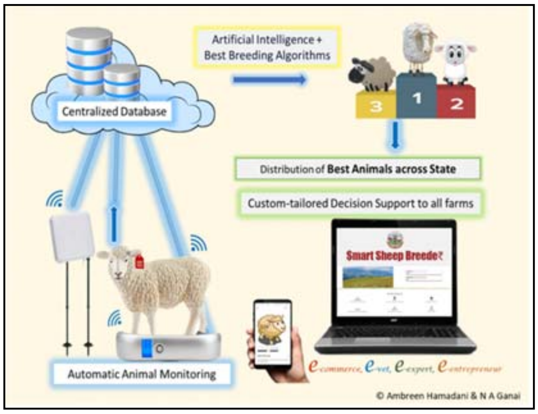

Figure 3: Smart Sheep Breeder; a SKUAST-K Innovation

SKUAST Kashmir has also built AppleDoc which is an AI-based decision support system for apple. It provides comprehensive support to apple growers of the valley from production, and weather to disease management. This is a very important tool as the apple industry is a major industry in Kashmir.

7. Conclusion

Cutting-edge technologies are rapidly enabling farmers to gather, visualize and assess crop and soil health conditions at all stages of production, in a convenient and cost-effective approach. These are helping in quickly identifying and combating challenges faced thatwere hitherto unprecedented and unavoidable. Real-time actionable insights would therefore improve crop yield, control pests, assist in soil screening, provide actionable data for farmers, and reduce their workload.Implementation of digital architecture at the national level has the potential to revolutionize agriculture and transform India into a sustainable bioeconomy.

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17. Agroforestry Potential for Carbon Neutrality: A Review

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Introduction

Agroforestry is a land use system that integrates forest crops, agriculture crops, livestock including medicinal and aromatic plants in a given space and time. Agroforestry is now emerging as a science. Empirical evidence suggests that it can provide a sound ecological basis for increased crop and animal productivity, more dependable economic returns, and greater biodiversity. It has an important role in reducing vulnerability, increasing resilience of farming systems and buffering households against climate related risk in addition to providing livelihood security. There are an estimated 1.2 billion people that depend on agroforestry farming systems, particularly in developing countries (Zomer *et al.,* 2016).

A review carried out by Dhyani *et al.* (2021) report that agroforestry, as a science, has ample potential of mitigating climate change within south Asia. Paudel and Shrestha (2022) have reviewed Agroforestry Practices Prevailing in South Asian Association for Regional Cooperation (SAARC) countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka). The review showed that agroforestry concept and practices are more or less similar in all these countries.

The Conference of Parties to the UNCFF in 2015, known as "Paris Agreement" had focused on International Climate Policy and keep the global warming below 2 degree-centigrade, initiating the new strategies that will have negative emission. Of the several measurers, avoiding deforestation and improved land management could be one of them. A project undertaken in Kerala, India to determine the interest of farmers in implementing a cost effective technique for converting current agricultural land into a more competent carbon sink showed that agroforestry with timber producing trees used in wood based construction and furniture production could result in long term carbon storage. Additionally, reduction of tree felling can also help to have long-term carbon sequestration and storage.

Agroforestry carbon neutrality

Carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks. Removing carbon oxide from the atmosphere and then storing it is known as carbon sequestration. Growing trees is one of the activities that help sequester carbon from atmosphere. And this activity can be referred to carbon neutrality, to some extent. A study conducted by J. He *et al.* (2022) suggests that enhancing agroforestry carbon sinks is one of the pathways on China's long-term low carbon transition pathways and strategies.

Agroforestry also helps to enhance carbon sequestration and to compensate for ongoing biodiversity loss (Pantera *et al.,* 2021). This system has the potential to contribute to climate change mitigation while improving livelihoods and incomes and providing important ecosystem services. Although we see complexity in agroforestry systems, agri-silvicultural, (crop + trees), silvo-pastoral systems (livestock + tree), and agri-silvo-pastoral systems (crop + livestock + tree) are some of the important systems being followed in almost all regions of the world. It has been reported that i**n** Switzerland, agroforestry systems may improve the climate balance of Swiss agriculture by sequestering carbon, as the wood obtained from this system can be used as timber/furniture wood or as a substitute for fossil energy sources (Briner *et al.,* 2011). This will reduce the greenhouse gas emissions

Agroforestry systems varies with location and edaphic factors. It is complex in nature given the socio-economic situation of the practitioners. Amatya *et al.* (2018) have identified seven agroforestry systems and 35 practices in Nepal. Some of the important agroforestry systems are (1) agri-silviculture, (2) silvo-pastoral, (3) agri-silvo-pastoral, (4) silvofi shery, (5) home gardens, (6) woodlots and (7) shifting cultivation. The number of practices and increasing.

Nath and Aziz (2013) conducted a survey of home garden having *Areca catechu*, in ecologically critical area of Cox bazaar in Bangladesh. The study concludes that carbon sequestration in homestead agroforestry can be considered permanent as complete biomass removal does not occur in comparison to other practices. Home garden are common practices in Nepal, Bhutan, and Pakistan. Likewise, homestead agroforestry and cropland agroforestry are common in Bangladesh and general practices of agri-silviculture are common in Afghanistan (Paudel and Shrestha, 2022).

Essential feature of tree species for carbon neutrality

Trees captures and store atmospheric carbon into its trucks, branches, leaves, and roots. It is said that trees having large trunks, dense wood are the best absorber of carbon. Trees having large leaves and wide crowns also help absorber atmospheric carbon. It is also said that trees store most carbon during their first decades. Fast growing trees are more desirable than the slowing growing ones. It is better if they are indigenous as this helps them to thrive in the native soil, having low maintenance cost.

Almost all tree species sequester carbon to some extent. Research on this issue is limited. If we are to recommend tree species for a carbon neutrality, we have to look at several other issues of agroforestry. Which trees absorb more carbon than others? It is very difficult to answer this question in the absence of adequate research. It is because, carbon sequestration rates vary by tree species, soil type, regional climate, topography, and management practice. There is no data available which tree species sequester more carbon, although but we can get some idea from the USA. It has been reported that Pine plantations in the Southeast USA can accumulate almost 493 metric tons of carbon per hectare after 90 years, or roughly one metric ton of carbon per acre per year. Changes in forest management (e.g., lengthening the harvest-regeneration cycle) generally result in less carbon sequestration on a per acre basis. Changes in cropping practices, such as from conventional to conservation tillage, have been shown to sequester about 0.25 – 0.75 metric tons of carbon per hectare per year.

Pütsep (2021) report that Pine species such as red Ponderosa, white Ponderosa and Hispaniolan pines and Oak trees are known to absorb a lot of carbon. Other evergreen trees that are good carbon absorber are tall Douglas firs and Bald cypress. Among the deciduous trees that absorbs carbon are Horse-chestnut and Black walnut. Teak tree,has the highest carbon sequestration capacity.

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Unfortunately, Pine species are not favored by agroforestry practitioners of almost all South Asian Countriesas these species tend to make soil acidic and other species hardly thrives as undergrowth. Similar is the case with Teak trees. Trees having lateral rooting properties (such as Ficus) are also not desirable in agroforestry practices as they compete with agriculture crops. One of the essential features of agroforestry tree species, in my opinion, is that these trees should have deep tap root system so that there is no or little completion for moisture, nutrients both for tree and agriculture species. Sthapit (1996) had carried out some study on Wind thrown Tree Roots of species such as *Acacia catechu*, *Adina cordifolia*, *Albiziaia lebbek*), *Dalbergia sissioo*), *Lagerstroemia parviflora* and some fruit trees. The study showed that majority of these species have deep tap root.

It has been reported by Boumenjel *et al.* (2021) that *Moringa oleifera* (drum stick) is a promising choice in arid zones of Tunisia. Similarly, Gliricidia (*Gliricidia sepium*) is a good species which supports agriculture production and provides services to environment. We need to test these trees in our environment.

The Seventy-eighth session of Economic and Social Commission for Asia and the Pacific (ESCAP) recently (May, 2022) has reviewed the implementation of the 2030 Agenda for Sustainable Development in Asia and the Pacific. The review highlights the opportunities in several sectors and emerging initiatives for raising climate ambition in the region, including blue carbon, ecosystems-based climate solutions, energy, sustainable cities, transport, trade and investment, and business.

Conclusion

Reducing Emission from Deforestation and the Forest Degradation (REDD) employing agroforestry practices, is one of the approaches that can help mitigate the effect of climate change to some extent and sequester atmospheric carbon. Carbon accumulation in forests and soils eventually reaches a saturation point, beyond which additional sequestration is no longer possible. This happens, for example, when trees reach maturity, or when the organic matter in soils builds back up to original levels before losses occurred. Even after saturation, the trees or agricultural practices would need to be sustained to maintain the accumulated carbon and prevent subsequent losses of carbon back to the atmosphere.

Many countries of the world are now working on REDD + concept (Reducing Emissions from Deforestation and forest Degradation) and have adopted UNFCCC definition which directly or indirectly contribute to reduce emission form forest degradation and deforestation through various ways and agroforestry is one such activity. A review on "Sustainability Challenges" edited by Cheikh Mbow (2014) and his colleagues recently showed that in addition to carbon benefits, agroforestry has the potential to deliver sustainable development goals.

Among the SAARC countries, Agroforestry practices are technologically advanced in India whereas it is slowly gaining momentum in other. All South Asian Countries have some sort of policy of forestry development in place. India and Nepal have their National Agroforestry Policy in place. Now the need is to implement them in the field. But as agroforestry systems and practices are very complex in nature, it is difficult to have carbon neutrality only from the lens of agroforestry.

Nepal is trying to achieve net zero emission by 2045. In this context, the World Bank has made a press release on September 15, 2022. Although the press release does not explicitly record agroforestry as one of the approaches to combat the effect of climate change and reduce the level of air pollution, it has emphasized to take integrated approach to water, agriculture and forests as one of the key strategies to build resilience towards climate change. In Nepal, different agroforestry systems and practices are prevailing in all five physiographic regions (Terai, Siwaliks, Middle Mountain, High Mountain and High Himal). The tree species planted in these systems have certainly helped in absorbing carbon from atmosphere. But the crucial point is that research is must needed to identify the absorbing capacity of these species (how much carbon is absorbed per unit area by species).

Monitoring of carbon stock dynamics is a crucial for successful and effective implementation of agroforestry. Agroforestry is not equally effective as carbon neutral strategy for all regions of the globe. One of the most difficult task is the choice of the agroforestry species, given its ability to grow in a given location under the climatic and edaphic condition. Dhyani et al. (2021) have identified some of the agroforestry implementation problems in this region of the World including carbon neutrality scenarios.

I reckon, The South Asian Association for Regional Cooperation (SAARC), which was established to promote socio-economic, scientific, and technical development within the SAARC countries, should take a lead role in identifying carbon neutral agroforestry practices. Similarly, other lead Government and Non-Governmental organizations of the World should take appropriate measurers for enhancing agroforestry practices that would neutralize carbon. UN agencies like ESCAP should also be instrumental in identifying tree species that absorbs carbon and its combination for successful agroforestry practices.

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18. Sustainable Animal Production in a Climate Change Impacted Ecosystem

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Keywords: Climate-change, ecosystem, animal production, animal health

1. Introduction

Climate change represents lasting changes in weather and temperature patterns caused due to natural cyclic patters or human interferences. The past few decades have witnessed unprecedented and alarming level of climate changes. Consequently, human, animal and plant populations are getting noticeably adversely affected. On the one hand climate change may lead to warming of oceans, melting of glaciers and rising of sea levels, and on the other hand it may lead to severe transformed weather patterns including storms, exceptional and untimely rains, drought, heat waves and other related changes. Such land and environment variations directly impact domestic and wild animal populations, and have a bearing on the ecosystem/vegetation upon which the animals are dependent. Variations, particularly if they are long-lasting, cause shifts in the ecosystem due to which the adaptability of the animals is affected. In turn this affects their health, and hence the productivity in the long run.

One of the biggest culprits in the manifestation of climate change is the ever-increasing amount in CO2 emission. Unfortunately, once released, the CO2 together with other contributing gases, will stay in the atmosphere for several decades to come. It has been noted that, the CO2 amounts has doubled since the onset of industrial revolution almost a hundred years ago and it is projected to stay in the atmosphere for several hundred (even thousands) years trapping the heat, and constantly contributing to increases in the surface or air temperatures. As indicated by the UN intergovernmental panel for climate change in their Global Food Policy Report 2022 the rapidly changing patterns in climate change are generating "code red for humanity" (Swinnen et al. IFPRI GFPR 2022). The "code-red" applies unquestionably also to animals. There are hints that the reliability of animal production will be in serious question due to climate change associated variations like higher average global temperatures and more extreme weather occurrences (Gerber et al., 2013). Hence, serious efforts are needed to manage the situation at multiple levels because the causes and the ripple effects are multiple.

2. Climate change and animal production

The highest impact of climate change is unfortunately expected to be in countries that are already on the lowest rung of food availability and affordability. While both animal production and animal care are already marginal in these countries, sparse vegetation and low agriculture production further exacerbate availability of fodder for animals. Climate change simply adds to the existing woes and makes a bad situation worse. Resultant drought or floods cause erosion or degradation of topsoil due to which the crops, forests or ground vegetation is destroyed leading to reduced availability of fodder for animals, thus adversely impacting animal production and health. Unfortunately, loss or reduction of vegetation (including trees) is a loss of natural sinks that can sequester harmful emissions. Additionally, the losses disrupt the highly efficient cyclic ecosystem of a variety of microorganisms, insects, pests and such, increasing the potential of new diseases or the spread of existing diseases in new regions where previously they were non-existent. Thus, climate change is consistently causing new challenges that may appear small in the present context, however, looking at the big picture and the future, the prospects appear deeply worrisome for sustainable animal agriculture.

Changes in climate impact the physiology, adaptability, breeding habits and reproduction of animals. Evidently, impact on all these factors are directly tied to health and production of animals (USDA 2016), which in turn affects the economy of the farmers/producers. Climate change also has a major impact on the availability of grazing lands and the types of available edible vegetation for the animals. Any shrinkage or change in the ranges and the vegetation affects the survival of the animals and it also disturbs their productivity. Moreover, the cyclic patterns of animal reproduction are most impacted by weather shifts, and therefore the patterns have a direct bearing on production – both milk and meat.

3. Climate change and animal health

Climate change and the variations it introduces in the ecological conditions has the potential to spread new set of pathogens, parasites, pests and diseases that can seriously jeopardies health, and hence the production in animals. Health impacts also include gastrointestinal illnesses from diverse waterborne pathogens, systemic disorders and respiratory diseases. Of particular concern are the transmissible infectious diseases. Furthermore, surfacing of vector borne diseases like those from ticks and fleas are indeed concerning. These vectors are key transmitters of diverse disease-causing organisms that can have devastating impact on animal populations. Next, climate change may contribute to diverse allergies and can also affect respiratory health. During recent years, unprecedented wildfires have ravaged across many continents. While these reduce the habitat and grazing lands of animals, they also add to constantly increasing global pollution and to smoke related pulmonary problems. Essentially, climate change causes unprecedented and unanticipated health problems in places and times of the year where they have not previously occurred. The lack of preparedness for such unanticipated health challenges exacerbates the problem further.

Climate change is causing heat waves in places where they were not registered in the past. In 2011, such episodes led to over $1 billion in losses because of increased vulnerability to diseases, reduced fertility and reduced milk production. Increased temperatures threaten pastures, grazing lands and feed supply. Warmer than usual temperatures promote some parasites and pathogens that undesirably affect animal health and production. Moreover, climate change induced extreme heat, drought and water scarcity affects overall immunity of the animals and opens the door to various disease that otherwise can be fended off easily due to innate defense threshold of animals.

4. Climate change and fish production

Climate change can have a devastating impact on fish production both in coastal and inland areas. Migration of fish

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species due to climate change induced temperature changes expose fishes to new unchartered environments that can be determinantal to their health, specially knowing that fishes are very sensitive to water temperature fluctuations. Moreover, migration to newer areas can increase competition for food and other resources. Thus, fish populations are experiencing new challenges due to climate change induced altering environments.

5. Conclusions

Livestock production, particularly meat and dairy production, accounts for ~15% for GHG emissions. In order to rein in on climate change, we will have to seriously consider reduction in dairy and meat consumptions through policy shifts that promote plant-centric diets (Hedeneus et al., 2014; Kim et al., 2020). Next, while there is discussion to engage in climate-smart animal production, the proportion of effort and finance to support/promote it globally is a mere miniscule of today's climate finances. Serious sustained investment is therefore needed to ensure that the most serious contributors to climate change are tackled on a global basis jointly by all countries and remedial means must be prepared should the situation becomes more challenging than now.

It is notable that 20-30% of the plant and animal species thus far evaluated in the climate change studies are at a risk of extinction if the changes keep occurring at the rate currently witnessed (IPCC). As of now, overall projections for the future are worrisome. Animal health and animal production are critical components of the human food chain/systems. Due vigilance, constant research and implementation of remedial measures must go in parallel on the agriculture and animal front to protect them from the perils of climate change because they are foundational for the survival of humanity.

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19. Making Agriculture ClimateResilient: The Farmers' Way*

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1. Introduction

Agriculture in most developing countries is low-producing (Fuglie *et al.*, 2020) and highly exposed to climate and non-climate risks (Dell, Jones and Olken 2012, Loayza, Olaberria and Rigolini2012, Ortiz-Bobea *et al.,* 2021), affecting the livelihood of millions of small-scale producers and poor consumers.The recent estimates show that since 1961 the climate change has slowed downthe productivity growth of world agriculture by 21%, and the effect has been more pronounced in developing countries located in the arid and semiarid tropics (Ortiz-Bobea *et al.,* 2021). Birthal, Hazrana and Negi (2021a) provide similar evidence from India—theclimatic shocks, since 1980, could reduce agricultural productivity growth by one-fourth, and the reduction being bigger in the poor and agrarian states.

Farmers face multiple risks and sometimes simultaneously. They do not accept the risk threats to thefarming and their livelihoods passively. Based on the probability of theiroccurrence, they followseveral risk managementmeasures, the traditional and the modern,ex-ante and ex-post the shocks, to reduce theiradverse effects on agriculture and their livelihoods.However, the market for modern risk management measures like the insurance is underdeveloped. Farmers also lack access to information and finances for the adoption of modern risk management measures (Ali, Abdulai and Mishra 2020; Binswanger-Mkhize, 2012; Mendelsohn, 2012). A majority ofthe farmers, thus, relies on the traditional risk management measures, including mulching, soil and water conservation, shifts in planting dates, input manipulations, diversification into low-risk,high-value crops and animal husbandry, non-farm employment and small-scale businesses, out-migration, borrowings, and sales of non-productive as well as productive assets (Jodha, Singh and Bantilan 2012, Binswanger-Mkhize, 2012). When farmers confront multiple risksand often more than one at a time, a single adaptation measure is unlikely toprovide an effective solution to all types ofrisks. Depending on their risk preferences, knowledge of mitigation and adaptation measures and liquidity constrains, farmers often use more than one measure at a time (Jodha, Singh and Bantilan 2012, Kakraliya *et al.,* 2018). Acombination of the adaptation measures also allowsthem to benefit from thecomplementaritiesamong these measures.

Several studies have assessed the effects ofdifferent adaptation measures on agricultural performancebut mostly of a single measure ignoring the effects of other measures (e.g., Dalton,Porter and Winslow 2004; Di Falco and Chavas 2008, 2009; Yesuf, Kassie and Kohlin 2009, Wossen *et al.,* 2017, Amondo *et al.,* 2019, Birthal *et al.,* 2015, Birthal and Hazrana 2019, Zaveri and Lobell 2019, Makate *et al.* 2018). There are only a few studies thathave analyzedthe effects of multiplemeasures on farm income and risk exposure (Kassie *et al.,* 2015; Teklewold *et al.,* 2013; Teklewold *et al.,* 2017; Vigani and Kathage 2019, Collin-Sowah and Henning 2019, Amondo *et al.,* 2019).

This paper identifies farmers'self-risk adjustment measures and their portfolios and then looks into their effects on farm income and its resilience to climatic shocks.The issue is important in an agrarian set-up as in India, which is dominated by smallholders, a majority of them because of the information and liquidity constraints is unable to adopt the modern risk instruments like crop insurance, and is compelled to use traditional agronomic and resource management practices that not only enhance the crop yields but also reduce their sensitivity toclimate change (Jodha, Singh and Bantilan 2012). Most of suchstudies compare crop yields with and without adaptation, ignoring its impact on yieldvariability.Arigorous economic analysis of the impact of traditional adaptation measures on risk reduction is still lacking.

2. Description of traditional risk adjustment measures

Farmers use several measures to manage the adverse effects of climate risks on agriculture and their livelihoods. Birthal, Hazrana and Negi (2021b) screened agricultural practices from a nationally representative survey of farm households in India for their risk attributes and found several of them providing a cushion against climatic shocks (details on data and methodology are given in Appendix 1). Based on their risk functions, these have been categorizedas (i) risk-mitigating, (ii) risk-transferring, and (iii) risk-coping measures. A risk mitigation measure is implemented prior to the occurrence of a risky event to effectively manage its adverse effects. A risk transfer measure shifts the expected output loss from farmers to financial institutions against a fee or premium or to other farmers through a tenancy contract. A risk coping measure is taken oncethe event has occurred.It helps farmers absorb and/or recover from it.

Table 1 presents the frequency distribution of adaptation measures by their risk functions. Farmers excessively rely on risk-mitigating measures. Livestock are less vulnerable to climatic shocks; hence they act a cushion against climate or income shocks. They produce a regular stream of outputs which farmers can sell for cash to meet the household expenditure. In case of a severe climatic shock, farmers may also be compelled to sales of live animals. More than 62% of the farm households are engaged in livestock production. Likewise, diversification into horticultural crops (i.e., vegetables, fruits, spices, medicinal and aromatic plants) that are more remunerative compared to the widely grown staple food crops, and generate a regular stream of outputs is an important ex ante measure of risk management. Close to 31% of the farm households have reported to grow high-value crops.Non-farm business activitiesare reported by 5% of the farm households.

Crop insurance and renting-out land are the two important means of transferring or sharing risk. In fact, the

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tenancy has been traditionally practiced in Indian agriculture as a risk sharing mechanism. The adoption of risk-transferring measures, however, is low. Renting-out of land is limited to only 4.1% of the households, and crop insurance used by 6.3% of the households.

Table 1 Frequency distribution of risk management measures

Measure/strategy	No. of households	% of total
No risk management	5385	15.30
Risk mitigation		
Cultivation of horticultural crops	11,007	31.27
Ownership of non-farm business	1,883	5.35
Ownership of livestock	21,740	62.11
Risk transfer		
Subscribe crop insurance	2,202	6.23
Renting-out of land	1,447	4.11
Risk coping		
Guaranteed employment (MGNREGA)	4,684	13.31
Out-migration	2,353	6.68
Remittances	3,734	10.61
Livestock sales	1,500	4.26
Total number of households	35,200	

Note: Sum of individual measures will not be equal to the total number of households because of the use of more than one measure by several households.

Once a climatic event has occurred, the farm households are compelled to adopt several measures to cope with its adverse effects. Most of these measures do not directly influence agriculture, and but are more related to management of livelihoods. These include the out-migration, receipt of remittances, off-farm employment and sale of assets. The out-migration (defined as staying away from a family member from his/her permanent residence at least for 15 day-employment) has been reported by 6.7% of the farm households, and the receipt of remittances by 10.6%. Sale of live animals is rare, only 2.3% of the households have reported the sale of animals.

From 2006 onwards, the Government of India has been implementing an employment guarantee scheme called the 'Mahatma Gandhi National Rural Employment Guarantee Act' (MGNREGA). The scheme provides guaranteed employment of 100 days to the willing households. Although, this scheme is not targeted to manage agricultural risks, butseveral of its components directly influence agriculture. Besides, the guaranteed wages supplement the household income and smoothen the household consumption in case of an adverse climatic shock (Fischer, 2020). Besides, wage incomeby relaxing the liquidity constraints help farmers adopt direct risk management measures ex-post the risk (Hansen *et al.,* 2019, Fischer 2020). Approximately 13% of the farm households have reported to have benefited from employment guarantee scheme.

Overall, 85% of the farm households have used one or the other adaptation measure ex ante or ex post the risky event to reduce its adverse effects on agricultural production and household welfare. Rest of the households who did not use the identified measures are considered as non-adopters.

It is sufficiently evident that farm households use more than one measure to manage adverse effects of climate risks. Thesemeasures have beengrouped intorisk-mitigating, risk-transferring and risk-coping measures,and were re-grouped to evolve risk management portfolios or strategies (Table 2). Most farm households have used risk-mitigating measures alone (46%). Stand-alone, implementation of the risk-coping and risk-transferring strategies is restricted to 6.9% and 1.6% of the farm households, respectively. Rest of the farm households have used these strategies in conjunction.

Table 2 Frequency distribution of risk management portfolios

Strategy/ Portfolio	Portfolio ID	No. of households	% of total
No risk management	N	5385	15.30
Risk mitigation alone	M	16368	46.50
Risk transfer alone	T	549	1.56
Risk coping alone	C	2419	6.87
Risk mitigation + risk transfer	MT	1905	5.41
Risk mitigation + risk coping	MC	7462	21.20
Risk transfer + risk coping	TC	264	0.75
Risk mitigation + risk transfer + risk coping	MTC	848	2.41
Total number of households		35200	100

3. Determinants of adoption of risk management strategies

Table 3 presents means and standard deviations of important characteristics of the non-adopters versus adopters of different risk management portfolios. There are three sets of characteristics. The first set includes the risk variables in terms of climate anomalies measured as standardized deviations of the rainfall and temperature from their respective long-term averages for all the districts to which the sample households belong to. The assumption is that farmers' decision to adopt or not adopt a risk management strategy is guided by their past exposures to climate shocks.

Another set of variables that have been hypothesized to influence farmers' risk preferences and choices of risk management strategies includes the demographic characteristics like household size, caste, and age, gender and education of the household-head; and institutional factors like farmers' access to credit, information and social safety nets (i.e., public food distribution system and employment guarantee scheme, and awareness of the policy of minimum support prices). Farmers' social status has also been hypothesized to differentiate them in their risk preferences and risk management decisions. In India, caste is an important form of social status, and it is represented as viz., scheduled caste (SC), scheduled tribe (ST), other backward caste (OBC) and upper or other caste. The SC and ST are at the bottom of the caste hierarchy, and the upper castes are at the top. The third set of explanatory variables comprises of farm and locational characteristics. These are the farm size, irrigation status and crop counts for individual sample households, and slope and altitude of the districts towhich the sample households belong to. Farm size and irrigation have been hypothesized to influence farmers' risk preferences, directly or indirectly mediated through crop yields (Sherrick *et al.,* 2004; Birthal *et al.,* 2015; Zaveri and Lobell, 2019).

Further, theyhave also includedMundlak fixed effects as the district averages of important farm inputs (fertilizers, seeds, pesticides and wages) to controlthe unobserved heterogeneity across farms. For example, a farmer having knowledge about the soil and water characteristics may adjust the input use accordingly.

To analyzethe farm households' risk management decisions and their impacts on agricultural productivity and resilience Birthal *et al.* (2021) have followedatwo-stage multinomial endogenous switching regression (MESR) approach that provides bias-corrected estimates of the impact (see Birthal, Hazrana and Negi 2021b). In its first stage the MESR models the risk management decision, i.e., whether to adopt or not a risk management measure and if adopt then what to adopt. In its second stage, MESR assesses the impact of risk management strategies on farm income incorporating the inverse Mills ratio (IMR) from the first stage to control for the selection biases arising due to farmers' selction of a risk management strategy or targeting of a select group of farmers by a risk management program.

Table 3: Variable definitions and summary statistics

Variables	Non-adopters		Adopters		t -value for difference in means	All	
Demographic characteristics							
Age of the household head (Years)	49.17	(0.19)	50.94	(0.08)	-8.90***	50.67	(0.07)
Gender of the household head (Male)	93.11	(0.35)	91.31	(0.16)	4.39***	91.58	(0.15)
Literate (%)	34.00	(0.65)	34.49	(0.28)	-0.69	34.41	(0.25)
Schedule caste (%)	17.53	(0.52)	19.22	(0.23)	-2.91***	18.96	(0.21)
Schedule tribe (%)	15.64	(0.49)	12.80	(0.19)	5.65***	13.24	(0.18)
Upper caste (%)	28.54	(0.61)	27.29	(0.25)	-3.30***	27.48	(0.23)
Other backward classes (%)	38.29	(0.66)	40.69	(0.28)	1.90***	40.32	(0.26)
Household size	4.79	(0.03)	5.46	(0.02)	-16.83***	5.36	(0.01)
Sex ratio	1.06	(0.01)	1.09	(0.00)	-2.33**	1.09	(0.00)
Farm characteristics							
Area irrigated (%)	50.44	(0.64)	49.64	(0.26)	1.18	49.77	(0.24)
Crop counts (No.)	1.66	(0.01)	2.29	(0.01)	-31.82***	2.19	(0.01)
Land owned (ha)	1.18	(0.02)	1.42	(0.01)	-9.73***	1.39	(0.01)
Slope (Degree)	3.42	(0.02)	3.53	(0.01)	-5.03***	3.52	(0.01)
Altitude (Metre)	315.68	(5.85)	374.70	(3.38)	-7.09***	365.67	(3.00)
Institutional characteristics							
Access to information (%)	40.61	(0.67)	47.83	(0.29)	-9.78***	46.72	(0.27)
Access to institutional loans (%)	47.87	(0.68)	52.32	(0.29)	-6.01***	51.64	(0.27)
Awareness about Minimum Support Prices (%)	23.29	(0.58)	27.07	(0.26)	-5.79***	26.49	(0.24)
Possession of BPL ration card (%)	40.06	(0.67)	34.64	(0.28)	7.65***	35.47	(0.26)
Risk characteristics							
Mean temperature (°C)	25.60	(0.02)	25.05	(0.01)	17.23***	25.13	(0.00)
Positive temperature deviations	4.21	(0.02)	4.40	(0.01)	-1186**	4.36	(0.00)
Negative temperature deviations	3.86	(0.01)	3.83	(0.00)	1.91*	3.83	(0.00)
Mean rainfall (mm)	1260.94	(9.50)	1317.68	(4.41)	-5.09***	1309.00	(4.01)
Positive rainfall deviations	3.27	(0.09)	3.65	(0.04)	-3.85***	3.60	(0.03)
Negative rainfall deviations	2.12	(0.53)	3.05	(0.03)	-1255***	2.91	(0.03)
Instruments							
Formal training in agriculture (%)	3.10	(0.24)	3.64	(0.11)	-1.97**	3.56	(0.10)
Net assets (Rs/household)	4740.16	(0.24)	11337.57	(0.11)	-3.69***	10328.28	(0.10)

Note: BPL stands for below poverty line. Standard errors are in parentheses.

The results of the first stage logit equationon the determinants of adoption of risk management portfolios are reported in Table 4. Lets first look at the coefficients of risk varaiables. The probability of adoptingrisk management strategies is higher in the case of deficit rainfall and excess temperature.

Theage and education of the household headis positively associated with adoption of risk management strategies. Household size (a proxy for availability of labour)also positively influence farmers'risk managementdecision, meaning that risk-averse farmers, in the absence of opportunities for employment outside agriculture,often utilize the surplus family labour in perfromingthe agricultural practices enhance farm productivity and its resilience to climate change. Along the caste hierarchy, the probability of adoption of risk management strategies is higher among the lower-caste households. On the other hand, a positive coefficient on land size suggests that large farmers are more inclined to adopt risk management strategies.

There are few other important observations emerging from the first stage MESR. One, the coefficient on farmers' access to information is consistently positive and significant across all risk management strategies. So is the coefficient on their access to credit. This implies that relaxing theinformation and liquidity constraintscan motivate farmers to adopt risk management strategies. Farmers' awareness about guaranteed output price also positively influences farmers' decision to adopt risk management strategies. In contrast, farmers' access to food security nets and employment guarantee scheme are found to reduce the requirement for risk management. Note, depending on farmers' risk preferences or degree of risk aversion, their access to such social safety nets can influence their risk management decisions positively as well as negatively.

Table 4: Estimates of the multinomial Logit model (dependent variable: probability of adopting risk measures)

	M		T		C		MT		MC		TC		MTC	
Farmer characteristics														
Age of the household-head	0.3255***	(0.0620)	0.2862*	(0.1774)	-0.1434	(0.0949)	0.2463**	(0.1078)	0.5235***	(0.0720)	-0.0716	(0.2659)	0.8832***	(0.0620)
Gender of the household-head	-0.0117	(0.0697)	-0.3794	(0.1823)	-0.8570***	(0.0884)	-0.3258**	(0.1180)	-0.8198***	(0.0723)	-1.2743***	(0.2132)	-0.9554***	(0.0697)
Education of the household-head	0.0589	(0.0386)	0.1914*	(0.1168)	0.1490**	(0.0587)	0.0882	(0.0674)	0.0181	(0.0440)	0.3395**	(0.1787)	0.1528*	(0.0386)
Caste of the household														
Schedule caste	0.2375***	(0.0574)	-0.2884	(0.1817)	0.8489***	(0.0866)	-0.1085	(0.1024)	0.9053***	(0.0641)	0.4843**	(0.2520)	0.3986**	(0.0574)
Schedule tribe	-0.0092	(0.0555)	-0.1526	(0.1739)	0.4633***	(0.0878)	-0.3588***	(0.1080)	0.2452***	(0.0657)	0.3119	(0.2563)	0.0683	(0.0555)
Other backward classes	0.2856***	(0.0424)	0.1051	(0.1126)	0.4288***	(0.0730)	-0.0036	(0.0667)	0.5456***	(0.0503)	0.3130*	(0.1918)	0.4166***	(0.0424)
Household size	0.3687***	(0.0362)	-0.1674*	(0.0960)	0.1909***	(0.0557)	0.0696	(0.0588)	0.5847***	(0.0415)	0.1132	(0.1495)	0.3904***	(0.0362)
Sex ratio	0.0547**	(0.0226)	-0.1384**	(0.0680)	-0.0532	(0.0361)	0.0149	(0.0376)	-0.0651**	(0.0262)	-0.2455**	(0.1124)	-0.0922*	(0.0226)
Farm characteristics														
Land owned	-0.2010***	(0.0111)	0.4393***	(0.0474)	0.0095	(0.0169)	0.3815***	(0.0290)	-0.2542***	(0.0127)	0.3142***	(0.0640)	0.2669***	(0.0151)
Irrigation	-0.3866***	(0.0423)	-0.3285**	(0.1153)	0.0240	(0.0632)	-0.6492***	(0.0740)	-0.5806***	(0.0487)	-0.3776**	(0.1755)	-0.8987***	(0.0173)
Crop counts	0.4953***	(0.0173)	-0.1560**	(0.0499)	-0.1311***	(0.0291)	0.4693***	(0.0256)	0.5943***	(0.0191)	-0.1227	(0.0789)	0.5317***	(0.0111)
Slope of the district	0.1181***	(0.0151)	-0.0971**	(0.0492)	0.0319	(0.0221)	0.1418***	(0.0308)	0.2945***	(0.0172)	0.0916	(0.0763)	0.2593***	(0.0199)
Altitude of the district	-0.2068***	(0.0199)	0.2137***	(0.0589)	-0.0389	(0.0297)	-0.2292***	(0.0371)	-0.2968***	(0.0232)	0.0312	(0.0934)	-0.3842***	(0.0369)
Institutional characteristics														
Access to information	0.2159***	(0.0369)	0.2809**	(0.1021)	0.1153**	(0.0576)	0.2278***	(0.0609)	0.1598***	(0.0422)	0.2959*	(0.1571)	0.3670***	(0.0426)
Access to institutional credit	0.2411***	(0.0355)	0.6203***	(0.1055)	0.0573	(0.0556)	0.9959***	(0.0640)	0.3444***	(0.0408)	0.6539***	(0.1618)	1.0421***	(0.0370)
Awareness about MSP	-0.0644	(0.0426)	0.7100***	(0.1072)	-0.0581	(0.0698)	0.5214***	(0.0645)	-0.0892*	(0.0494)	0.4332**	(0.1727)	0.2609**	(0.2612)
Possession of BPL ration card	-0.1605***	(0.0370)	-0.0977	(0.1086)	-0.2455***	(0.0552)	-0.2656***	(0.0687)	0.0273	(0.0419)	-0.0252	(0.1603)	-0.0767	(0.0254)
Risk characteristics														
Temperature	-0.6434***	(0.2612)	0.4270***	(0.8848)	-0.5990***	(0.4003)	-0.0995**	(0.4802)	-0.8264***	(0.2962)	0.4761	(1.3120)	-0.6140***	(0.0849)
Temperature deviation (+)	0.0713**	(0.0254)	0.1027	(0.0682)	0.1311***	(0.0402)	-0.0577	(0.0411)	0.0434	(0.0292)	0.0171	(0.1080)	0.0796	(0.0059)
Temperature deviation (-)	-0.0289*	(0.0156)	0.0348	(0.0436)	0.0682**	(0.0245)	0.0146	(0.0259)	0.1316***	(0.0181)	0.1294*	(0.0692)	0.1323***	(0.0044)
Rainfall	-0.6698***	(0.0849)	1.0835***	(0.2547)	0.9814***	(0.1343)	0.1638	(0.1503)	-0.0608	(0.0948)	0.8881**	(0.3898)	0.7524***	(0.0952)
Rainfall deviation (+)	0.0427***	(0.0044)	-0.0681***	(0.0150)	-0.0630***	(0.0072)	-0.0196**	(0.0080)	0.0011	(0.0050)	-0.0827***	(0.0233)	-0.0497***	(1.4824)
Rainfall deviation (-)	0.0484***	(0.0059)	0.0866***	(0.0153)	0.0263**	(0.0101)	0.0798***	(0.0091)	0.0815***	(0.0066)	0.0793***	(0.0245)	0.1214***	(0.0045)
Instruments														
Formal training in agriculture	0.0705	(0.0952)	0.0685	(0.2212)	0.1282	(0.1456)	0.2042	(0.1361)	0.2510**	(0.1067)	0.5688*	(0.2943)	0.4839	(0.0620)
Net assets	0.0322***	(0.0045)	0.0067	(0.0119)	-0.0333***	(0.0072)	0.0603***	(0.0073)	0.0345***	(0.0051)	-0.0433**	(0.0194)	0.0382***	(0.0697)
Constant	19.9640***	(1.4824)	-26.5491***	(4.6512)	-5.7021	(2.3512)	-0.9682	(2.6538)	12.0788***	(1.6706)	-16.9383**	(7.1415)	-6.1727*	(0.0386)
Joint-significance of district dummy variables: χ2 (15)	36.23**		72.33**		46.56***		56.99**		57.45***		71.26**		89.16**	
Joint significance of excluded instruments in productivity functions: χ2 (8)	19.53**		20.36**		14.36**		15.48**		25.89**		14.87**		12.10**	
Joint significance of household varying covariates: χ2 (10)	36.66**		39.98***		24.64**		49.10**		35.36**		45.66**		42.64**	
Wald χ2							365.69***							

Notes: These models were estimated including the full set of controls. N= no risk management the reference category. M= risk mitigation, T= risk transfer, C = risk coping, MT = risk mitigation + risk transfer, MC = risk mitigation + risk coping, TC = risk transfer + risk coping, and MTC = risk mitigation +risk transfer+ risk coping.
Bootstrapped standard errors are reported in parenthesis. ***, **, * represent 1%, 5%, and 10% significance level, respectively.

4. Impacts of risk management strategies

The bias-corrected estimates of different risk management portfolios and several other covariates influencing the mean income, its variance and skewness yieldsome important findings that merit attention. In the mean function, agricultural productivity is positively associated with irrigation, and access to information and institutional credit. In contrast, the farm size and food security nets have a negative impact on it. In the variance function, irrigation, crop diversification and access to information are found to reduce variance in agricultural productivity, while the farm size and access to institutional credit and food security nets have an opposite effect. In the skewness function, a positive sign on an explanatory variable indicates its risk-reducing role, and accordingly, the farm size, irrigation, credit and food security nets appear to reduce skewness in farm productivity.

The estimates of the second stage MESR have been used to estimate the average treatment effects for the treated (ATT), that is what would have been the productivity for adopters had they notadopted the risk management measures (See Birthal *et al.,* 2021).The implementation of the risk management strategies, independently or jointly, improves farm productivity (Table 5). The payoffs are higher to risk mitigation, followed byrisktransfer and riskcoping strategies. More importantly, their joint implementation is more effective compared to any of these when implemented in isolation.

All the risk management strategiesare found to reduce variance in productivity and as expected the reductionis largerin the case of their joint adoption. Similarly, all the risk management strategies reducefarmers' exposure to downside risk, but a greater reduction is found in case of theirjoint adoption.

From these findings it is amply evident thattraditional agricultural practices are effective not only in improving agricultural productivity but also in reducing farmers' exposure to downside risk. Importantly, their joint adoption is even more effective.

Table 5: Average treatment effects for the treated (ATT)

Risk portfolio	Non-Adoption (j=1)	Adoption (j=2, …,8)	Adoption effect	% change
Mean of farm income				
Risk mitigation	7.4678(0.0600)	7.5630 (0.0578)	0.0952	24.51
Risk transfer	7.1332(0.3542)	7.1914 (0.2964)	0.0582	14.35
Risk coping	7.2651(0.1427)	7.3081 (0.1344)	0.043	10.42
Risk mitigation + risk transfer	7.5301(0.2030)	7.6780 (0.1570)	0.1479	40.58
Risk mitigation + risk coping	7.3942(0.0805)	7.4564 (0.0758)	0.0622	15.41
Risk transfer + risk coping	7.3279(0.8580)	7.3954 (0.9955)	0.0674	16.8
Risk mitigation + risk transfer + risk coping	7.3896(0.4609)	7.5109 (0.4779)	0.1213	32.23
Variance of farm income				
Risk mitigation	0.6171(0.2055)	0.5503 (0.1923)	-0.0669	-16.64
Risk transfer	0.4203(0.1649)	0.3661 (0.1376)	-0.0543	-11.75
Risk coping	0.3397(0.1057)	0.2929 (0.1484)	-0.0468	-10.22
Risk mitigation + risk transfer	0.6157(0.1397)	0.5248 (0.1958)	-0.0908	-18.87
Risk mitigation + risk coping	0.6385(0.1958)	0.5569 (0.1846)	-0.0816	-17.13
Risk transfer + risk coping	0.5063(0.1641)	0.4351 (0.1066)	-0.0711	-15.11
Risk mitigation + risk transfer + risk coping	0.4161(0.1951)	0.3182 (0.1688)	-0.0978	-20.17
Skewness of farm income				
Risk mitigation	0.0775 (0.0353)	0.1236 (0.0414)	0.0461	11.2
Risk transfer	0.0769 (0.0419)	0.1056 (0.0447)	0.0287	6.83
Risk coping	0.1718 (0.0556)	0.2249 (0.0626)	0.0532	13.02
Risk mitigation + risk transfer	0.1358 (0.0535)	0.1885 (0.0519)	0.0527	12.9
Risk mitigation + risk coping	0.1385 (0.0364)	0.1833 (0.0332)	0.0448	10.86
Risk transfer + risk coping	0.1139 (0.0268)	0.1644 (0.0498)	0.0506	12.35
Risk mitigation + risk transfer + risk coping	0.1407 0.0899()	0.2045 (0.0677)	0.0639	15.84

Note: Standard errors are in parentheses

5. Discussion

There is not much empirical evidence on the productivity and risk effects of different risk management measures and their portfolios. In an Ethiopian study, Di Falco and Veronesi (2014) have treated anyor all adaptation measures as asingle strategy and foundit reducing farmers' exposure to downside risk. In a similarlya study in Pakistan, adaptation measures have been reported to reduce exposure to downside risk but no significant impact of farmincome (Shahzad and Abdulai, 2020).

Nevertheless, different adaptation measures differ in their productivity and risk effects. In Ethiopia, Yesuf *et al.* (2009) have found the use of fertilizers increasing farmers' exposure to downside risk, while the soil-water conservation technology having just an opposite effect. Wossen *et al.* (2017) and Amondo *et al.* (2019) have reported adoption of drought-tolerant maizebeingeffective inimproving yield and reducing downside risk exposure.In Zimbabwe, crop diversification and fertility management being the most promising adaptations to climate change (Homann-Kee Tui *et al.,* 2021).

Most of these studies haveanalyzed the productivity and risk effects of a single or at the most two adaptationmeasures and rarely of their joint adoption.In practice,as observed in this paper, farm households often use more than one adaptation measure. The evidence on the effects of the joint adoption of different risk management measures or strategies is scarce. From their Ethiopian study, Di Falco and Veronesi (2013) have found larger payoffs to the joint adoption ofrisk management strategies than to a single adaptation measure.In Malawi, Kassie *et al.* (2015) have reported the joint adoption of crop diversification and minimum tillage resulting inhigher yield and lowerrisk exposure. Similar evidence is reported from Ghana (Issahaku and Abdulai, 2019). Teklewold *et al.* (2017) have also found joint adoption of improved maize varieties, chemical fertilizers and water conservation practices resulting inhigher yield and lowerrisk exposure.

Some studies have also founda mixed evidenceof the impact of joint adoption of different risk management strategies. In France and Hungary,Vigani and Kathage (2019) found the total factor productivity of wheat negatively associated with adoption of complex risk management portfolios because of their higher cost of implementation. They have also shown that the less complex risk management portfoliosbeing more efficientat reducing downside risk exposure.Collins-Sowah and Henning (2019) from Senegal have found a mixed impact of different risk management strategies on farm income, but their joint adoption, especially mitigation and coping strategies, could cause an improvement in farm income and a reduction indownside risk exposure.

There is considerable ambiguity in the impacts of risk management strategies on downside risk exposure and farm productivity, perhaps because of context specificity in the probability of occurrence of extreme climatic events, farmers' risk preferences and adaptation practices, and the level of economic development. Most of the above studies are location-specific, based on small samples, and the inferences drawn from these cannot be generalized. The findings reported in this paper have been derived from a rigorous empirical analysis of the farm survey data of more than 35000 households, and thus are robust enough to draw creditable inferences on the impacts of different risk management. The findings provide an empirical basis to the claim that the conjunctive application of scientific innovations and traditional risk management measures is a robust path of improving productivity, sustainability and resilience of smallholder agriculture.

6. Conclusions and implications

A few important conclusions that have emerged from the empirical studies in India and elsewhere are as follows:

Farmers, in the absence of a market for crop insurance and technical and financial services, often rely on multiple adaptation measures or strategies to manage the adverse effects of climate risks.

All the risk management strategies are effective at improving farm income and reducing risk exposure, but it is the risk-mitigating strategy that yields larger payoffs.

Thepayoffs are magnified when different risk management strategies are implemented jointly.

The joint adoption of risk management strategies is positively associated with farm size, but with liquidity and information constraints relaxed the probability of their joint adoption is expected to increase further.

In the absence of a market for crop insurance, a majority of the farmers will continue usinga mix of traditional and modern risk management measures. Hence, there are three key implications of these findings.

Agricultural research need to identify and refinethe traditional agronomic practices and blend these with the scientific innovations so as to evolvelocation-specific packages of climate-smart practices for their recommendation for adoption by the farmers.

The climate-smart packages so evolved need to be mainstreamed into the agricultural development agenda, which need to transmitted at farm level by improving information dissemination channels and outreach of the financial institutions to farmers.

The adoption of climate-smart practices should also to be understood from a broader policy perspective regarding the social safety nets, input subsidies and price support.

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20. Revisiting Research on Sustainable Intensification Innovations, Adoption Process, and Impact Assessment

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Farmers in many developing countries face co-existing biotic, abiotic, biodiversity loss, socio-economic, and institutional risks that affect their livelihoods and resilience. In these countries, mitigating and adapting to these challenges and achieving the Sustainable Development Goals requires a shift toward adopting a holistic and integrated approach by promoting innovations for sustainable agricultural and ecological intensification (SAEI). However, there is limited evidence on how farmers should adopt SAI innovations to optimize socio-economic and environmental benefits. Until recently, innovation development, promotion, and impact analysis have been focused on a single innovation. Such conventional approaches do not recognize the real-world complexities farmers face and their deliberate strategy to adopt multiple innovations and simultaneously achieve a range of objectives. The combined use of innovations, improved practices, and local knowledge can allow sustainable agricultural and ecological intensifications and greater food production. Local and innovative marketing models that bring producers, processors, and consumers closer also address critical social imperatives associated with food production and consumption. This keynote speech, drawing from advanced impact evaluation methods, will highlight the importance of promoting SAEI innovations/practices bundles to boost farmers' socio-economic empowerment and resilience. Multiple innovations adoption and impact analysis are essential to inform agricultural policiesto designeffective interventions and extension packages to achieve maximum impact from innovations by exploiting the potential synergies/interlinkages, minimizing trade-offs, and identifying bottlenecks.

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21. Safeguarding Commons for Sustainability of Indigenous Food Systems

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Keywords: Common Pool Resources; indigenous food system; indigenous knowledge; indigenous Institutional Arrangements; agroecological food system

1. Introduction

Commons or Common Pool Resources (CPRs) of land, water, forest, fisheries, wildlife and agriculture constitute an important component of community assets in India, and they underpin the livelihoods of millions of poor and indigenous people living particularly in less favored or underprivileged areas with few alternative economic opportunities. CPRs are essentially the flow resources with critical minimum levels below which a decline in the flow may have irreversible consequences (Marothia, 2002). Rapid depletion and continuous decline in the physical productivity of CPRs, and, the unequal access and control of the indigenous people on CPRs have been the major factors of displacing a large number of tribals/ indigenous people from their landscape and reducing their status to environmental refugees. People dependent on CPRs are fisher, dwellers, cattle herders, landless and marginal farmers, communities, forest often representing a target for development interventions which largely focus on poverty reduction. However, there is widespread lack of understanding of the relationship between people and CPRs, particularly in the context of indigenous people' food systems dependence on CPRs. As a result, overexploitation, degradation, privatization or state control over CPRs became a visible phenomenon. Design and implementation of appropriate policies for CPRs management has therefore become a major Challenge to sustain livelihoods of rural poor and indigenous people.

Since time immemorial, village communities have been the most potent natural resource management institutions in India. In recent years, however, most of the village commons have degraded into an open access situation due to weak property rights relations, institutional arrangements and breakdown of local authority systems (village Panchayat, village council or traditional tribal authority systems). Curiously, most of the researchers who have addressed the issue of common property have grossly confused the open access situation with common property resources (see Hardin's, 1968, 'tragedy of commons' article). As a result of the persistent confusion in the literature, many researchers and policy makers suggested privatization or state takeover of the CPRs for their management. This misunderstanding has been increasingly challenged by many natural resource economists and they have documented that the breakdown in common property systems may be due to the deficiencies in specifications of property and institutional arrangements rather than in its viability as a property rights regime (Ciriacy-Wantrup and Bishop, 1975; Oakerson, 1986, 1992, Jodha, 1986, 2002, Bromley, 1989; Bromley and Cemea, 1989; Marothia, 1993).

In recent years, new knowledge and understanding about management and conservation of CPRs in sustaining IFSs has increased significantly. The realization that design of an effective CPRs management system must be based on fair understanding of interplay between technical and institutional arrangements has led to fresh research interest and work in the IFSs.

This paper advocates that CPRs management problems are associated with inadequate understanding of the role of IFSs in sustaining livelihoods of indigenous people and relevance of traditional technical and institutional arrangements. Initially this paper discusses links between CPRs and IFSs and then documents characteristics of different types of IFSs derived from CPRs followed by brief discussion related to assessment of common pool resource management regimes in relation to Sustainability of IFSs in the context of tribal villages of Bastar Plateau of Chhattisgarh state of India, and, finally identifies important policy and research issues to strengthen CPRs - IFSs link.

2. Key background concepts

It has been adequately documented that agrochemical and agroindustrial driven food systems have caused severe socio-ecological impacts by degrading the productive capacity of natural resources in general and CPRs in particular. However, IFS and their related activities still have a strong potential to solve the problem of food and nutritional security of indigenous people by using CPRs sustainability. The key concepts used in this paper are CPRs, IFSs and framework for assessing sustainability of IFSs. To this end a brief description of these background concepts is given.

2.1. Common pool resources

Common Pool Resources are those resources that are used in common by a well identified group of people or community with a co-equal use rights and the such group can collectively exclude non-members of a group to use commons (for detail description of commons see Ostrom 1990, Bromley and Cernea,1989, Gupta 1987, Jodha, 2002, Singh,1994, Marothia 1993, 2002).

A sizable proportion of people in rural India depend directly for their livelihood, food security and healthcare on CPRs. The beginning of the studies to explore CPRs-livelihood links made during early eighties in India (see NSSO, 1999 report for nation level status of CPRs). A number of scholars have documented the availability, usages and contribution of CPRs to the food system of rural poor, in different parts of the country. They have also identified the factors responsible for the degradation and depletion of CPRs, and analyzed efficiency of alternative property right regimes and approaches for the management of CPRs (See Chapter 1 and 31 of Marothia, 2002 for detailed account of CPR studies in India and elsewhere, and efficiency of alternative CPRs governance systems, see also Arnold & Stewart, 1991).

Issues of safeguarding CPRs are closely related to institutional arrangements, property rights structures and authority systems. CPRs are managed and controlled through technical and institutional arrangements. The technical arrangements provide tools and knowledge or technological components which define how land, water, fish, forest and other CPRs are used as factors of production. The institutional arrangements define who can control the resources and how the technique is applied. Technological

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and institutional arrangements must complement each other if resources are to be used efficiently and sustainably (Gibbs and Bromley, 1989). The nature of institutional arrangements defines the extent of property regime over land, water and related resources. A property regime is a system or a set of institutional arrangements or working rules of rights and duties characterizing the relationship of co-users to one another with respect to a specific natural resource (Bromley 1991, Dietz, Ostrom and Stern, 2003). Property rights in resources exist either under state property regime (where the secure claim rests with government) or private property regime (claim rests with individual or corporation) or common property regime (individuals have claims on collective goods as members of organized group) or open access (or no property regime with no secure claims) (Bromley, 1991). The basic requirement for any property regime is an authority system (for example, Central or State Governments / Panchayats / resource development committees / user groups, indigenous village council) that can guarantee the security to resource users, groups or communities. When the authority system breaks down, a particular resource regime starts degenerating. Under such a situation, new institutional arrangements are used to define the resource regimes over natural resources and the authority systems protect the interests of those (resource users) holding the rights under a particular regime (Gibbs and Bromley, 1989).

My earlier research adequately provided evidence that indigenous institutional arrangements play a much greater role to maintain the continuity of adaptation of IFSs, using indigenous management and conservation technologies, where collective actions are required for sustainable development of CPRs. Most indigenous technologies including IFSs activities based on CPRs have an element of interdependence between or between (among) users (Marothia 1994, 1996a,b, 2012). With indigenous system of property rights regimes over CPRs, the indigenous people within their territory can prevent others from using, benefiting from or damaging the CPRs without making compensation. When such uncompensated benefits or damages occur, these are called spillover effects or externalities or interferences. In recent years secure tenure over CPRs in many parts of the indigenous dominated areas are suffering with dilution of traditional ownership over natural resources. Whenever property rights are not clearly defined or enforceable, externalities or divergences between private and social costs or third party effects arise (Bromley 1991, Marothia, 1997). It is these market and policy failures, which provide the rationale for improvement of institutional structures and property rights within interdependent situations. This also becomes necessary to make sure that the current technical and institutional arrangements are not counter- productive (Gibbs and Bromley, 1989). These issues are important in the socio-ecological transformation of IFSs heavily dependent of CPRs.

2.2. Indigenous food systems

A typical food system involves the complete range of farmers, fishers, gatherers, and their interlinked value adding activities extend from production, processing, distribution consumption and marketing. In all parts of the world food systems largely occur in agro ecosystems, and agro ecosystems in turn depend on natural resources in general and CPRs in particular, that have been since centuries managed through common property institutions. According to FAO (2015)" A sustainable food system (SFS) is a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised. This means that – It is profitable throughout (economic sustainability); – It has broad-based benefits for society (social sustainability); and – It has a positive or neutral impact on the natural environment (environmental sustainability)." A sustainable food system can effectively meet the SDGs related to hunger, food and nutritional security (refer also FAO, 2013).

As mentioned earlier, CPRs can be managed under different property rights or distributed property rights regimes (see Townsend and Polley, 1995). Recent research studies also convincingly argued that agro-ecosystems and their links with the larger ecological environment and cultural landscape ecosystems are managed under different property regimes. This is a common phenomenon in indigenous peoples' landscape in which CPRs play a vital role in sustaining livelihoods. Agro-ecosystems provide major ecosystem services and play a critical role in achieving SDGs. Food production is the well recognised ecosystem service provided by agro-ecosystems (Altieri, 2004, Porter *et al.,* 2009, Power, 2010, Augstburger et.al 2019 a,b). Other ecosystem services provided through CPRs based agro-ecosystems are mentioned in table 2. CPRs provide all the ecosystem services in the context of IFSs (refer Marothia, 2021, 2022 for ecosystem services provided through agriculture-commons interactions).

Indigenous food systems are basically agroecological food systems.For indigenous people their food systems are based on ancestral food systems evolved over centuries through indigenous knowledge and crucial for nutritional and food sovereignty as well as for social, cultural, spiritual wellbeing and secure tenure over natural resources. Today indigenous peoples are making all efforts to sustain indigenous food systems through protecting their CPR, cultural and spiritual norms. Indigenous food system even sustained the survival of indigenous people during Covid-19 in Bastar and other tribal dominated areas. Today IFSs are confronted with many challenges including indigenous knowledge to manage CPRs, particularly those food centric disconnect social cultural values of indigenous people and fast entry of market driven forces. These recent changes need assessment to ensure sustainability of IFSs derived from CPRs. To the end a brief discussion about assessing sustainability of IFSs is discussed.

3. Assessing sustainability of IFS

In recent years few attempts have been made to investigate the sustainability of IFSs derived from CPRs and to account transformation activities in the socio-ecological context (Basurto, Gelcich and Ostrom, 2013 Marshall, 2015, Rist and Jacobi, 2015, Ottiger, 2018 Allen, *et al.,* 2019. The seminal work of Gliessman, *et al.* (1981); Francis *et al.* (2003); Gliessman and Rosemeyer (2010); Gliessman (2013, 2015a) has adequately proved that agro-ecology of food system can effectively transformed current agrochemical or industrial food system towards economic, social and environment sustainability. These scholars have emphasized that traditional and indigenous agro-ecological systems conserving natural resources for centuries through their traditional knowledge with minimum external input to produce IFSs. Altieri (2004) and Altieri and Toledo (2011) suggested agroecological principle to transform or to pushup transition process from agroindustrial or agrochemical to agroecological food system based on traditional knowledge accumulated over centuries (for detail description of agroecological principle see introduction chapter authored by Gliessman (2015b) of proceeding of the FAO international symposium)[2]. In the case of our study there may be a tragedy of reverse transition, i.e. from IFSs to agrochemical driven transition. For assessing IFSs derived from CPRs we have used main characteristics developed by FAO and Alliance of Bioversity International and CIAT (2021). Almost similar characteristics were used in assessing a large number of food systems, including indigenous food systems, in Bolivia and Kenya(refer Augstburger et.al.2019, Colonna et.al 2013).To assess sustainability of IFSs we have used six policy attributes and drivers of sustainability affecting the IFSs developed by FAO-CIAT (2021 pp.415-1640-44). IFSs characteristics and policy attributes relevant to our study area, Chhattisgarh, are given in table 2 and 3 respectively.

4. Profile of Chhattisgarh and extent of common pool resources

The State of Chhattisgarh, lies between 17°46′ N to 24°6' latitude and 80° 15′ E to 84° 51′ E longitude. The climate of Chhattisgarh is tropical. It is hot and humid because of it proximity to the Tropic of Cancer and dependence on the monsoons for rains. The monsoon season is from late June to October. Chhattisgarh receives an average of 1292 millimeters of rain. Winter months are from November to January with low temperatures and low humidity. The temperature varies between 30° C and 47° C in summer, and between 5°C and 25°C during winter. However, extremes in temperature can be observed with scales falling to less than 0°C and touching 49°C. The summer months in Chhattisgarh extend from April to June and temperatures can reach 49° C.

The state is divided into three agro-climatic zones, namely, the Northern Hills, the Central Plains and the Bastar Plateau (Map 1). The Northern Hills region is densely forested, inhabited by several tribal communities and also rich in coal and other mineral resources.

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2. For different aspects of food systems see also Ericksen, 2009, Duru, Therond, and Fares, 2015, Heusser, et.al. 2017.
3. FAO and Alliance of Bioversity International and CIAT. 2021. Indigenous Peoples' food systems: Insights on sustainability and resilience in the front line of climate change. Rome. https://doi.org/10.4060/cb5131en

The southern Bastar Plateau is also rich in forests and boasts a diverse tribal population and unique culture. The Northern and southern regions are rich in non timber forest production, which forms forest based nutritional and livelihood security for the tribal and other marginalized people. The fertile Central plains region hosts numerous indigenous wild races of rice, and is also known as the 'rice bowl' of Central India.

At aggregate level the State has about 44 percent of its geographical area (135,224 sq. km) under forest cover. Forests of the state provide catchments to at least four main river systems, i.e. Mahanadi, Godavari, Narmada and Ganges. Major rivers of the state are Mahanadi, Indravati, Hasdeo, Sheonath, Arpa and Ib. The climate of the state is generally sub-humid with an annual rainfall ranging from 1200 to 1500 mm. The forests of the state fall under two major forest types i.e. Tropical Moist deciduous forest and the Tropical Dry deciduous forest. Sal (*Shorea robusta*) and Teak (*Tactona grandis)* are the two major tree species in the state. Other notable overwood species are Bija (*Pterocarpus marsupium*), Saja (*Terminalia tomentosa*), Dhawra (*Anogeissus latifolia*), Mahua (*Madhuca indica*). Tendu (*Diospyros melanoxylon*) and a few others. Amla (*Embilica officinalis*), Karra (*Cleistanthus collinus*) and bamboo *(Dendrocalamus strictus*) constitute a significant chunk of the middle canopy of the state's forests. A large number NTFPs are available year round in abundant quantities and are used for food, fruit, health care and household needs.

The availability of CPRs and their contribution varies widely from region to region in India, depending mainly on the ecological conditions and agricultural systems or agro-climatic conditions prevailing there and partly on the present and past land settlement and land tenure systems. These factors affect the nature and extent of CPRs as well the institutional arrangements that govern their management and integration with private property resources in the different agro-ecological regions (Singh 2002). Availability of CPLRs in Chhattisgarh and in all the three zones play a significant role to meet the livelihood needs of tribals and other poor's in the villages of respective zones. Moreover CPLRs, NTFPs and CPWRs are vital natural resource bases sustaining IFSs.

Community pastures and grazing grounds are an important source of cattle rearing and sustaining livestock keeping. Village forests and woodlots are the chief source of fuel wood and a natural source of food and livelihood for the dependents. The category of other CPRs consists of fisheries, non-timber forest products and medicinal plants play an important role in enhancing livelihoods. While the collection of Non-Timber Forest Products provides seasonal employment and critical income, fisheries activity, which is followed almost throughout the year, is a constant source of income. CPLRs form a substantial part of the total geographical area under their respective agro-climatic zones. The common pool water resources (CPWRs- natural streams, human made ponds, wells, flood plains) are used by a number of households for different purposes. Most important use of CPWRs is for livestock rearing, fisheries, aquatic crops and household demands. These CPRs are owned by village Panchayat or tribal communities. Extent of these three categories of CPRs in the three agro-climatic zones (ACZs) of the state are estimated using land use data of the districts that fall under each ACZ and presented in table 1.

5. Database and coverage of IFSs

Data used in this study are drawn from the author's ongoing research work dealing with *"sustainability of indigenous peoples' food system and common pool resources resilience"*. The ongoing field work covers a large number of villages, inhabited with more than 80 percent population of indigenous people, scattered in different districts of three agro-climatic zones of Chhattisgarh state and have strong link between livelihood and CPRs. For this paper I have selected villages from two blocks of Bastar district of agro-climatic zone two. A brief description of Bastar district is given herein, followed by criteria adopted for selection of study villages for in-depth analysis.

Bastar district situated in the south-eastern corner of Indian state of Chhattisgarh lies between 17046' and 20034' North latitudes and 80015' and 82015' East longitudes with varying elevations ranging from 550 to 760 meters above mean sea level (MSL). The Bastar district has an area of 5374 s.q.km and consists of 611 total villages. The district has 7 blocks. This district with a population of 834375 having a sex ratio of 1,024 and a literate population of 54.94 percent. The population density of the district is 155 km^2. Nearly 70 percent of the total district area is covered under forest. About 70 percent of the total population belongs to ST and SC communities.

Boundaries of the Bastar districts' villages located to its east touch the villages of Odisha. The rest are the villages of Kondagaon district of Chhattisgarh in the north, the villages of Dantewada district in the south west and the villages of Sukma district in the south. The general topography of the district consists of underlying terrains full of numerous hillocks, covered with dense forest. The climate of Jagdalpur (Bastar) district is considered as sub-humid which is mild in summer and moderate in winter. The mean annual rainfall of the district is 1277 mm.

Table 1 Extent of Common Pool Resources, Agro-climatic Factors and Indigenous People in ACZs of Chhattisgarh

Characteristics	Central Plain	Bastar Plateau	Northern Hills	State
CPLRs* (in lakh ha)	11.67(56.40)**	4.42(21.36)	4.60(22.24)	20.69(100)
CPLRs in respective ACZs (%)	15.20	13.55	16.17	15.01
Forest[#] (in lakh ha)	27.90(44.17)	21.29(33.71)	13.97(22.12)	63.16 (100)
Forest Area in respective ACZs (%)	36.32	65.25	49.07	45.80
Water Resources (in lakh ha)				
Area under Reservoirs Tanks/Ponds/Dams	1.84(64.62)	0.46(16.29)	0.54(19.09)	2.84(100)
Dabries (MMITs)	0.29(59.70)	0.05(9.98)	0.15(30.31)	0.48(100)
Rainfall	950-1200(54)***	1160-1380(63)**	1250-1410(59)**	1190(58)**
Temperature (Max/Min.)	32.4/20.2	31.1/18.7	29.8/16.6	31.1/18.5
Total population	19332839	2341887	3870472	25545198
Sex ratio	1006	1085	997	1029
Literacy % (Male/Female)	88.35/67.67	37.00/20.48	63.98/44.56	69.67/48.76
Total tribal population	4033231	1654385	2135286	7822902
Tribal population as % of total population in each ACZs	20.86	70.64	55.17	30.60
Average CPLRs (ha) per household (w.r.t. total population)	0.060	0.189	0.119	0.081
Average CPLRs (ha) per household (w.r.t. total tribal population)	0.289	0.267	0.216	0.265
Average forest area (ha) per household (w.r.t. total population)	0.144	0.909	0.361	0.247
Average forest area (ha) per household (w.r.t. total tribal population)	0.692	1.287	0.654	0.807
Average CP WRs area (ha) per household (w.r.t. total population)	0.010	0.020	0.014	0.011
Average CP WRs aera (ha) per household (w.r.t. total tribal population)	0.046	0.028	0.025	0.036

*Includes Barren and Unculturable Land, Permanent Pasture and Other Grazing Land, Culturable Waste Land, Fallow land excluding current fallow, Miscellaneous group of Trees & Garden and Submerged Land.
[#] Reserved Forest, Protected Forest, Unclassified Forest and Revenue Forest.
**Indicates % of respective characters.
***Figures in brackets are Annual Average Rainy days. Source: Author's estimates derived from the data given in statistical Abstract of CG, 2018-19

The southwest monsoon starts by the third week of June and withdraws during the first week of October. The mean day temperature varies from 18°C (January) to 29°C (May) and night temperature varies from 10.8°C to 23°C.

As previously mentioned, for this paper appropriate data pertaining to IFSs derived from three types of CPRs (CPLRs, NTFPs and traditional water structures) were collected from six villages, three villages from each block of Bastar (Junapani Bakel, Godiyapal Kadamunda, Cherakur Banva Jhori) and Bakawand (Mokagaon, Kodomali and Sandhkarmri) of Bastar district of Bastar Plateau agro-climatic zone. In all the studied villages the primary livelihood activity of the majority of population is collection of NTFPs followed by traditional agriculture. Subsistence agriculture with poor paddy and minor millet productivity due to poor soil base and other biophysical, socio-economic and cultural constraints provide livelihood support for a maximum two to three months. For the remaining period of the year NTFPs and other CPRs based food provide life support to the poor tribals. Primary criteria for selection of villages in these blocks were due to the large population of tribals and heavy dependence of local population on NTFPs and CPRs for sustaining life support systems. NTFPs (nationalized and non-nationalized) provide gainful employment and generate sizable income in the study villages. However, the extent of employment and income generated from NTFPs collection are significantly higher in villages of Bastar district due to a large number of NTFPs available throughout the year. The other basic facilities like safe drinking water, health care, basic education and sanitation are poor. The blocks have poor market network for NTFPs and as a result in several villages in both the blocks poor tribals trade their valuable NTFPs under barter system. Other criteria considered were related to more than 70% area under forest, high concentration of availability of indigenous natural and human made water resources and higher share of CPLRs in land use; IFSs importance in food and nutritional and livelihood security; importance of locational specific, economics, social and cultural relevance of IFSs, signals of socio-ecological transition and implication for CPRs resilience; evidence of moving IFSs towards agrochemical driven food systems.

6. Characteristics of indigenous peoples' food systems derived from CPRs

In recent years FAO, UNDRIP and other international organizations have precisely recognised the contribution of indigenous knowledge and rights over natural resources to sustain IFSs and addressed the challenges of climate change and sustainable use of community or common pool resources. In collaboration with some institutions and scholars FAO had identified emblematic or characteristics of IFSs, which emerged from the insights of case studies conducted in different countries, to assess the sustainability of IFSs in respective geographical clusters (see FAO Report, 2021). Scholars from different disciplines have also assessed the IFSs using basic socio-economic-ecological parameters. For our analysis we have added a few characteristics to FAO (2021) and earlier research efforts (Augstburger *et al.*, 2019, Colonna *et al.*, 2013), keeping in view the location-specific physical and technical attributes of CPRs and socio-economic and cultural characteristics of indigenous people in the study villages. Characteristics of IFSs derived from CPRs are given in table 2. Characteristics of IFSs are linked to three major categories of CPRs, namely, CPLRs, NTFPs and CPWRs. It is evident from a brief narrative given in table 2 that all components of IFSs derived from CPRs play vital roles to sustain food, nutritional, health security and provide opportunities for value addition and market driven gains. Indigenous common pool water resources (natural streams, ponds and human made Munda, small water storage well/pond), now being used by a small group of farmers in a few cases in adopting agrochemical food systems. In recent years nearly forty-six NTFPs have been procured under minimum support price (MSP) initiative. A good number of NTFPs are processed at local level for onward export to domestic and international markets. Most of the traded NTFPs are used for pharmaceutical and food industries. In some cases extraction of NTFPs being carried out beyond their regenerative capacity, may lead to irreversible losses of biodiversity composition. All the three categories of CPRs substantially contribute to ecosystem services and SDGs (table 2).

Map 1: Location of India, Chhattisgarh and Study Area

Table 2 Common Pool Resources Based Indigenous Peoples' Food Systems and Their Basic Attributes: Reflections from Study Villages

Characteristics of indigenous food systems	CPLRs centric food and livelihood systems	NTFPs centric food and livelihood systems	Water centric food and livelihood systems
1. Natural resource base	Diverse and rich bio-mass, dotted with sacred hills, mountains and groves, with indigenous fruit and non-fruit trees, medicinal herbs, shrubs and aquatic weeds, good status of grazing land	Tropical Moist deciduous forest and Tropical Dry deciduous forest, rich diversity of aromatic and medicinal herbs and shrubs. very rich in mineral resources, national parks and wildlife sanctuaries	Forests provide catchments to major rivers of the state. These are: Mahanadi, Indravati, Hasdeo, Sheonath, Arpa and Ib; high density of natural water streams and human made community water structures, historical karsts and caves wetlands with known and unknown biodiversity
2. Extent of CPRs availability (range in %)	10% to 22%	80% to 90%	Landscape is dotted with natural and human made water bodies, perennial and seasonal streams
3. Main tribes/ indigenous people	Gond, Halba, Dhurvaa, Abujmadia, Bison horn muria, Muria		
4. % of tribal population	85% to 95%		
5. Food centric activities (hunting/fishing/gatherings)	Largely gathering indigenous berries, small ruminants keepers for meat consumption (piggery, goats are most common),	Collection/gathering of a large number of biological products, NTFPs for food, health, leaves, fruits and seeds	Fishing, irrigation of tradition crops, domestic needs for human and animal activities
6. *Seasonality of food system*	Around the year	NTFPs collection in rainy season is difficult	Most of the water resources are perennial and even seasonal water sources have enough water to grow kharif crops
7. *Types of Indigenous food*	Collection of seasonal fruits (Indian blackberry, stone apple, honey tree or butter tree, edible seeds) fodder and leaves, tamarind, collection for goats and pigs and other animals. Hunting of wild mouse and other craters., sulphi drinks	16 tubers and roots and 12 fruits (food consumption), 3 leaves (for domestic and industrial uses), 12 seeds (for home consumption and industrial uses), and 6biological products (for household use and local handicrafts)*	Minor millets (kodo, kutki, ragi and sawa, fisheries catch in seasonal and perennial streams, river and human made ponds and munda (common water storage pond), chest nuts, lotus (naturally grown), a large number of leafy vegetables, beans, backyard garden with fruit plants and trees, traditional verities of poultry (*kadaknath)* ducks, quail and piggery,
8. *Main uses*	For household consumption, largely fodder collection for livestock, especially small ruminants, few items for human and animal medicines	Basically food and nutritional security, non-food uses, NTFPs have very high market value for agro-industrial products	Food, nutritional and medicinal security, Few indigenous rice varieties have high zinc value. Still subsistence farming
9. *Indigenous technology and knowledge in producing or collecting food and non-food items*	Indigenous technology of food and non-food extraction supported with traditional knowledge	Indigenous technology of food and non-food extraction supported with traditional knowledge	Indigenous technology of food and non-food extraction supported with traditional knowledge
10. *Exchange of Input /Seeds*	Seed exchange is common among and within a tribal/indigenous people	Seed exchange is common among and within a tribal/ indigenous people	Seed exchange is common among and within a tribal/indigenous people- it's a festival for

			indigenous people being self organised every year in a form of annual fair
11. Entry of agro-chemicals use	Not applicable	Not applicable	Yet to be applied at large scale, IFSs is under transit phase, small numbers of farmers in a few villages recently started using chemical inputs-introduced through agricultural extension program.
12. Production: main and by-products and value addition	Age-old use of main and by-products are still in practice	A large number of NTFPs have multiple use and a range of value added by- products	All the traditional crops have value added by -products
13. Nutritional level	Very high	Very high	Very high
14. Consumption	Largely home consumption	60% for home consumption, remaining for sale, but all nationalized NTFPs are sold to CGMFPCS	Nearly 80-90% for home consumption, remaining for distress sale
15. Processing	Traditional method of processing	Indigenous processing for a large number of NTFPs	Indigenous processing for crops and some varieties of fish
16. Price determining mechanism (sale or exchange)	Collected products are not sold, but exchange among local community	At MSP, direct to open market	Largely price fixed by producers
17. Barter exchange in the food system	Declining	Still prevailing for high value non-nationalized NTFPs	Declining
18. Marketing channels	Non-existing	MFPPSs/ weekly market/ traditional merchants still dominates trade of NTFPs despite MSP support for 46 NTFPs	Not much marketable surplus, merchants from nearby town purchase in weekly market
19. Export opportunity/agro industrial	Non-existing	High export opportunity for NTFPs after MSP operation	Not applicable
20. Ecosystem Services	CPLRs-IFSs provide Provisioning, Regulating, Cultural and social, Supporting and Biodiversity services	NTFPs-IFSs provide Provisioning, Regulating, Cultural and social, Supporting and Biodiversity services	CPWRs – IFSs provide Provisioning, Regulating, Cultural and social, Supporting and Biodiversity services
21. Contribution to achieve SDGs	SDG: 1,2,5,6,13, and 15	SDG: 1,2,5,6,13, and 15	SDG: 1,2,5,6,13, and 15

*Almost all the NTFPs have multiple uses like raw foods (all tubers and fruits), Vegetable, juices, making Sweets, condiments, oil extraction, brewing traditional liquor, medicines, soap and shampoo, few NTFPs have industrial uses, like starch Manufacture, silk Manufacture, tanning industry, Colouring agent, Oil for soap and cattle feed, herbal oil & medicine, Pulp, huts, Basket, mats, gum and medicine, Cashew, ice cream, herbal oil and medicine, cosmetics, Stuffing mattress and pillow, furniture, soft cotton for surgical purpose, furniture, leaves wrapping bidi (Indian smoking tobacco) and leaves plate and cups for serving food, nutritious biscuits for cattle.

**SDG 1: End poverty in all its forms everywhere, SDG 2:End hunger, achieve food security and improved nutrition and promote sustainable agriculture, SDG 5: Achieve gender equality and empower all women and girls, SDG 6: Ensure availability and sustainable management of water and sanitation for all, SDG 13:Take urgent action to combat climate change and its impacts, Goals 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage for – forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

7. Assessment of CPRs management in relation to sustainability of IFSs

The analysis in this section is based on the policy attributes applied in inter-country studies conducted by FAO (2021). These attributes are used here to assess CPRs management regime being practiced in producing IFSs. We have also used here drivers of sustainability of IFSs adopted by FAO. These drivers may have positive or negative impact on sustainability of IFSs derived from CPRs. All the three types of CPRs considered in this study are being used by indigenous people under three different types of property rights arrangements. For example different types of land under CPLRs category are officially under state revenue department, but traditionally it has been collectively owned, used and managed by indigenous peoples under territorial rights. Similarly, common water is also collectively shared and managed by tribal communities following traditional soft institutional arrangements. Nationalized NTFPs are managed under cooperative structures, but on rest of the NTFPS indigenous community have *usufructuary* rights or access to forest landscape to collect NTFPs. (See Marothia, 1994, 1996 a,b, 2001, 2004a, 2009, 2010,a,b, Marothia, and Gauraha,1992, for detail analysis of NTFPS under different governance systems /property regimes in Madhya Pradesh and Chhattisgarh states) Using seven policy attributes, listed in table 3, assessment of effectiveness of the CPR regime in relation to sustainability of IFSs is carried out. Further, what are the impact of internal and external drivers, associated with each policy attribute, on sustainability of IFSs is also presented in table 3. If I relate observations presented in this table with my earlier studies (Marothia, 1994, 2004,a, 2009, 2010a,b) conducted in the study villages, I can see a gradual socio-ecological transformation in terms of use of CPLRs from multisite to single use, conversion of CPLRs to another category of CPRs. For example, in all the villages under investigations, CPLRs are now being used for dumping cow dung, keeping cattle and construction of vermin-compost pits. In some cases small water ponds have been created under MGNREGA on CPLRs. Such interventions reduced the land based multifunctional biodiversity and in turn food gathering activities. Similarly, NTFPs collection now is market driven and exponential NTFPs extraction process may lead to threshold level. In few cases water interventions introduced by different agencies without knowledge and collective consent of tribal community. As a result such initiatives largely failed (Marothia 2004b).

Table 3 Assessment of Common Pool Resource Management Regimes in Relation to Sustainability of Indigenous Food Systems

Attributes of assessment	Drivers	CPRs		
		Common pool land resources (CPLRs)	Non-timber forest products (NTFPs)	Common pool water resources (CPWRs)
1. Rights to land, territories and natural resources base	Positive	Indigenous people have collective rights over CPLRs to have equal access to indigenous food collected from different categories of CPLRs within their territories clearly defined by their communities which are also well recognized by the local governing body/ village (Panchayats).	A large number of non-nationalized NTFPs have been/are being collected under usufruct rights arrangement. Traditional rights of indigenous people for collecting items of IFSs are well recognised	Indigenous people have collective rights over natural streams, *Munda* (small water storage structure constructed by group of farmers for collective use), ponds, floodplains to grow indigenous crops, fish and other aquatic crops within their territories which are clearly defined by their communities as well recognized by the local governing body
	Negative	Over the years indigenous people have been straggling to protect tenure security over CPLRs, In recent years CPLRs have been transfer for single use development program, e.g. construction for dumping cow dung and making vermin-compost. Multiuse reduced to single use	Gradual shift from food NTFPs to industrial use NTFPs	Growing tenure in- security to well defined traditional boundaries of common water resources, emergence of subsidy driven tube well construction has spillover effects on group water harvesting traditional technology (Munda), and, other natural and human-made water sources collective management
2. Biodiversity, multi-functionality of the systems, and self-sufficiency	Positive	Biodiversity is collectively managed with traditional institutional arrangements, signals from ancestral spiritual belief and cosmogony embedded in nature. This is very common in studied villages	Food system is integrated with seasonal availability of food, fruit and other agro industrial centric NTFPs	Diverse water resources are collectively managed with traditional institutional arrangements, signals from ancestral spiritual belief sand cosmogony embedded in nature
	Negative	CPLRs is shrinking due to external pressure and peri-urbanization	MSP and market driven operation in long run result in irreversible loss of some NTFPs	fast emerging pri-urbanization may affect natural streams and other water resources
3. Continuity of traditional practices, adaptation and innovation	Positive	Still traditional practices are operative	Extraction and collection of NTFPs is still largely governed through traditional practices	Indigenous water use and management is still being practiced in fish, field and aquatic crops production.
	Negative	Climate change affecting gathering and hunting and rearing of indigenous cattle and other household daily needs	To adhere the industrial and pharmaceutical companies demand, modern methods for value addition are introduced by Forest Deptt in case of many NTFPs	Introduction of Agrochemical technology replacing traditional gene bank of crops, promotion of non-traditional water resources inducing water intensive crops. It is still at initial phase.
4. Governance, Prior and well informed collective consent from indigenous community	Positive	Indigenous management of CPLRs is self organised and governed	NTFPs are collected through primary NTFPs cooperative society- part of three tier system NTFPs cooperative structure	Indigenous management of water resources is self organised and governed
	Negative	Many land centric development programmes are being introduced without indigenous consultation and participation, in some cases nature of multiuse of CPLRs has been converted to single use. In the process diverse biodiversity is disappearing	NTFPs collection is governed under well structure three tier cooperative system (see Marothia, 2009 for changes in NTFPs policy in Madhya Pradesh and Chhattisgarh), in few cases usufruct rights of tribal are not functional	Many water centric development programmes are being introduced without indigenous consultation and participation, village Panchayats are not willing to own them (see Marothia, 2004,b)
5. Youth, education systems, interculturality, indigenous, languages and traditional knowledge	Positive	Indigenous languages are essential for traditional knowledge and in turn for sustaining food systems and surrounding natural landscape	Generally entire family members are engaged in NTFPs collection, including the youth. In the process young family members are connected with traditional knowledge and local vocabulary	Indigenous languages are essential for traditional knowledge and food systems and surrounding natural landscape
	Negative	A few cases of slow transformation of traditional knowledge to youth and present generation is observed	Some signals of low participation of youth are visible as many a times youth have to choose between schooling and assist the family in NTFPs collection	A few cases of slow transformation of traditional knowledge to youth and present generation is observed

6. Globalization, income, barter, trade, processed foods, waste	Positive	Barter system is still prevailing among members of village, but declining between indigenous people and traders/ local marchants	Pre-fixed MSP for selected NTFPs, still sold in weekly local markets at prices generally dictated by local traditional buyers and middlemen or in many remote forest area under barter system	Group irrigation is still prevailing at large scale, water sharing is a common practice
	Negative	Market and retail trade is changing the gathering and hunting pattern	Under distress condition if money is needed for household needs, indigenous people exchange/sale their high value NTFPs under barter system to traditional buyers	Market and retail trade is changing fish varieties and crop pattern, but backyard cultivation is not affected as it is household centric activity

8. Strengthening CPRs-IFSs link: policy and research issues

In the preceding sections, I have argued that CPRs form the foundation to sustain IFSs and livelihoods in the indigenous inhabited landscape. I have also argued that CPRs and IFSs sustainability depends on drivers of policy attributes in the changing socio-ecological transition. Now, I identify a number of policy and research issues to strengthen the vital link between CPRs and IFSs.

1. The indigenous peoples' dominated areas have extensive CPRs (common grazing land, common water bodies, freshwater aquaculture, capture fisheries, non timber forest products, plant and animal genetic resources) and these have traditionally been managed under the common property regimes or community based management. These resources have degraded to an open access regime due to weak institutional arrangements and property rights regimes and ineffective local authority systems. CPRs are blood vessels of the tribal areas and significantly contribute to support the livelihoods of millions of the underprivileged and deprived people living therein. The tribal areas have a sizable deprived rural population and the livelihood options are depleting day by day due to various physical, biological, socio-economic and political factors. Such factors are responsible for distress migration in a large number. These migrants largely have become environmental refugees due to degradation of natural resource base in their local settings and unequal access and control over CPRs under fast emerging peri urban areas (Marothia 2010, a, b).
2. A large number of CPRs are guarded by government laws, as a result poor find it difficult to use these natural resources. Further, the encroachment on usufruct rights of the poor by the government in the name of environment conservation laws or, due to private lobbying, has deteriorated the prospects of the rural and indigenous people. Moreover, the use of CPRs is not determined by their mere availability, but mainly on their accessibility. IFSs are sustainable when households have secure ownership or access to CPRs. A comprehensive CPRs Management Policy needs to be designed involving the indigenous people and their traditional leaders to sustain the flow of IFSs.
3. In most of the tribal areas of the country rich biodiversity is available with very vibrant and living traditional ecological knowledge. There is an urgent need to synthesize the traditional ecological knowledge with the contemporary knowledge to accommodate the socio-ecological transformation taking place. Reconciling the system of indigenous ecological knowledge with modern science is urgently needed to design appropriate strategies for development of tribal areas.
4. In some of the tribal areas traditional CPRs are now being recognized for their high ecosystem services and monetary and non-monetary values and the role they play in developing social and ecological capital for local communities. Local communities, resource managers, and governments are starting to realize the multiple benefits that arise from common property regimes of CPRs. It is also true that in many tribal pockets of the country, CPRs remain under threat as a result of global economic forces, regional and national political developments, and inadequate legal recognition of CPRs. At the same time the global implications of poor CPRs management are increasingly recognized in terms of loss of biodiversity, continuous erosion of traditional common ecological knowledge, destruction of valued resource systems both natural (forest and fisheries for example) and human-made (macro and micro irrigation systems including traditional water harvesting), and global warming impacts. Some of the environmental systems in the tribal areas are becoming recognized as "global commons" and climate change that should be explored from a common property resources management perspective. It is here that local experience and knowledge may hold lessons or provide insights into problems of dealing with global issues such as climate change, carbon sequestration and biodiversity loss, IPR, TRIPS and food security. Conflict over the management of such resources is likely to intensify, and the governance issues are likely to become increasingly complex. How should we manage CPRs at local, regional, national and global scale. What form of governance is required? is it a single property right regime or combination of property rights regimes or distributed governance? (see for further details on such issues (Marothia 2002, 2010,b).These are the questions that the policy makers responsible for integrating CPRs in tribal area development have to address.
5. Building the information base is extremely necessary to support and manage sustainable development of CPRs. Information/ data related to degradation, dependence of human and animal population, ecological crisis due to biodiversity erosion, legislative and policy reform, ownership, entitlements, technical and institutional arrangements needs to be built up.
6. IFSs have been evolved over the centuries using an indigenous peoples' ancestral knowledge of food security, socio-cultural, spiritual values and secure tenure over natural resources in general and CPRs in particular. Recently indigenous people around the world, including various parts of India, making all efforts to sustain IFSs in the face of climate change, aggressive entry of agro-chemical centric food system and technologies, rapid loss of indigenous knowledge, languages, methods of natural resources management and policy disconnect with the indigenous institutional arrangements. Systematic research is urgently needed

to address the continuous challenges being confronted by indigenous people to sustain IFSs, tenure over CPRs and conserve multifunctional agro –biodiversity. There is a visible research gap in the area related to nutritional values of different IFSs and consumer willingness to adopt these highly nutritional foods. It's high time to showcase at different platforms the vast diversity of IFS. Research initiatives on different aspects of agro-ecology of food systems in different agro-climatic zones of India are urgently needed to add value to the on-going efforts of many institutions and individuals to transform agrochemical food systems to agroecological ones.

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22. Communities of Practice: The Importance of Collective Viewpoints for Sustainable Agri-food Systems

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1. Introduction

Our planet currently sits at the nexus of an enormous and dichotomous concern: how do we ensure the health and prosperity of 8 billion people while ensuring the sustainability and viability of our ecosystems? On the one hand, the ability to grow grains in high quantities has massively reduced the starvation and malnourishment of our world's population. At the same time, the current practices used are not sustainable. Yet while our traditional methods are sustainable, they are not scalable. The real dilemma is to connect these two strategies at the production and consumption sides. According to a report by the IUCN (Oberč and Schnell 2020), sustainable agriculture must first consider two inseparable, intertwined societal priorities – preserving the environment and providing safe and healthy food for all.

Achieving food security through sustainable practices in the Global South faces many concerns, including population growth, urban migration, poverty, social inequalities, fluctuations in the market, and depletion of natural resources. These issues, though all interconnected, look different when viewed from different lenses. Smallholder farmers in Asia and sub-Saharan Africa provide up to 80% of the food supply (FAO, 2012). Meanwhile, the average farmer owes up to 60% of their income in debt (MoSPI 2021a, 2021b), and an estimated 40% of the food they produce does not reach our tables due to loss in production, processing, and/or distribution (FAO, 2022). Amidst these concerns, agricultural systems need to feed an ever-increasing population whose food demands are projected to double over the next 50 years (HOW2050 2009). These concerns and the adverse impacts of climate change have threatened our food security. In 2020, 45.4 million children under five were impacted by malnutrition, 17% of which live in India (UNICEF *et al.,* 2021). Food systems are locked in a spiral of decline with environmental systems: they are also significant causes of degradation of the ecological systems on which they depend.

Systems-level solutions that work for every sector and individual in the process are needed. These solutions must be human-centred, which means they need to consider the social, cultural, and historical context wherever they are implemented. A collaborative approach is required that considers the view points of each stakeholder in the system, identifies common interests and points of inflexion and establishes communities of practice (Wenger-Trayner and Wenger-Trayner 2015) that work iteratively together across the system. These communities of practice must learn from each other, cocreate standard solutions, and iteratively enhance solutions through regular interaction and reevaluation of the process.

To begin the development of such communities, we present the biggest challenges in sustainable food systems through the perspectives of the three corners of the food systems triangle in India: the producers, the consumers, and the environment itself. Here we offer key recommendations and examples adapted from our recent white paper (Paroda *et al.,* 2022) that all stakeholders in the agricultural system can use to identify a common path that embraces both food and environmental security sustainably.

2. Discussion

2.1 The producer's perspective

In India, agricultural economy and food security depend primarily on smallholder farmers. Roughly 86% of farmers in India are smallholder farmers (including marginal farmers) who own 47% of the crop area (MoAFW 2020). Despite this contribution, smallholder families, who constitute about one-half of the national population, comprise almost three-fifths of the nation's hungry and poor. Therefore, it is socially beneficial that agricultural lands with smaller land holdings and their farmers are supported to adopt sustainable practices that increase productivity for themselves and their communities and, at the same time, conserve the environment. However, the complication of transitioning to sustainable practices arises in bringing the benefits of finances, technologies, and scale to these small landholdings.

Financial benefits are limited due to a need for product marketing and capital for organic farm inputs. Many investments have been initiated by government and bilateral agencies, private donors, and investors. Yet CoSAI research (CoSAI 2020) shows that only a tiny fraction of such funding is intended to promote environmental and social objectives.

Technologies must provide better logistical linking of producers to consumers to minimise post-harvest losses, greater responsiveness to consumer needs, and accessibility to solutions promoting sustainable food systems. As production and value chain systems become increasingly digitised, farmers should be empowered to gain more revenue from the food they produce and the knowledge they bring to the process within these digital spaces. Farmers can be trained to use agricultural apps, participate in policy-making decisions, interpret meteorological data, analyse consumer patterns, and other participatory interventions. We also need to increase their digital literacy to ensure they take advantage of connectivity to reach consumers as directly as possible and with virtual support networks.

Finally, to address scale and maintain the value chain, we need more local and contextualised market solutions for different localities, agricultural practices, stakeholders, landscapes, and other conditions. We need to develop mechanisms to create regional funds and focus on bringing diverse investors and donors together locally to create the

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ecosystem required for farmers to flourish, particularly small and marginal farmers. Stakeholder consultations that involve key decision makers from the government and corporate sectors can help influence the implementation of programs with mechanisms that increase farmers' incomes and can be scaled. Farmers could be incentivised directly to adopt sustainable approaches through direct account transfers. Unless our producers are empowered with increased revenues and capabilities, our proposed recommendations and techniques will not be implemented successfully.

2.2 The consumer's perspective

In 2018, the Food and Agriculture Organisation of the United Nations (FAO) and the United Nations Environmental Programme (UNEP) jointly framed sustainable agriculture as "a consumer-driven, holistic concept that refers to the integrated implementation of sustainable patterns of food consumption and production" (FAO and UNEP 2022). Consumers worldwide can be a powerful force for change towards more sustainable and equitable agri-food systems. However, marketing approaches view consumers as passive actors, deepening the disconnect between consumers, producers, and nature.

From a market perspective, communication strategies should encourage the consumption of healthy, nutritious, and sustainable food as aspirational for all. Policies can be framed to promote green lifestyles in circular bioeconomies. Simultaneously, mechanisms must be established to ensure that food is economically accessible to consumers. Studies on consumer behaviour show that people in India are willing to spend a premium price for organically grown and sustainably sourced food. Still, their purchase intention is chiefly affected by accessibility and availability, amongst other factors (Singh and Verma, 2017).

Consumers must also play an active role in the sustainable transition. For example, including both producers and consumers in the production and distribution process can collectively allow both parties to peer review the production process and ensure that the producer abides by the criteria and standards that guarantee the quality and integrity of the product. Such inclusion leads to equal sharing of power and responsibilities, the formation of trust, and a permanent learning process through the engagement of all stakeholders.

From being the largest drivers of global environmental change to becoming agents of global sustainability, the transition to more sustainable practices requires a significant shift from farm-level solutions to focusing on the entire value chain - uniting producers and consumers in all our discussions. Most agricultural value chains are outlined in a linear format, placing consumers at the end of the value chain. However, consumers directly impact not just the market but also the producers and the environment. In the entire value chain, consumers can disrupt the system towards more sustainable and equitable agri-food systems.

2.3 The environment perspective

Historically, we have approached agriculture primarily from an extractive and intensive approach to increase productivity for the ever-growing population. These approaches have led to the degradation of the ecosystems on which agriculture inherently depends. It is estimated that 33% of the world's soils have been degraded (FAO and ITPS 2015). Three additional challenges that are being faced today are the ecosystem services on which agriculture depends, the health of biodiversity, and climate change. In most countries across the Global South and particularly in India, cultivation patterns such as mono-cropping with heavy reliance on groundwater and chemical inputs have reduced food sovereignty and have added to growing environmental problems. In addition, these farming methods have decreased the carbon-sequestering ability of soil, which is one of the reasons for our increasing global temperatures. As a specific example, healthy soils potentially hold up to 50 times more water than chemically driven agricultural soils (Kumar and Jehne, 2020). Increased soil water-holding capacity decreases the chances of floods. Healthy soil also promotes the soil's ability to sequester carbon. Therefore, farmers will suffer less from a low-yield season than conventional chemical-based farming because of better carbon sequestration and soil resilience.

For finance ministries, incentivising sustainable agricultural practices is critical regarding food security, biodiversity conservation, and the overall well-being of humans, animals and the larger ecosystem. Incentives should be advocated not only by the ministers themselves but by governments at national and international levels. It is also essential to ensure that government schemes and strategies are adapted across various agroecological zones. Better adaptation of policies for agroecological considerations in India could be achieved through effective implementation of programs and activities under the National Action Plan on Climate Change (NAPCC; DBT 2008), National Water Mission (NWM 2020), National Mission for a 'Green India' (MoEFCC 2022), National Mission for Sustainable Agriculture (MoAFW 2019), and the proposed National Mission on Biodiversity and Human Wellbeing (PSA 2020). Important policy areas include rural development (e.g., guaranteed employment for the rural poor for part of the year, investment in rural infrastructure); spatial planning (e.g., land use planning, zoning regulations); environmental regulations (e.g., strategic environmental assessments); water policies and planning (e.g., integrated water resources management approaches, water tariffs); agricultural pricing (e.g., tariffs, minimum price guarantee, and subsidies for agricultural commodities); and risk management (contingency plans, insurance, seed banks). The policies of local and national governments directly contribute to adapting various schemes and strategies across different agroecological zones.

Through community consultations with farming communities, researchers and local environmental experts can work together to identify gaps and develop guidelines and toolkits that are contextualised and region-specific. Advancing agroecology requires harnessing the power of a social movement and knowledge-intensive practices. Both must be intrinsically linked for success to happen.

3. Conclusions

Social, economic, and environmental sustainability are closely intertwined and necessary for sustainable food systems. Farmers faced with poverty are often forced to mine natural resources to make ends meet, even though environmental degradation may affect their long-term livelihood. Consumers, who in most cases are placed at the end of the traditional linear agri-supply chain, play an essential role in the transition to sustainable food systems. Consumption patterns regulate markets and farm production while determining the nature of the waste and side streams produced in the process that can be used as inputs for subsequent production. On the other hand, the behavioural aspects of consumers can also negatively impact the soil, water, biodiversity, and climate inputs for producers. Understanding the interrelationships between the various actors and stakeholders in our agriculture and food systems is important. By creating policies and practices that integrate social, environmental, and economic interests, societies can promote more sustainable food security. There is enormous power when all stakeholders come together. Listening and learning how to trust each other is just the beginning. We need to turn networks into communities of practice that share, multiply, expand and scale knowledge.

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23. Improving Diets for People and the Planet: Priorities for South Asia

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Home to one-quarter of humanity — one-fifth of whom are youth – South Asia has the world's largest concentration of poverty and malnutrition. The Green Revolution positioned South Asia to produce one-quarter of the world's consumed food, but the region's agrifood systems today face formidable poverty reduction, climate change adaptation and mitigation, environmental health and biodiversity challenges. Significant hurdles remain to securing an adequate and affordable supply of diverse foods necessary for sustainable healthy diets. Social, economic, and geographic inequalities create barriers from production to consumption, disproportionately affecting the poor. Unhealthy food consumption is rising, with many nutritious foods too costly for the poor.

Many of South Asia's agricultural policies and the research systems supporting them focus primarily on the production and related value chains of single crops in isolation, with less emphasis on developing an evidence base around the multisectoral farm, market, and policy interventions needed to sustainably intensify *and* diversify farming systems equitably without overstepping environmental boundaries. Integrated approaches are essential that consider household food production alongside market purchase. In addition, increased nutrition awareness among rural households, improved affordability of nutritious diets and efforts to strengthen women's empowerment are essential to accelerate progress.

Today's obstacles must be overcome through coordinated efforts to transform agrifood systems in ways that ensure that people can equitably access and consume healthy diets produced within environmental boundaries. Economic development efforts must consider the critical role of agriculture in South Asia's economies, while also creating other opportunities to improve livelihoods and reduce poverty. Food systems transformation must support and incentivize farmers to produce nutritious foods profitably, while also reducing prices for consumers purchasing healthy products by shortening and reducing inefficiencies within value chains. Solving these challenges will require accompanying coordinated research and action across the public and private sector.

While South Asia's food environments are diverse, diets are poor and limited in diversity, and increasingly include unhealthy and/or ultra-processed foods. Insights are needed into how factors across agri food systems and within households and communities shape diets to support actions toward equitable SHDs. Much more evidence is needed on dietary practices of consumers and on both behavioral, structural and commercial determinants of food choices. On behavioral determinants, public health programs in South Asia have focused primarily on increasing dietary diversity, with limited success due to insufficient efforts to tackle some of the intractable structural determinants of diets. These include the challenges of affordability of nutritious diets as well as gendered labor allocations within homes and across communities, and other structural constraints related to water and energy/fuel. Finally, commercial determinants related to the rampant marketing and widespread distribution of low nutrient-value ultra-processed foods are critical for actors at all levels – global, regional, national and local – to tackle.

In my keynote, I aim to present evidence on these challenges, and explore insights from ongoing research on to understand and address diverse challenges to improving diets for the poor. My presentation will draw on evidence from primary and secondary empirical analysis, behavior change trials in nutrition as well as integrated programs in sectors such as agriculture, social protection and women's group programs. Considering the importance of local governance for food systems and diets, I will also reflect on the essential role of data-informed diagnostics to support and strengthen the efforts of local, national and global actors to support food systems transformations.

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24. Transitioning Towards Agroecology for Sustainable and Healthy Food Systems in Africa

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Globally, majority of people who care about the value of the natural resource base to the foundation of most economies are making efforts towards slowing down or reducing the negative effects of climate change, dwindling water sources, declining soil fertility, loss of biodiversity and harmful pesticide residues. In Africa, a typical example of agroecology has been supported by the African Union, development partners, public institutions, civils society organizations and the private sector. This has been the Ecological Organic Agriculture Initiative for Africa. The EOA Initiative envisions actors in Africa achieving resilient and vibrant ecological organic agricultural systems for enhanced food and nutrient security and sustainable development. The mission is to promote ecologically sound strategies and practices among diverse stakeholders involved in production, processing, marketing and policy making to safeguard the environment, improve livelihoods, alleviate poverty and guarantee food security among farmers in Africa.

The EOA-I aims to transform and create sustainable food systems through promoting ecologically sound strategies and practices among diverse stakeholders in production, processing, marketing and policy making, to safeguard the environment, improve livelihoods, alleviate poverty and guarantee food security. The overall goal of the initiative is to mainstream EOA into national agricultural production systems by 2025 in order to improve agricultural productivity, food security, access to markets and sustainable development in Africa.

The presentation I will make at the IESIC 2022 will draw from the current results of the initiative from 9 African countries - five in Eastern Africa (Ethiopia, Kenya, Rwanda, Tanzania, and Uganda) and four in West Africa (Mali, Nigeria, Benin, and Senegal), and findings from studies that have been done comparing the resilience or organic and conventional farming systems in Africa.

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25. Fluazaindolizine (Reklemel^{tm} Active): A Novel Highly Selective Nematicide

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Plant-parasitic nematodes remain a significant threat and source of yield reduction in numerous important crops around the world. Over the last two decades many conventional synthetic nematicides frequently used against these soil dwelling pests have come under significant regulatory as well as public pressure due to a range of toxicological and environmental concerns. In response, the crop protection industries have initiated intensive efforts directed at the discovery and development of new biological or chemical nematicides as well as native and transgenic traits in crops. Fluazaindolizine (Reklemel™ active), is a selective nematicide developed by Corteva Agriscience ™ with a favorable toxicological and ecotoxicological profile. It is the first member from the novel chemical class of sulfonamide nematicides. Reklemel helps preserve healthy soils by controlling damaging nematode species while being highly compatible with beneficial organisms. Reklemel™ active provides targeted protection against plant-parasitic nematodes, enabling root establishment and contributing to healthy crops and high-quality harvests. Commercially, it is formulated as a liquid suspension concentrate under the trade name Salibro™ 500 SC. It has been extensively tested in laboratory, greenhouse, micro-plot and field trials in North America, Latin America, Europe, Africa, the Middle East and Asia where it has proven very effective against a range of important plant parasitic nematode species. An introduction to the discovery of Salibro™, its chemical and biological properties as well as an overview of its field performance in key crops in India will be presented.

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Theme 1

Genetics Innovations for Climate-resilient Agri-food Systems

1.1 Varietal Response of Bio-inoculant on Horticultural Traits in Aubergine (*Solanum melongena* L.)

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Keywords: Aubergine; Bio-inoculant; Consortium; *Pseudomonas*

1. Introduction

Aubergine, commonly known as brinjal, is one of the most important vegetable crops grown all over the world and is popularly known as a poor man's crop. The high nutrient requirement of the crop along with high vulnerability toward various abiotic and biotic stresses causes yield losses in this crop and deterioration of soil health. To sustain the eco-balance, plant growth-promoting substances (bio-inoculants) provide a tool for maintaining soil fertility and promoting plant health (Gosal *et al*., 2011). These bio-inoculants are the soil bacteria that inhabit the root surface and promote plant growth and development by direct mechanisms, such as fixation of atmospheric nitrogen, production of siderophores, solubilization of minerals like phosphorus, synthesis of phytohormones, or by indirect mechanisms, such as induction of disease resistance, stimulation of other beneficial symbiosis, xenobiotics degradation, and antagonism against pathogens.

2. Materials and methods

The experiment comprised three varieties (Punjab Raunak, Pusa Purple Long, and Punjab Sadabahar) and five bio-inoculants as treatments (*P. fluorescens*, *Bacillus* species, phosphate solubilizing bacteria, consortium of all bio-inoculants, and control). The treatments were arranged in a randomized block design (factorial). The data were statistically analyzed by using OPSTAT software. The plots were delineated as per the treatment requirements and the layout was marked according to the plan. All the production strategies were followed as per the Package and Practices of Vegetables of Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu.

3. Results and discussion

Plant height, though a varietal character, varied significantly under different treatments of bioagents in all three varieties. Maximum plant height (92.73 cm) was recorded in consortium inoculation, which was significantly more than other treatments (Table 1).

Table 1 Varietal response of bio-inoculants on horticultural traits in Aubergine (*Solanum melongena* L.)

Bio-inoculants (B) / Varieties(V)	Plant height(cm)	Days to first picking	Number of fruits per plant	Average fruit weight (g)	Marketable fruit yield (q/ha)	Total phenol content (mg/100g)	Fruit borer infestation (%)	Phomopsis blight incidence (%)
B_1	86.11	67.20	49.34	71.59	224.51	29.73	7.59	3.80
B_2	82.90	67.96	48.06	70.66	218.78	27.51	8.44	4.08
B_3	89.10	66.00	50.43	73.18	231.60	31.80	6.71	3.59
B_4	92.73	65.90	54.97	74.35	237.97	34.06	5.76	3.07
B_5	73.94	68.92	47.37	69.98	207.05	25.10	9.17	4.56
C.D (at 5%)	1.50	0.57	1.43	0.97	6.86	0.55	0.36	0.28
V_1	88.65	66.16	53.73	74.17	244.05	34.81	7.18	3.70
V_2	78.52	68.23	47.55	69.65	203.22	24.87	8.13	4.03
V_3	87.69	67.02	48.82	72.03	224.67	29.23	7.29	3.72
C.D (at 5%)	1.16	0.44	1.11	0.75	5.31	0.42	0.28	0.22

B_1: *Pseudomonas fluorescens* V_1: Punjab Raunak; B_2: *Bacillus* species V_2: Pusa Purple Long; B_3: Phosphate solubilizing bacteria (PSB) V_3: Punjab Sadabahar; B_4: Consortia of all; B_5: Control

Minimum plant height (73.94 cm) was under control treatment. Among the various varieties, Punjab Raunak had the maximum plant height which was at par with Punjab Sadabahar. Pusa Purple Long had the shortest plants. The increase in height was due to increased uptake of primary nutrients that enhanced cell division and cell elongation (Singh *et al*., 2017). Punjab Raunak tooka minimum number of days for first picking (66.16) under the influence of consortium treatment (T_4). Which resulted in earliness. However, it was at par with T_3(PSB). The yield attributes, namely, the number of fruits per plant, fruit weight, and marketable fruit yield, also responded favorably under bioagent treatment in all three varieties. The mixed inoculants interact synergistically as bio-enhancer. A maximum number of fruits/ plant (54.97), average fruit weight (74.35g), and marketable fruit yield (237.97 q/ha) were recorded under consortium inoculation. Punjab Raunak proved superior to Pusa Purple Long and Punjab Sadabahar for the number of fruits, fruit weight, and marketable yield. The minimum number of fruits was recorded in Pusa Purple Long (47.55). The synergistic association among the rhizobacterial inoculants plays acritical role in elevating inhibitory products, providing the nutrients, and stimulating each other through physical or biochemical activities (Gajbhiye *et al*., 2003). The biochemical factors of the host plant play a vital role in resistance to various insectpests and relatively resistant genotypes contain a higher amount of phenols inherently. The phenolic content provides resistance against various biotic stresses. Punjab Raunak possessed the maximum phenolic content (34.81mg/100g), which was statistically more than the other two varieties. Consortia of bioagents also enhanced the phenolic contentin the plant. The application of bioagents minimizes the insect pest and disease incidence in all the varieties grown. Consortial application of bioagents resulted in minimum fruit borer infection (5.76%) and Phomopsis blight incidence (3.07%), which proved to be statistically lower than other bioagent treatments. Maximum infection was recorded under the control. The cultivars also showed variable responses toward biotic stress parameters. Punjab Raunak had shown the minimum incidence of fruit borer and phomopsis blight as compared to Punjab Sadabahar and Pusa Purple Long.

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Maximum fruit borer infestation (8.13%) and Phomopsis blight incidence (4.03%) were recorded in Pusa Purple Long. So, Punjab Raunak can be recommended for Jammu conditions under the consortial application of *Pseudomonas, Bacillus*, and PSB.

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1.2 Standardization of Micropropagation Protocol in Garden Pea (*Pisum sativum* L.)

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Keywords: Garden pea; *In vitro*; Leguminous; Tissue culture

1. Introduction

Garden pea (*P. sativum* L.) is an important leguminous vegetable crop in the Indian subcontinent, but its productivity is too low to fulfil the required demand due to the heavy infestation by various diseases and insect pests. Non-conventional approaches like plant tissue culture is another way of propagating plants independent of season and space in a short span of time. The presence of totipotent tissues that react well to *in vitro* methods is a requirement for the success of tissue culture-based approaches in crop plants. A reliable tissue culture protocol is a prerequisite for the production of disease-free, high-quality planting material and the rapid production of many uniform plants. However, legumes in general are not amendable to *in vitro* propagation due to their recalcitrant nature. Therefore, an attempt was made to develop a reliable and efficient protocol for obtaining rapid shoot multiplication under *in vitro* conditions which could be further used in crop improvement programmes and genetic transformation studies.

2. Materials and methods

Two explants, namely, seed and embryo, were used for standardization of micropropagation protocol in garden pea variety 'P-89'. The experiments were conducted in the Plant Tissue Culture Laboratory of the Division of Vegetable Science and Floriculture, SKUAST-Jammu during the year 2020-21. Different concentrations and combinations of growth regulators (auxins and cytokinin) have been used to optimize the media concentration for obtaining morphogenic responses at various stages, that is, shoot initiation, shoot proliferation and rooting to obtain *in vitro* raised pea plantlets. All the cultures were incubated at 25°C with a 16-h photoperiod using cool white fluorescent tubes and an irradiance of 40 µmol/(ms).

3. Results and discussion

A reliable and efficient *in vitro* protocol has been standardized. The results obtained during different *in vitro* experiments revealed that pre-treatment of seeds with Bavistin (0.2%)+Streptomycin (0.02%) for 10 min followed by 70% ethanol dip and 2% sodium hypochlorite treatment for 3 min resulted in the highest survival for both the explants, namely, embryo and seed. The best shoot initiation response was observed on MS media fortified with 2.00 mg/L BAP and 1.00 mg/L Kinetin in both the explants. Embryo explant was found to be superior as compared to seed explant for culture establishment. Our results are in agreement with the findings of Rajput and Singh (2010) who also reported embryo explants to be superior to other explants in peas. On MS medium fortified with 2.00 mg/L BAP and 1.00 mg/L TDZ, the highest number of shoots/explant (5.50) and the average length of the shoot (3.50 cm) were reported for shoot multiplication. For rooting, MS medium fortified with 1.00 mg/L IBA was found to be the optimum concentration forming the maximum number of roots (3.67) and root length (4.24 cm).

Table 1 Effect of various treatment combinations on explant survival, shoot initiation, shoot multiplication, and rooting response under *in vitro* conditions

Explant survival as influenced by various surface sterilization treatments

Time duration (in minutes)		Explant survival (%)	
Pre-treatment with 0.2% Bavistin+0.02% Streptomycin	70% ethanol dip followed by treatment with 2% NaOCl	Embryo	Seed
10	3	68.24	50.64

Shoot initiation as influenced by different MS media concentrations using embryo and seed explants

Concentrations used (mg/L)		Percent response		Days taken for shoot initiation	
BAP	Kinetin	Embryo	Seed	Embryo	Seed
2.00	1.00	73.33	53.76	15.00	17.23

Shoot multiplication as influenced by various MS media concentrations and combinations

Concentrations used (mg/L)		Days taken for the formation of multiple shoots	No. of shoots/explant	Average length of the shoot (cm)
BAP	TDZ			
2.00	1.00	19.00	5.50	3.56

Rooting response as influenced by various concentrations of IBA

Concentrations used (IBA) (mg/L)	No. of roots/shoots	Average length of root (cm)
1.00	3.67	4.24

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1.3 Effect of Transplanting Dates and Method of Seed Production in Broccoli (*Brassica oleracea* var. *italica*) under Jammu Sub-tropics

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Keywords: Broccoli; Ex situ method; In situ method; Seed Production; Transplanting dates

1. Introduction

Broccoli (*B. oleracea* var. *italica*) is one of the most nutritious cole crops and it is a good source of carbohydrates, protein, calcium, phosphorous, iron, fibers, β-carotene, thiamine, riboflavin, and ascorbic acid. Sowing and transplanting time plays a key role to guarantee the desired crop performance and high economic returns to the farmers. The transplanting dates and methods directly affect yield and quality parameters in broccoli. Broccoli seed production can be done either by *in situ* (seed to seed) or *ex situ* (head to seed) methods, depending upon the purpose of the seed production. The *in situ* method of seed production is followed for commercial seed production, whereas for nucleus or breeder seed production *ex-situ* method of seed production is followed. Similarly, the optimum date of transplanting of seedlings has a direct impact on the quality parameters for both the seed production methods. Keeping in view the importance of seed in this crop, the present investigation was carried out to study the suitable method and optimum date of transplanting for quality seed production of broccoli under the Jammu sub-tropics.

2. Materials and methods

The present investigation was carried out at the experimental farm of the Division of Vegetable Science and Floriculture, SKUAST-Jammu during the rabi season of 2019-20. The experiments comprised two methods, namely, *in situ* (M_1) and *ex situ* (M_2), and three dates of transplanting, that is 30 September (D_1), 15 October (D_2), and 30 October (D_3). Seeds of the Jammu broccoli-07 variety were sown on different dates at 15 days intervals (1st September, 15th September, and 30th September) in raised nursery beds. Healthy seedlings of 30 days old were transplanted in the afternoon hours as per treatments. For *ex situ* seed production, a separate field was selected and after proper ploughing, pits of 1 ft diameter and 1 ft depth were dug. The plants were lifted with mud ball without disturbing the roots and were replanted in these pits. Data were recorded for both the crops (*in situ* and *ex situ*) for various parameters, namely, days to 50% bolting, days to 50% flowering, plant height (cm), plant spread (cm), days to seed maturity, number of siliqua per plant, siliqua length (cm), number of seeds per siliqua, seed yield per plant (g), seed yield per ha (kg), test weight (g), and germination percentage from 10 plants per treatment and per replication.

3. Results and discussion

The analysis of data revealed that the *in situ* method of seed production took a lesser number of days to 50% bolting (107.17), 50% flowering (130.92), and days to seed maturity (193.11) than the *ex-situ* method. Maximum plant height (85.39 cm), more plant spread (51.79 cm), and more number of primary branches (25.58) were recorded in the *in-situ* method of seed production. The number of siliqua per plant (712.32), siliqua length (6.13 cm), number of seeds per siliqua (12.71), seed yield per plant (27.59 g), seed yield per hectare (715.33 kg), test weight (3.23), and germination percentage (94.58) were observed to be maximum in the *in situ* method of seed production. Among dates, 30th October of transplanting was the earliest for days to 50% bolting (104.62), days to 50% flowering (130.38), and days to seed maturity (187.74) followed by 15th October. Plant height (82.23 cm), plant spread (55.97 cm), and number of primary branches (27.07) were maximum when transplanted on 30th September. The number of siliqua per plant (754.47) was highest on the 15th October planting. The number of seeds per siliqua (13.49), siliquae length (6.18 cm), seed yield per plant (28.51 g), and seed yield per hectare (739.12 kg) were recorded to be highest on 30th September transplanting (Table 1). These findings are in accordance with the earlier work of Chandra and Shukla (2013). Analysis revealed that the interaction effect, M_1D_1, that is, *in situ* method of seed production and 1st date of transplanting (30th September) performed better for seed production under Jammu Sub-tropics.

Table 1 Effect of methods of seed production and dates of transplanting on various characters in broccoli

Characters	Method of seed production		Dates of transplanting		
	M_1	M_2	D_1	D_2	D_3
Days to 50% bolting	107.17	115.75	118.87	110.87	104.62
Days to 50% flowering	130.92	142.17	143.13	136.13	130.38
Plant height (cm)	85.39	63.83	82.23	73.41	68.19
Plant spread (cm)	51.79	35.29	55.97	43.65	31.00
Number of primary branches	25.58	21.44	27.07	23.44	20.03
Days to seed maturity	193.11	203.83	207.96	199.71	187.74
Number of siliquae per plant	712.32	552.66	648.45	754.47	494.54
Siliqua length (cm)	6.13	5.73	6.18	6.06	5.56
Number of seeds per siliqua	12.71	11.15	13.49	11.79	10.50
Seed yield per plant (g)	27.59	23.02	28.51	25.26	22.14
Seed yield per hectare (kg)	715.33	596.66	739.12	654.75	574.12
Test weight (g)	3.23	3.02	3.29	3.12	2.96
Germination %age	94.58	93.50	97.02	93.98	91.12

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1.4 Standardization of Micropropagation Protocol in Tomato (*Solanum lycopersicum* L.)

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Keywords: *In vitro*; Solanaceae; Tissue culture; Tomato

1. Introduction

Tomato (*S. lycopersicum* L.) is one of the most popular vegetables belonging to the family Solanaceae. It is the second largest cultivated vegetable crop after potato and ranks seventh in the list of important crop species grown worldwide. Tomato is highly sensitive to several biotic and abiotic stresses which affect its production and quality under open field conditions. Biotechnological tools can be used for disease-free multiplication of promising hybrids since the development of hybrid seeds every year is a cumbersome and costly affair. Efficient standardized plant regeneration protocol in tomato hybrids requires the optimization of multiple factors including growth regulator concentration, explant types, cultivars, and so on. Therefore, an attempt was made to develop a reliable and efficient protocol for obtaining rapid shoot multiplication under *in vitro* conditions for the multiplication of disease-free plants at a faster rate using plant tissue culture.

2. Materials and methods

Micropropagation protocol for tomato commercial hybrids, namely, Arka Rakshak, PTH-1, and BSS-488, using three explants, namely, cotyledon, hypocotyl, and shoot tip, was standardized in the Plant Tissue Culture Laboratory of the Division of Vegetable Science and Floriculture, SKUAST-Jammu during the year 2020-21. Different explants, that is, shoot tip, cotyledons, and hypocotyl, were put on MS media with various concentrations of BAP and Kinetin to standardize the media concentration for obtaining morphogenic responses at various stages, that is, shoot initiation, shoot multiplication and elongation, and finally rooting to obtain *in vitro* raised tomato plantlets. All the cultures were incubated at 25°C with a 16-h photoperiod using cool white fluorescent tubes and an irradiance of 40 μmol/(m^2 s).

3. Results and discussion

Standardization of shoot multiplication protocol for three tomato commercial hybrids, namely, Arka Rakshak, PTH-1, and BSS-488, revealed that among the three explants used, the best shoot regeneration response was recorded in cotyledon explant for genotypes Arka Rakshak and BSS-488, whereas for PTH-1 the best response was observed in shoot tip explant. Genotypic differences were observed regarding shoot initiation and multiplication. Best shoot bud initiation response was observed in PTH-1 on MS media supplemented with 1 mg/L BAP and 0.2 mg/L Kinetin followed by Arka Rakshak on MS media supplemented with 1.5 mg/L BAP. However, the minimum response was observed in BSS-488 on MS media fortified with 1.5 mg/L BAP+0.1 mg/L Kinetin. For shoot multiplication, the best response was recorded in PTH-1 on MS media supplemented with 2.0 mg/L BAP followed by Arka Rakshak on MS media supplemented with 1.5 mg/L BAP. However, the minimum response was observed in BSS-488 on MS media fortified with 1.5 mg/L BAP+0.1 mg/L Kinetin. Similar results were reported by El-Shafey *et al*. (2017). Best rooting response and root length were recorded on MS medium supplemented with 1 mg/L IBA in all the three genotypes, respectively (Table 1).

Table 1 Effects of various treatments and types of explants on shoot initiation, shoot multiplication, and rooting response under *in vitro* conditions

Shoot initiation as influenced by various MS media concentrations and combinations								
Genotype	Hormonal concentration (mg/L)			Days to shoot bud initiation		Percentage response		
	BAP+Kinetin	Cotyledon	Shoot tip	Hypocotyl	Cotyledon	Shoot tip	Hypocotyl	
PTH-1	1.0+0.2	16.33	12.33	24.33	76.00	80.67	53.33	
Arka Rakshak	1.5+0.0	12.33	15.33	20.67	76.33	73.33	62.33	
BSS-488	1.5+0.1	13.33	15.33	18.33	78.33	73.67	68.33	

Shoot multiplication as influenced by various MS media concentrations and combinations				
Genotype	Hormonal concentration(mg/L) (BAP+Kinetin)	Days to multiple shoot formation	Number of shoots/explants	Shoot length (cm)
PTH-1	2.0+00	17.00	4.24	5.51
Arka Rakshak	1.5+00	19.67	4.92	2.48
BSS-488	1.5+0.1	19.67	5.64	3.93

Rooting response as influenced by various concentrations of IBA					
Genotype	Hormonal concentration of IBA (mg/L)	Percentage response	Days to root initiation	No. of roots per plantlet	Average root length (cm)
PTH-1	IBA (1.0)	80.67	3.88	5.20	9.62
Arka Rakshak	IBA (1.0)	84.33	2.86	5.32	7.00
BSS-488	IBA (1.0)	74.67	3.00	5.10	7.10

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1.5 Genetic Association of Traits for Improvement in Backcross (BC_2F_1) Populations of Bell Pepper

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Keywords: *Capsicum annuum* var. *grossum*; Genetic analysis; Horticultural traits

1. Introduction

Bell pepper is one of the most important vegetables in the world (Rani *et al*., 2021). Fruit yield is a very complex trait and it is the result of interactions of a number of factors inherent both in plants and the environment. Sufficient knowledge about the magnitude and degree of association of yield with its attributing traits is of great importance to breeders. Using these genetic associations of traits, breeders would apply suitable selection strategies for crop improvement. Therefore, the present research was initiated to study both correlation and path coefficient analysis in six different BC_2F_1 populations of bell pepper.

2. Materials and methods

The plant materials consisted of six BC_2F_1 populations, namely, MS-12/PAU SM-1//PAU SM-1 (MSSM-1), MS-12/PAU SM-2//PAU SM-2 (MSSM-2), MS-12/PAU SM-3//PAU SM-3 (MSSM-3), MS-12/PAU SM-9//PAU SM-9 (MSSM-9), MS-12/PAU SM-17//PAU SM-17 (MSSM-17), and MS-12/PAU SM-21//PAU SM-21 (MSSM-21) of bell pepper. The materials were planted in a randomized complete block design with three replications under a polynet house at the Vegetable Research Farm, Punjab Agricultural University, Ludhiana, India. The data were recorded from 20 plants from each genotype in each replication. Mean data were used for statistical analysis for 13 diverse traits, namely, plant height (PH), plant spread (PS), primary branches per plant (PBP), fruit weight (FW), fruit length (FL), fruit width (FWT), pericarp thickness (PT), number of lobes per fruit (NLF), number of fruits per plant (NFP), number of seeds per fruit (NSF), 1000 seed fresh weight (SFW), 1000 seed dry weight (SDW), and total fruit yield per plant (FYP). All the statistical analyses were performed using the computer software program WINDOSTAT 9.1 developed by INDOSTAT Services Ltd., Hyderabad, India.

3. Results and discussion

Significant association of traits suggested that there is high scope for direct and indirect selection for further improvement of fruit yield and its component traits (Table 1). The genotypic correlation coefficient provides measures of genetic association between traits and thus helps to identify the more important as well as less important traits to be considered in breeding programmes. Our research data exhibited significant positive genetic and phenotypic association between FYP and FW (r = 1.023 and 0.923), PS (r = 1.160 and 0.507), PBP (r = 0.885 and 0.786), FL (r = 0.761 and 0.589), FWT (r = 0.873 and 0.777), PT (r = 0.840 and 0.623), NLF (r = 0.747 and 0.689), NSF (r = 0.625 and 0.494) indicating that these traits are important for getting higher fruit yield in bell pepper. A significant positive association of FYP with FL and FWT was also reported by Sharma *et al*. (2010). The trait FW showed a significant and positive association with PS, PBP, FL, FWT, PT, NLF, SFW, and FYP at both levels, indicating that as the FW increases, the FYP and these traits would also increase. NSF showed a significant positive relationship both at genotypic and phenotypic levels with FWT, PT, and FYP. NLF had a very high positive direct genotypic effect (1.408) on FYP, followed by NSF, FL, PS, NFP, and SFW (Figure 1). The traits showing the high direct effect on FYP indicated that direct selection for these traits might be effective and there is a possibility of improving FYP through selection based on these traits. NFP exhibited a positive indirect effect on FYP through the traits PH, FW, PT, NSF, and SDW.

Table 1 Estimates of genotypic (G) and phenotypic (P) correlation among different traits in backcross populations of bell pepper

Traits		PS	PBP	FW	FL	FWT	PT	NLF	NFP	NSF	SFW	SDW	FYP
PH	G	0.228	0.535*	0.213	0.140	0.170	–0.493*	0.833**	–0.087	–0.444	0.629**	0.448	0.226
	P	0.113	0.359	0.145	0.073	0.107	–0.319	0.701**	–0.147	–0.283	0.530*	0.173	0.173
PS	G		0.852**	1.290**	1.308**	0.900**	0.791**	0.813**	–1.047**	0.714**	1.024**	0.412	1.160**
	P		0.535*	0.561*	0.701**	0.499*	0.566*	0.390	–0.326	0.000	0.423	0.268	0.507*
PBP	G			0.891**	0.770**	0.982**	0.439	0.908**	0.073	0.387	0.792**	0.180	0.885**
	P			0.749**	0.654**	0.811**	0.419	0.721**	0.131	0.283	0.651**	0.252	0.786**
FW	G				0.938**	0.868**	0.911**	0.755**	–0.226	0.665**	0.598**	0.092	1.023**
	P				0.577*	0.804**	0.583*	0.604**	–0.105	0.399	0.551*	0.009	0.923**
FL	G					0.913**	0.697**	0.625**	–0.647**	0.399	0.895**	0.568*	0.761**
	P					0.533*	0.424	0.347	–0.345	0.086	0.545*	0.314	0.589*
FWT	G						0.736**	0.610**	0.133	0.743**	0.779**	0.005	0.873**
	P						0.613**	0.498*	0.222	0.497*	0.559*	–0.112	0.777**
PT	G							0.041	–0.174	1.054**	0.292	–0.524*	0.840**
	P							0.155	0.074	0.669**	0.171	–0.236	0.623**
NLF	G								–0.025	–0.062	0.717**	0.439	0.747**
	P								–0.207	–0.036	0.464	0.360	0.689**
NFP	G									0.364	–0.379	–0.626**	–0.024
	P									0.275	–0.184	–0.391	–0.075
NSF	G										0.248	–1.020**	0.625**
	P										0.137	–0.439	0.494*
SFW	G											0.255	0.558*
	P											0.085	0.430
SDW	G												–0.006
	P												0.009

Note: * and ** represent significance at 5% and 1%, respectively.

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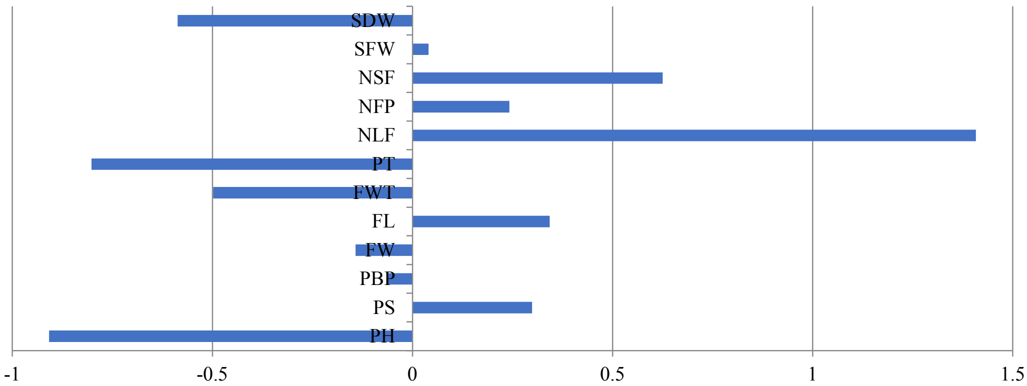

Figure 1: Direct (path coefficient analysis) effect of different traits on FYP at the genotypic level

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1.6 Growth Analysis in Relation to Environment and Nitrogen Levels in Three Varieties of Wheat Under Irrigated Conditions of N-W Himalayas

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Keywords: CGR; Dry matter; LAI; Sowing environments; Temperature; Varieties; Wheat; Yield

1. Introduction

Wheat occupies an important position in the agricultural sector and overall financial system, especially in the Asian region and its widespread cultivation is mainly due to its adaptation to different agro-climatic conditions. Advance or delay in sowing date, increasing N application, and choice of a suitable variety with the best thermal requirement represent the main agronomic manipulations that help to maintain existing crop production levels (Ventrella *et al*., 2012). The unfavorable environments created by high temperature mostly during reproductive stages, especially the grain filling stage, could be minimized by adjusting the sowing time to an optimum time for different varieties, which are suitable for early, normal, and late sown environmental conditions for assured higher yield. It is also reported by various researchers that the cool period for wheat crop in India is shrinking, while the threat of terminal heat stress is expanding (Gupta *et al*., 2021). High-yielding new varieties can never be fully exploited with the existing fertilizer practices and thus fails to provide adequate/desired yield. Thus, an experiment was planned by selecting a set of recommended wheat varieties under different sowing environments with enhanced N levels.

2. Materials and methods

Field experiments were conducted in *rabi* 2015-16 and 2016-17 at Agromet Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), Chatha, J&K, to evaluate the effect of sowing environments and N levels on yield of wheat varieties. Three wheat varieties (HD 2967, RSP 561, and WH 1105), three sowing dates or environments (25th October, 14th November, and 4th December), and three N levels (100, 125, and 150 kg/ha) were laid out in split plot design with three replications. The recommended dose of P and K was 50:25 kg/ha for the wheat crop. However, nitrogen was applied as per the treatment combinations.

3. Results and discussion

Among wheat varieties, WH 1105 recorded significantly superior grain yield as compared to the other two varieties; however, varieties HD 2967 and RSP 561 were statistically similar. A similar trend was noticed for straw and biological yields of wheat crop. The higher grain, straw, and biological yields of wheat could be attributed to greater genetic potential with efficient utilization of radiation by leading to the production of maximum leaf area and dry matter which in turn results in higher yields. Significantly higher grain yield of wheat was observed in early sown conditions (25th October) and followed by statistically lower values registered with normal and late sowings. Normal and late sown wheat recorded about 9.1% and 27.6% less grain yield than early sown crops, respectively. The possible reason behind the significantly higher yield values in early sowing may be optimum environmental conditions that were available for proper growth and development of the crop which could have enhanced the accumulation of photosynthates from source to sink and thus resulted in higher yield values. Wheat crop when applied 150% RN (150 kg N/ha) performed outstandingly with respect to grain yields, but the values were at par with that of 125% RN (125 kg N/ha). The recommended dose of nitrogen (100 kg/ha) also performed well but the values were significantly less than those of the other two doses of nitrogen. Higher wheat yield with enhanced N levels (125 kg/ha) could be traced to the reason that an adequately N fertilized crop might have benefitted from higher rates of N nutrition that could have resulted in a more vigorous and extensive root system of crop leading to increased vegetative growth means and greater carbohydrate translocation (Hameed *et al*., 2003).

Table 1 Performance of different wheat varieties as affected by various sowing environments and N levels (pooled data of 2 years)

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
Varieties			
V_1: HD 2967	4277	6118	10,395
V_2: RSP 561	4115	6206	10,320
V_3: WH 1105	4595	6510	11,104
CD (5 %)	104	292	280
Sowing environments			
D_1: 25th October	4782	5943	11,725
D_2: 14th November	4481	6328	10,809
D_3: 04th December	3723	5562	9286
CD (5 %)	140	193	269
Nitrogen levels			
N_1: 100% RDN (100 kg N/ha)	4067	5957	10,024
N_2: 125% RDN (125 kg N/ha)	4392	6354	10,746
N_3: 150% RDN (150 kg N/ha)	4507	6522	11,050
CD (5%)	119	171	193

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1.7 Effect of Plant Growth Promoting Beneficial Microorganisms in Growth Promotion of Drought Tolerant Rice Genotypes

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Keywords: Bio-stimulant; Microbial consortium; Plant Growth Promoting Microorganisms; Water deficit stress

1. Introduction

Plant growth promoting microorganisms (PGPMO) can colonize as an endophyte in plant cells which influences phytohormone production and phosphate solubilization and thereby increasing the agronomic efficiency and reducing the cost of production and environmental pollution by curtailing the use of agrochemicals (de Souza *et al*., 2015). However, the extent of growth stimulation by PGPMO is largely influenced by crop genotypes, suggesting that the response to PGPMO is under genetic control (Tucci *et al*., 2011). The balanced response of plants due to inoculation of PGPMO depends on the in-depth regulations of hormones and hormone-like compounds which are largely affected by crop genotypes, physiological status of the crop, cultivation conditions, and particular strains. The current studies involve the use of a locally developed seed germination pouch for determining the impact of PGPMO on the growth performance of six different rice genotypes having different levels of water deficit tolerance under soilless culture.

2. Materials and methods

A seed germination pouch was developed using polypropylene plastic bags (26.5×17.5 cm) and blotting paper. Experiments were conducted in a factorial completely randomized design where the first factor was rice genotypes and the second factor was PGPMO with two replications. Rice genotypes includeNR11374-B-B-23 (V1), IR 889665-39-1-6-4 (V2), NR-11271-13-B-6(V3), NR11115-13-B-B-31-3 (V4), NR 11105B-B.27 (V5), and Khumal-10(V6) having a different level of water deficit tolerance and PGPMO includes two *Bacillus* spp. isolates (29C and D22) and two *Trichodermaasperellum* isolates (T25 and T31) native to Nepal. Rice seeds were surface sterilized followed by soaking overnight in either bacterial suspension (10^6CFU/mL) or *Trichoderma* spore suspension (10^6spores/mL) or sterile water (non-biocontrol, B_0). Then the seeds were placed in germination pouches using a sterile tweezer. Rice was grown for20 days, and seedling and root length were monitoredat every three days interval. The area under the shoot growth curve (AUSPC) and area under the root growth curve (AURPC) were calculated for final analysis as mentioned by Wilcoxson *et al*. (1975). Statistical differences were assessed using the function "lm in the lme4 package of R Studio (R-3.2.5) (R Studio Team 2019) and Fisher's test of least significant difference (LSD) by utilizing the Agricolae package in R studio (Mendiburu, 2015).

3. Results and discussion

Rice shoot and root growth as indicated by AUSPC and AURPC were significantly (p<0.001) affected by the genotypes. The AUSPC was highest in NR 11105B-B.27 (V5) followed by NR11115-13-B-B-31-3 (V4) and IR 889665-39-1-6-4 (V2). AUSPC was lowest in NR11374-B-B-23V1 (43.6). The AURGC was significantly highest in NR 11105B-B.27 (V5) (65.3) and lowest in NR11374-B-B-23 (V1) (43.6).

Inoculation of PGPMO significantly (p<0.001) increased the root and shoot growth. The AURPC and AUSPC were significantly increased in *Bacillus* spp. D22 (68.1,77.8) inoculated seeds compared tonon-inoculated control. Similarly, root and shoot growth was also higher in *Bacillus* spp. 29C inoculated seeds compared to non-inoculated control. Inoculation of *T.asperellum* T25 did not change both root and shoot growth compared to the non-inoculated control. The shoot growth was increased by 19%, 33%, 20.3%, and 27.2% by 29C, D22, T25, and T31 respectively. *Bacillus* spp. 29C increased root growth by 13.5% and D22 by 21.6% compared to the non-inoculated control.

The interaction between genotype and PGPMO was also significant (p<0.001). In genotypes V1, V5, and V6, the root and shoot growth was not significantly affected by inoculation of PGPMO in the seed. However, in V2 both root and shoot growth was higher in D22 and T31 inoculated seeds compared to non-inoculated control. Root growth was also higher in other PGPMO inoculated seeds compared to the non-treated control. In the case of the V3 shoot, growth was not significantly affected by inoculation of PGPMO but root growth was higher in PGPMO inoculated seeds. No significant effect of PGPMO was found in v5 and v6 but in the case of v4 shoot growth was higher in D22 and 29C inoculated plants compared to non-inoculated control, but root growth was not significantly affected by PGPMO inoculation.

Table 1 Effect of plant growth promoting microorganisms and genotypes in root and shoot growth of rice

Genotype	PGPMO[1]	AUSPC[2]		AURPC[3]	
NR11374-B-B-23 (V1)		43.6	D	64.2	Bc
IR 889665-39-1-6-4 (V2)		64.2	Ab	81.2	A
NR-11271-13-B-6 (V3)		51.5	C	56.6	C
NR11115-13-B-B-31-3 (V4)		60.9	Ab	61.2	C
NR 11105B-B.27 (V5)		65.4	A	69.9	B
Khumal-10 (V6)		58.5	B	63.0	Bc
*P*value		2.22 E-12	***	4.23E -07	***
	29C	56.1	C	70.6	Ab
	D22	68.1	A	77.8	A
	T25	56.9	Bc	56.0	D
	T31	62.4	B	64.3	Bc
	B0	45.4	D	61.1	Cd
*P*value		7.93 E-13	***	7.42E -10	***

[1]Plant growth promoting microorganisms 22C and D22 are *Bacillus* spp. and T25 and T31 are *T. asperellum*; B0 indicates non-inoculated control; [2]AUSPC (area under the shoot growth curve); [3]AURPC (area under the root growth curve); ***:pvalue ≤ 0.001

The results indicate that the locally developed seed germination pouch could be utilized for screening the effect of PGPMO in plant growth stimulation in rice. The PGPMO

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strains have differential interaction with rice genotypes indicating the root and shoot growth stimulation by PGPMO is PGPMO and rice genotypes dependent.

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1.8 GGE Biplot Analysis of Genotype×Environment Interaction in Eggplant (*Solanum melongena* L.)

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Keywords: AMMI; Eggplant; GEI and GGE biplot

1. Introduction

Eggplant (*S. melongena* L.) is a popular and principal vegetable crop widely grown in the tropics and subtropical parts of India. There are umpteen numbers of commercially grown varieties and hybrids in the market, released both by public and private sectors. However, a genotype possessing considerably high yield potential coupled with stable performance in different environments has great value for its adaptation on large scale and in plant breeding programmes. There is an utmost need for the development of high-yielding stable varieties for specific environments. Most of the economic characteristics in brinjal are quantitative in nature that are susceptible to environmental fluctuations. The GGE model covers very critical areas in the study of the stability of multi-locational trials, such as the which-won-where pattern, mean performance and stability of genotypes, discriminating ability, mega-environment investigation, and representativeness of environments. Besides their individual effect, it becomes imperative to assess the stability of desirable genotypes capable of giving higher yields under different environments. Therefore, the present investigation was carried out to have an insight into the nature and magnitude of GEI among 25 brinjal genotypes across six environments using GGE biplot analysis as well as identification of mega environments within the test locations.

2. Materials and methods

The present investigation was carried out at the Experimental Farm of Division of Vegetable Science & Floriculture, SKUAST-Chatha during the years 2013-14 and 2014-15. The experimental material comprised 25 brinjal genotypes including 10 F_1 hybrids, namely, Rajni, PPL-74, Navkiran Improved, Sandhya, MH-80, Chhaya, PBH-3, Nisha Improved, Shamli, and Abhishek, and 15 open-pollinated varieties, that is, Punjab Sadabahar, Arka Shirish, Arka Kusumkar, Arka Keshav, Arka Nidhi, Arka Neelkanth, Pusa Shyamala, Pusa Kranti, Pusa Ankur, Pusa Uttam, PPL, PPR, PPC, BR-14, and Puneri Kateri, collected from different parts of the country, which were tested under six environments consisting of three seasons of sowing spread across 2 years (V_1 – Autumn-winter, 2013; V_2 – Spring summer, 2014; V_3 – Rainy; V_4 – Autumn winter, 2014; V_5 – Spring summer, 2015; and V_6 – Rainy, 2015). The individual experiment was replicated thrice in a randomized block design. The uniform healthy seedlings were planted on ridges maintaining inter- and intra-row spacing of 90×60 cm. All standard crop management practices were followed to raise a healthy crop. The data so generated were analyzed using R studio software. GEI was analyzed by the use of a biplot graph in which the yield means are plotted against the scores of the first principal component of interaction (IPCA1) (Yan *et al*., 2000). Similarly, data were analyzed for discrimitiveness versus representativeness ranking of environments and ranking of genotypes relative to ideal environment and ranking of environment based on ideal genotype was also performed. Mega-environments and winning genotypes in a given set of environments were identified by using the option 'which-won-where'.

3. Results and discussion

The AMMI analysis of variance for fruit yield per plant and fruit yield per hectare presented in Table 1 revealed significant environment variance for both the traits, which indicates that the environments under study were different from each other. The graphical representations further revealed the presence of GEI and the partitioning among the first two interaction principal component axis (IPCA), as 45.84% and 19.02%, respectively, while the cumulative variance was 64.86% for PCAI and PCAII (Figure 1), thereby demonstrating that genotypes may be selected for adaptation to specific environments. As per the ranking of environments, the discriminating ability of V3 and V6 was found to be closest to the ideal environment. The stability mean of genotypes revealed that G1, G9, and G23 were the best performing genotypes, whereas G8 was observed as the most unstable genotype. 'Which-won-where' biplots gave rise to a hexagon with six genotypes, that is, G8, G25, G12, G14, G15, and G16 at vertices (Figure 2). Three mega-environments (ME) were observed among the test locations with ME1 represented by four locations, V1, V2, V4, and V7, with G1 as the winning genotype and second ME (ME2) was composed of V3 and V6 with G15 and G16 as winning genotypes. Third ME (ME3) was represented by V5 with G8 as the winning genotype.

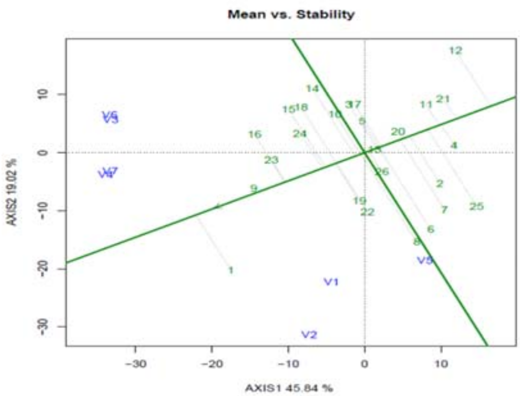

Figure 1 GGE biplot of combined analysis for yield: Mean versus stability of genotypes

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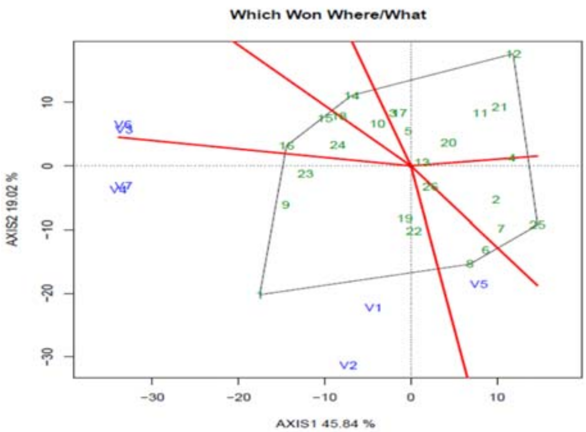

Figure 2 GGE biplot combined analysis: 'Which-won-where'

Table 1 Additive main effects and multiplicative interaction (AMMI) analysis of variance for fruit yield per plant (kg) and fruit yield per hectare (q) of 25 brinjal genotypes across six environments

Additive main effects and multiplicative interaction (AMMI) analysis of variance for fruit yield per plant (kg)

Source of variation	df	MS	Variation explained (%)
Environment	5	3782516.17***	
Genotype	24	151513.24	
G×E interaction	120	283346.17	84.99
IPCA 1	28	671628.39	55.31
IPCA 2	26	388165.79	29.68
Error	66	77327.81	

Additive main effects and multiplicative interaction (AMMI) analysis of variance for fruit yield per hectare (q)

Source of variation	df	MS	Variation explained (%)
Environment	5	36359.07***	
Genotype	24	1196.20	
G×E interaction	120	2481.90	84.37
IPCA 1	28	5700.77	53.60
IPCA 2	26	3524.93	30.77
Error	66	705.43	

***Significance at $p < 0.0001$.

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1.9 Thermal Requirement for Phenophases of Maize (*Zea mays* L.) Varieties Affecting Grain Yield with Various Sowing Dates in Rainfed Subtropics of Jammu and Kashmir

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Keywords: Heat units; Heliothermal units, Maize, Photothermal units; Sowing dates; Varieties

1. Introduction

Growth and development are different concepts although they have related stages. Plant growth refers to an irreversible increase in an organ or whole plant size (length, area, volume, and weight), while plant development refers to processes related to cell differentiation, organ initiation, member appearance, and extends to plant senescence (Streck *et al*., 2003). Temperature is a major environmental agent that determines the rate of plant growth and development. Different genotypes may behave differently under similar environmental conditions. Different sowing dates might cause different environmental conditions from emergence to seed filling. The most common temperature index used to estimate plant development is growing degree days (GDD) or thermal unit (TU). The accumulation of GDD determines the maturity of the plant, yield, and yield components. Fischer (1985) showed that the thermal time requirement needed by a specific growth stage is more or less constant. Temperature changes in the field can be created by planting at different dates in a season so that the plant could grow with different ambient temperatures. Thus, keeping in mind the differential behavior of maize cultivars, the present investigation was planned to study the phenological behavior and heat unit requirements of maize under different dates of sowing.

2. Materials and methods

The field experiments were conducted at Research Farm of Advanced Centre for Rainfed Agriculture (ACRA), Rakh-Dhiansar, SKUAST-J, Jammu and Kashmir (32°39′ N, 74°53′ E, the elevation of 332 m MSL) during *Kharif* seasons of 2016 and 2017 under rainfed conditions. The soil of the experimental site was sandy loam having available nitrogen 178.4 kg/ha (low), phosphorus 14.5 kg/ha (medium), and potassium 112 kg/ha (medium), with a pH of 6.62 and organic carbon content of 0.26% (low). The climate of the region represented subtropical conditions characterized by hot and dry summer, cold and dry winter, and humid monsoon. The rainfall received was 576.5 mm in 2016 and 658.5 mm in 2017 during the crop season. The experiments comprised two maize varieties, namely, *Double dekalb* (V1) and *Mansar* (V2), with four sowing dates, namely, the onset of monsoon (D1) (24 June 2016 and 30 June 2017), 10 days after onset (D2), 20 days after onset (D3), and 30 days after onset (D4), laid out in factorial randomized block design with three replications.

3. Results and discussion

Conspicuously a maximum number of days (45 days) were taken to attain the vegetative stage when maize was sown at 30 days after onset, while minimum days (41 days) were taken when maize was sown just after the onset of monsoon (Table 1). Almost a similar trend was observed for reaching the reproductive stage of the crop. Brar *et al.* (2011) also reported that a delay of 20 days in sowing could cause a delay in vegetative and reproductive stages, which corroborates the present findings.

Varieties and sowing time also affected the phenology of maize (Table 2). The maize variety *Double dekalb* took 100 days as compared to *Mansar* with 96 days taken for attaining physiological maturity. Among the different dates of sowing, 30 days delay in sowing took a maximum number of days (102.8 days) for attaining the physiological maturity when maize was sown at 30 days after the onset of monsoon. Minimum numbers of days (94.3 days) were taken for physiological maturity when maize was sown just after the onset of the monsoon. Also, the decline in the cardinal maximum and minimum temperatures during the crop growth and developmen t was found to be inversely proportional to the grain yields of maize crop.

Table 1 Effect of sowing dates on the vegetative and reproductive period of maize in relation to mean maximum and minimum temperature (mean of 2 years)

Sowing dates	Vegetative stage			Reproductive stage		
	Days taken	Mean T_{max} (°C)	Mean T_{min} (°C)	Days taken	Mean T_{max} (°C)	Mean T_{min} (°C)
Onset of monsoon	41	33.2	22.9	53	33.2	21.7
10 days after onset	43	33.0	22.7	54	33.2	20.9
20 days after onset	43	32.7	22.2	56	33.1	18.0
30 days after onset	45	33.1	22.0	58	30.7	14.9

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Table 2 Effect of maize varieties and different dates of sowing on days to attain various phenophases (mean of 2 years)

Treatments	Knee high	Tasseling	Silking	Milking	Dough	Physiological maturity
Varieties						
Double Dekalb	29.5	48.4	53.3	69.2	87.9	100.0
Mansar	27.5	46.5	50.8	66.7	85.9	96.0
Dates of sowing						
Onset of *monsoon*	31.3	45.0	49.7	65.2	83.5	94.3
10 days after onset	29.0	47	51.0	66.9	86.6	96.0
20 days after onset	28.8	48.1	52.7	68.5	87.2	98.7
30 days after onset	25.1	49.7	54.8	71.3	90.2	102.8

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1.10 Isolation and Characterization of NAC Transcription Factor from Recretohalophyte *Aeluropus lagopoides* for Abiotic Stress Tolerance

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Keywords: Abiotic stress tolerance; *A. Lagopoides*; Transcription factor; Transgenic

1. Introduction

The NAC transcription factors (TFs) play a significant role in plant growth, development, and stress tolerance. A typical NAC protein contains a highly conserved NAC domain and a variable transcriptional regulatory region. NAC regulates genes at the transcriptional, translational, and post-translational levels and, therefore, are propitious candidates for the production of stress-tolerant crops (Puranik *et al*., 2012). *A. lagopoides* of the Poaceae family is a salt and drought-resistant stoloniferous halophyte and a close relative to wheat (Razavi *et al*., 2005). However, the detailed study of functional characterization of genes and TFs of *A. lagopoides* imparting abiotic stress tolerance is very limited. Hence, four NAC TFs were isolated from *A. lagopoides* and characterized to study their role during abiotic stress. RT-PCR analysis was performed to study the stress-induced expression of AlNACs transcripts while the EMSA study revealed the DNA-binding property of recombinant AlNAC proteins. Transgenic tobacco plants overexpressing AlNAC genes were developed to evaluate the role of AlNACs in abiotic stress.

2. Materials and methods

Total RNA was isolated from shoot tissues of salt stress-treated *A. lagopoides* plantlets using Trizol reagent protocol followed by first strand cDNA synthesis. Four full-length NAC cDNAs were amplified using 5' and 3' RACE. The transcript expression of AlNACs was studied at different time points (1, 3, 6, 12, 24, and 48 h) of various stress treatments (250 mM salinity, drought, 20 mM H_2O_2, 100 µM ABA, and 1 mM salicylic acid) by RT-PCR using gene-specific primers. AlNACs were cloned in the pET28a protein expression vector and transformed in *E. coli* BL21 Star (DE3) cells (Invitrogen). Recombinant proteins were induced with 1 mM IPTG at 37°C and purified using Ni–NTA Fast Start Kit (Qiagen, Germany) using the manufacturer's protocol under native conditions for the EMSA study. The *cis*-element CATGTG (MYC-like sequence) motif harboring CACG region of *erd1* promoter was used as DNA probe, while MCS of pBSK+ vector was used as a negative control. The cDNAs of AlNACs were cloned in the pRT101 shuttle vector under the 35S promoter and then into pCAMBIA1301. This recombinant plant expression vector was mobilized into the LBA4404 strain of *Agrobacterium tumefaciens* and transgenic *Nicotiana tabacum* plants were generated following the *Agrobacterium*-mediated transformation protocol for functional validation of AlNACs *inplanta*.

3. Results and discussion

The four NAC TFs, namely, AlNAC1 (NCBI accession no. MT155795), AlNAC2, AlNAC4 (NCBI accession no. KY569078), and AlNAC23, were isolated showing the closest homology of 73%, 88%, 81%, and 87% with BeNAC1, MlNAC2, MlNAC4, and SsNAC23 proteins at the amino acid (aa) level, respectively, in NCBI BLAST analysis. Table 1 shows an *in silico* analysis of all AlNAC TFs. The transcript expression of AlNAC2, AlNAC4, and AlNAC23 genes was studied at different time points of various stress treatments. The AlNAC2 transcript expression was maximum at 3 h (5.9-fold) under salinity stress 24 h (71-fold) under drought, 3 h (10-fold) under H_2O_2, 3 h (10-fold) under ABA, and 24 h (47-fold) under salicylic acid stress.

Table 1 *In silico* analysis of isolated AlNAC TFs

Sr. No.	*In silico* analysis parameters	*AlNAC1*	*AlNAC2*	*AlNAC4*	*AlNAC23*
1	ORF (bp)	1128	921	936	882
2	5' UTR (bp)	43	118	191	120
3	3' UTR (bp)	189	349	202	190
4	Amino acid	375	306	312	293
5	Protein size (kDa)	40.68	34.3	34.9	32.39
6	Isoelectric point	8.55	6.04	6.11	8.89
7	Alpha helices	10	10	3	7
8	Beta strands	6	5	5	7
9	Phosphorylation sites	15	12	16	13
10	N-glycosylation sites	2	1	2	1
11	Myristoylation sites	8	4	4	6
12	Amidation sites	1	0	2	0

AlNAC4 showed a maximum transcript level at 12 h (14.5-fold) under drought stress, 6 h (7-fold) under H_2O_2, and a trivial increase in the transcript at 12 h (1.8-fold) and 3 h (1.7-fold) under salinity and ABA stress, respectively. In the presence of salicylic acid, transcript expression was not changed. A subtle increase in the AlNAC23 expression was observed under salinity stress at 24 h (3.3-fold). In drought stress conditions, AlNAC23 transcript increased enormously at 24 and 48 h to 73.6- and 287.7-fold, respectively. In the presence of H_2O_2, the maximum transcript accumulation was observed at 24 h (40.7-fold). Under salicylic acid and ABA stress, the transcript level elevated at 48 h (69.9-fold) and 24 h (17.8-fold), respectively. EMSA study revealed a strong DNA-binding ability of all AlNAC recombinant proteins. Functional validation of AlNAC1 and AlNAC4 *in planta* showed a significant increase in drought tolerance (Joshi *et al*., 2021) and oxidative stress tolerance (Khedia *et al*., 2018).

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1.11 Genetic Analysis for Fruit Yield and Its Component Traits in Eggplant

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Keywords: *Solanum melongena* L.; Half diallel and Vr-Wr analysis

1. Introduction

As an economically important vegetable crop in the *Solanaceae* family, eggplant is widely cultivated in India as well as in the world. Most of the intervarietal F_1 hybrids of eggplant are reported to have exhibited considerable vigor in economic traits, mainly fruit yield. Diallel analysis assists in understanding the genetic control of trait, which escorts crop breeder to forward and select segregating generations. The nature of gene action involved in the inheritance of different traits is most important to decide the breeding strategy for the improvement of the crop. Thus, the current approach was used with the objective to assess the gene action for various horticultural traits in eggplant.

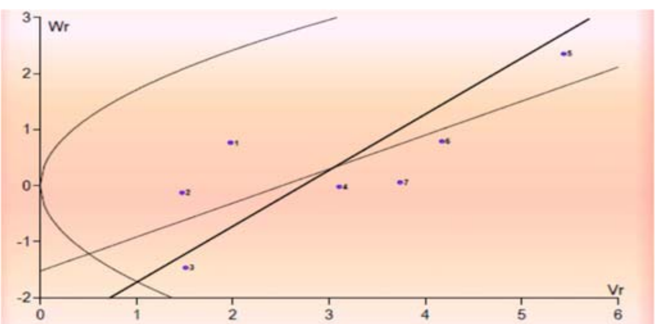
2. Materials and methods

Seven genetically diverse parental indigenous collection of eggplant, namely, Pusa Purple Cluster (PPC), IC 261797, IC 261767, IC 354611, IC 203585, IC 104101, and IC 310886 was included in the research. Twenty-one F_1 hybrids were generated through 7×7 half diallel mating design (excluding reciprocals) at the Vegetable Experimental Farm, SKUAST-J, Chatha, Jammu, India. The resultant 21 F_1 hybrids along with their parents and one standard check (Pusa Hybrid-5) were sown in randomized complete block design with three replications. The observations on fourteen fruit yield and biochemical traits were recorded from five plants from each line in each replication. The graphical analysis was done according to Hayman (1954). The data collected were analyzed by using computer software WINDOSTAT (INDOSTAT services Ltd. Hyderabad, India).

3. Results and discussion

The regression coefficient (b) was nonsignificant for all the traits that depicted the presence of nonallelic interactions. The t^2 values were not significant for any of the characters; hence, the basic assumptions of diallel analysis are fulfilled and were further analyzed. Graphical analysis depicted partial dominance for all the traits except for days to first picking and average fruit weight for which no dominance was observed. Scattering of array points along the regression line indicated wide genetic diversity among parents for the studied traits.

The relative position of the parental points along the regression line indicated the distribution of dominant and recessive genes in the parents (Figures 1–4). The parent IC 261767 and IC 203585 had excess of dominant and recessive alleles for days to 50% flowering, respectively. Parent IC 261797 had mostly recessive genes for days to first picking as it was lying far from the point of origin. The rest of the parents possessed almost equal proportions of dominant and recessive genes. The parent IC 261767 exhibited maximum frequency of dominant genes for the number of fruits per cluster. However, IC 354611 had the greater number of recessive genes, being farthest from the origin, and remaining parents had a mostly equal proportion of dominant and recessive genes. The distribution of parental arrays near the regression line exhibited that parent IC 104101 had a higher number of dominant genes for fruit length, while the rest all the parents were having recessive genes. The parent IC 203585 and PPC had a high number of dominant genes and the remaining parents had recessive genes for average fruit weight. In the case of the number of fruits per plant, all the parents had a balanced proportion of dominant and recessive genes, as they were lying far away from the point of origin. The distribution of parental arrays along the regression line suggested that the parents IC 310886 and IC 104101 had the maximum number of dominant genes, and the parent IC 261767 and IC 203585 had the maximum number of recessive genes for crop duration. The parent IC 104101 had the maximum number of dominant genes for fruit yield per plant, and the remaining parents carried the recessive alleles being farthest from the origin. The parents IC 261767, IC 354611, and IC 310886 possessed the maximum number of dominant genes and the maximum number of recessive genes was shown by parent IC 104101 for total phenol content (mg/100 g). The parents PPC, IC 261797, IC 203585, and IC 310886 had a balanced proportion of dominant and recessive genes. Most of the results are in agreement with the findings of Samlindsujin *et al*. (2020) for various traits in eggplant.



1. Pusa Purple Cluster
2. IC 261797
3. IC 261767
4. IC 354611
5. IC 203585
6. IC 104101
7. IC 310886

b = 0.606±0.22

Figure 1 Vr-Wr graph for days to 50% flowering

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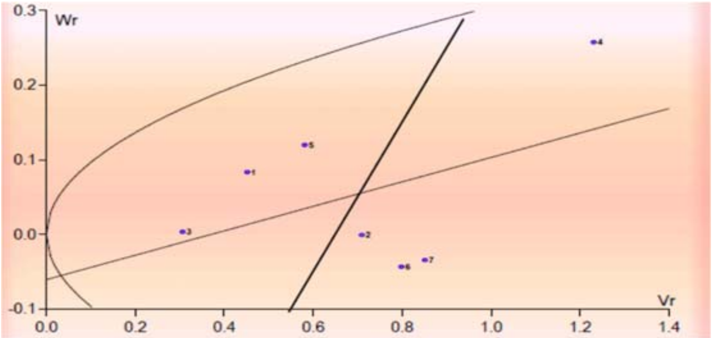
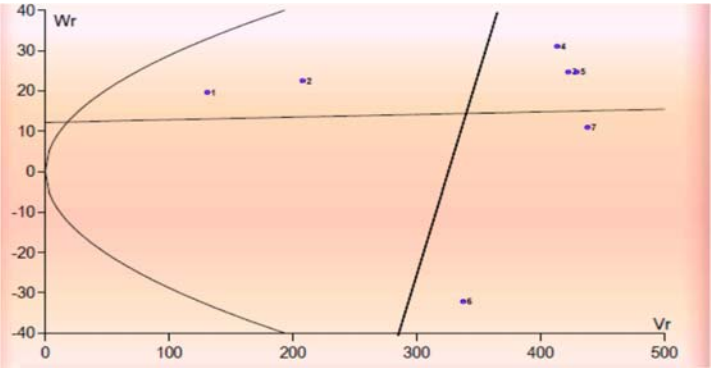


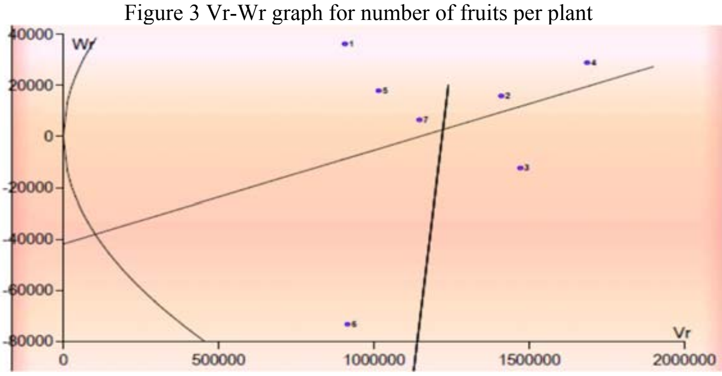
b = 0.164±0.14

Figure 2 Vr-Wr graph for number of fruits per cluster



b = 0.01±0.78

Figure 3 Vr-Wr graph for number of fruits per plant



b = 0.036±0.05

Figure 4 Vr-Wr graph for fruit yield per plant (g)

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1.12 Genetic Variability Studies in Chilli (*Capsicum annuum* L.) under Subtropical Conditions of Jammu

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Keywords: Chilli; Genetic advance; Genetic variability; Heritability

1. Introduction

Chilli (*C. annuum* L., 2n = 2x = 24) is one of the most important solanaceous vegetables as well as spice crop grown for its green and ripe fruits. It originated in the New World tropics and subtropics. It adds flavor, vitamin C, and pungency and is the constituent of many foods. The nature and amplitude of variability in the germplasm are the main prerequisites for working out an effective breeding strategy for the genetic improvement of any crop which largely depends on the amount of genetic variability and the extent of heritability of economically important characters as well as the influence of environment in the expression of these characters (Jogi *et al*., 2017).

2. Materials and methods

The present study was conducted at Vegetable Experimental Farm, Division of Vegetable Science and Floriculture, SKUAST, Chatha, Jammu during 2021-22 in randomized complete block design with three replications. The experiment comprised 20 genotypes (SJC-01, SJC-02, Pusa Sadabahar, Pusa Jwala, DKC-8, Suraj Mukhi, Hot Queen, Hy-509, TNAU-1, TNAU-2, TNAU -3, TNAU-4, TNAU-5, TNAU-6, TNAU-7, TNAU-8, TNAU-9, Bareilly Local, Mahabaleshwar Local, Chandigarh Local) collected from different locations of the country for studying genetic variability, heritability, genetic advance, and genetic advance as percent of the mean.

3. Results and discussion

The data presented in Table 1 elucidate that genotypic and phenotypic coefficient of variation ranged from 3.17% and 6.50% for days to first picking to 34.95% and 37.43% for yield per plant. High genotypic and phenotypic coefficient of variation was recorded for yield per plant and per hectare (34.95% and 37.43%), number of fruits per plant (30.57% and 32.83%), number of seeds per fruit (27.41% and 30.34%), and fruit weight (25.25% and 28.00%), respectively.

In the present study, the estimates of heritability (h^2) ranged from 23.84% for days to first picking to 87.21% for yield per plant and per hectare. High heritability was also obtained for the number of fruits per plant (86.71%), fruit length (82.55%), the number of seeds per fruit (81.64%), red fruit dry matter content (81.37%), fruit weight (81.33%), the number of primary branches per plant (73.12%), and plant height (69.55%).

The genetic advance of the 13 characters ranged from 0.18 for fruit diameter to 282.21 for yield per plant. The high genetic advance was recorded in yield per plant (282.21), followed by the number of fruits per plant (76.32) and yield per hectare (72.25). Genetic advance as % of mean ranged from 3.19% for days to first picking to 67.24 for yield per plant. The high genetic advance was observed for yield per plant and per hectare (67.24%), the number of fruits per plant (58.65%), the number of seeds per fruit (51.02%), fruit weight (46.91%), fruit length (34.35%), red fruit dry matter content (23.83%), the number of primary branches per plant (22.75%), and plant height (21.82%). High genotypic coefficient of variation, phenotypic coefficient of variation, heritability, and genetic advance coupled with high genetic advance as % of the mean suggested that these characteristics can be improved through mass selection, pure line selection, progeny selection, hybridization, and selection with pedigree breeding. Similar results have been reported by Jogi *et al*. (2017).

Table 1 Estimates of mean, range, components of variance, heritability, genetic advance, and genetic advance as percent of mean for growth, yield, and quality characters of chilli (*C. annuum* L.)

Characters	Mean	Range		GCV (%)	PCV (%)	h^2 (%)	GA	GAM
		Max	Min					
Days to 50% flowering	44.60	49.33	39.33	6.24	8.61	52.53	4.16	9.32
Days to first picking	69.60	74.33	64.33	3.17	6.50	23.84	2.22	3.19
Number of primary branches per plant	5.41	7.07	3.73	12.91	15.10	73.12	1.23	22.75
Plant height (cm)	91.41	106.00	69.20	12.70	15.23	69.55	19.95	21.82
Fruit length (cm)	8.45	11.89	5.70	18.35	20.20	82.55	2.90	34.35
Fruit diameter (cm)	1.17	1.42	0.83	10.90	15.81	47.56	0.18	15.49
Fruit weight (g)	3.60	5.95	2.20	25.25	28.00	81.33	1.69	46.91
Number of fruits per plant	130.14	217.70	76.59	30.57	32.83	86.71	76.32	58.65
Yield per plant (g)	419.69	804.80	200.47	34.95	37.43	87.21	282.21	67.24
Yield per hectare (q)	107.44	206.03	51.32	34.95	37.43	87.21	72.25	67.24
Number of seeds per fruit	34.30	60.73	22.40	27.41	30.34	81.64	17.50	51.02
Dry matter content (g/100 g)	18.92	24.43	15.53	12.82	14.21	81.37	4.51	23.83
Ascorbic acid content (mg/100 g)	137.81	167.78	112.78	9.78	12.89	57.57	21.06	15.28

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1.13 Molecular Screening of Bacterial Leaf Blight Resistance in Rice Mapping Population and its Impact on Yield Traits

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Keywords: Bacterial leaf blight; Rice; xa13 gene; Xa21 gene; Yield

1. Introduction

Rice is an important staple food crop for more than 60% of the world's population. With the increasing population worldwide and decreasing agricultural land, the food grain demand is accelerating at a fast speed. Increasing crop yield becomes difficult due to various environmental factors including biotic and abiotic stresses. Rice crop suffers major yield loss due to bacterial blight infestation caused by *Xanthomonas oryzae* pv. *oryzae* (Xoo) that can lead up to a yield loss of 80% (Noh *et al*., 2007). Developing bacterial blight disease-resistant cultivars is the only economical solution. Two major blight resistance genes are *xa13* and *Xa21*, which provide broad-spectrum resistance to the disease. In the present study, molecular characterization of the rice population is done for *xa13* and *Xa21* genes and its effect on crop yield and other yield components.

2. Materials and methods

In the present study, a set of 48 rice genotypes were selected from the BC_3F_4 population of a cross between Ranbir Basmati *PAU148, Ranbir basmati as a susceptible parent, and PAU148 as a resistant parent. The field trial was conducted during the *Kharif* season 2021 at the Research Farm of the School of Biotechnology, SKUAST-Jammu in a space planting of 20 x 15 cm. Phenotypic data were recorded on seven traits in three replicates each. Data were analyzed by statistical software R version 4.1.2. Molecular screening of the rice population was done by *xa13* and *Xa21* primer. For genotyping, PCR reactions were carried out in a volume of 10 µL including 1 µL 10X Taq buffer, 1.5 µL of 2.5 mM dNTP mixture, 1 µL of each forward and reverse primer concentration of 5 pmol/µL, 0.2 µL of 5 U/µL Taq DNA polymerase, 2 µL of genomic DNA (50 ng/µL) and volume makeup by nuclease-free water. PCR was performed in the Eppendorf thermo cycler using the following profile: initial denaturation 94ºC for 5 min followed by 35 cycles of initial denaturation at 94ºC for 30 s, annealing at 55ºC for 30 s and extension at 72ºC for 1 min, and final extension at 72ºC for 8 min.

3. Results and discussion

In the present study, phenotypic analysis of 48 rice genotypes indicated significant variation in these advanced lines of rice. Several components of genetic variability involving phenotypic and genotypic coefficient of variation (PCV and GCV), broad-sense heritability (h^2_{bs}), and genetic advance were also calculated along with the mean values. The results depicted a narrow difference between GCV and PCV values for all the evaluated traits, thereby revealing a limited amount of environmental influence on trait expression. Moreover, a high rate of heritability coupled with high genetic advance observed in nearly all the traits marked the role of additive gene action in the expression of traits, demonstrating their effectiveness for continuous selection (Table 1).

Table 1 Descriptive statistics of phenotypic traits of 48 rice genotypes in the present study

Parameters	FPDTF (days)	DM (days)	PH (cm)	TPP	PL (cm)	TGW (g)	YPP (g)
Max	119	148	195	23	37	29.36	21.06
Min	77	82	117	7	14	17.51	1.67
Mean	91.45	96.77	137	12.87	24.74	23.77	13.29
SEM(±)	0.41	0.55	2.4	1.4	1.87	0.51	0.78
CD (5%)	1.13	1.53	6.75	3.95	5.27	1.44	2.21
PCV (%)	11.79	13.95	8.56	24.25	20.21	11.65	21.01
GCV (%)	11.77	13.91	8	15.13	15.35	11.03	18.33
Heritability (%)	99	99	87	38	57	89	76
Genetic advance (%)	24.19	28.6	15.43	19.45	24.03	21.53	32.96

FPDTF = 50% DTF, DM = Days to maturity, PH = Plant height, TPP = Tillers/plant, PL = Panicle length, TGW = 1000 grain weight, YPP = Yield/plant.

Molecular screening of 48 rice genotypes for bacterial blight was done through Xa13 and Xa21 disease-resistant genes (Figure 1). Positive check PAU148 has an amplification of 500 bp and negative check of Ranbir basmati has an amplification of 250 bp. For the Xa13 gene, 12 rice genotypes were positive (four heterozygous and eight homozygous) and 33 rice genotypes were negative. For the Xa21 gene, positive check PAU148 has an amplification size of 1000 bp and the negative check of Ranbir basmati has an amplification of 650 bp. For the Xa21 gene, 13 rice genotypes were positive (six heterozygous and seven homozygous) and the remaining 32 rice genotypes were negative. Out of these positive genotypes, eight rice genotypes were double positive for both Xa13 and Xa21 genes.

The presence of disease-resistant genes was directly correlated to the high yield of the plant (Dong and Ronald, 2019). All eight BLB-resistant genotypes had a high yield as compared to the whole population under study. The trait of TGW of 48 rice genotypes ranged between 19.81 and 28.69 g while the yield range of these eight genotypes ranged between 23.1 and 26.4 g. These resistant rice genotypes can be further used for advanced breeding programmes and further released as high-yielding BLB resistant varieties.

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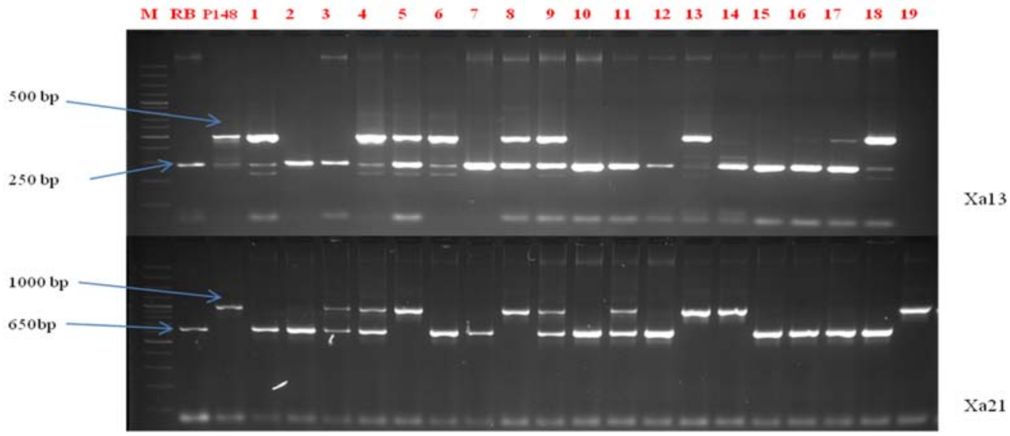

Figure 1 Agarose gel image of screening of BLB-resistant genes Xa13 and Xa21 in rice population. Xa13 gel image – P148-resistant parent (500 bp); RB – susceptible parent (250 bp); Xa21 gel image – P148-resistant parent (1000 bp); RB – susceptible parent (650 bp)

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1.14 Exploring Factors Affecting Adoption of Technologies in Fodder Crops in Subtropical Jammu

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Keywords: Adoption; Fodder crop; KVK; Production

1. Introduction

The role of green fodder in the animal diet for increasing milk production is well established. The cultivation of green fodder is the main element necessary for the dairy industry to succeed. The livestock industry is essential to the overall expansion of the agricultural sector and the nation's GDP. The main barrier preventing growth at the desired rate is the lack of feed and fodder of the desired quality. In India, cultivated fodder occupies only 4% of the entire cultivable land in the country. Presently, the country faces a net shortfall of 35.6% green fodder, 10.5% dry crop leftovers, and 44% concentrate feed ingredients (Singh *et al*., 2022). Although it is exceedingly challenging to expand the area under fodder because of the severe impact on our land resources, there is plenty of potential to increase productivity per area to boost the availability of green fodder all year round if proper cultivation practices are followed. Keeping the above fact in mind, the study was conducted to identify the factors responsible for the adoption of technologies by farmers cultivating fodder crops.

2. Material and methods

The study was carried out in the Jammu district of Jammu and Kashmir Union Territory. Five clusters, namely, R. S. Pura, Nagrota, Bhalwal, Akhnoor, and Bishnah, having a maximum number of extension activities carried out by Krishi Vigyan Kendra (Agricultural Science Centre) were selected. From each of the selected five clusters, 20 trained farmers were selected randomly making a total sample size of 100 farmers. Out of 100 farmers, 81 farmers were found cultivating sorghum and 72 farmers were doing berseem cultivation. Besides, 10 farmers were selected from nearby villages located 5 km away from selected clusters of villages, and a total of 50 farmers were selected from the control group. In the control group, out of 50 farmers, 43 and 24 farmers were doing sorghum and berseem cultivation, respectively. Therefore, the total sample size for the study was 150 farmers so as to identify the factors that affect the adoption of fodder production technologies. The independent variables included age, education, family size, landholding, land fragmentation, irrigated land, unirrigated land, extension contacts, participation in extension activities, farming experience, distance of the village from KVK, distance of the village from the nearest seed store, distance of KVK from the nearest market, distance of the village from the nearest department of agriculture, distance of the village from pesticide dealer, and occupation of the respondent.

3. Results and discussion

A linear regression model (stepwise method) was applied by using SPSS 20.0 software. A score of one was given for adoption and zero for no adoption. In sorghum crop, the variables excluded by the model include age, education, landholding, family size, land fragmentation, extension contacts, distance from KVK, distance from the nearest market, distance from seed store, distance from pesticide dealer, distance of the village from agriculture office, irrigation sources canal and tube well, possession of electric and diesel pumps by the farmers, and irrigated and unirrigated farm area. The study revealed that farmers who regularly participated in extension activities organized by Krishi Vigyan Kendra have a significant and positive effect on the adoption of production technologies in sorghum crop. It was observed that a unit increase in extension activities increases the adoption of technologies by 12.25%. A similar type of findings showing that training significantly affected the adoption of recommended technologies was reported by Sharma (2011). Further, it was observed that farmers having off-farm income and more farming experience significantly affected the adoption of technologies but negatively in sorghum crop. In berseem crop, the variables included age, education, family size, fragmentation of land, extension contact, distance of the village from KVK, distance of the village from the nearest market, distance from seed store, distance from pesticide dealer, distance of the village from agriculture office, irrigation sources canal and tube well, possession of electric and diesel pumps by the farmers, and irrigated and unirrigated farm area. The variables that significantly affected the adoption of technologies by farmers in berseem crop included landholding and other sources of income. It was observed that one unit increase in landholding increases the adoption of technologies by 3.12%. It was also found that farmers having another source of income significantly but negatively affected the adoption of production technologies in the berseem crop. The adoption of production technologies in berseem crop decreases by 14.46% with one unit increase in income from other sources in the berseem crop. Thus, it is concluded that the adoption of production technologies in fodder crops depends on the farmers' source of income. The results indicate that farmers never mind having less production from fodder crops if they are having income sources other than agriculture. On the basis of results, it is recommended fodder is an important component of dairy farming, and to get a good quantity of milk yield, a sufficient quantity of fodder is required. As the dairy sector is a good source of family income for small and marginal farmers, more number of capacity building programmes on the production technology of fodder crops should be organized by the KVKs with wider publicity and involving the Panchayati Raj Institutions (PRIs). The farmers cultivating fodder and having income from sources other than agriculture are negatively affecting the adoption of production technologies, which indicates that they have the least preference to adopt scientific production technologies. It may be due to practicing farming as a subsidiary occupation.

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Table 1 Factors affecting the adoption of technologies in fodder crops

Crop	Variable	Coefficient (B)	*t* value	*p* value	Model summary
	Constant	27.37	6.38	0.00	$R^2 = 0.24$
Sorghum	Participation in extension activities	12.25	4.44	0.00	df = 123
	Agriculture+labour	–10.79	3.10	0.00	$F = 12.71$, $p =$
	Farming experience	–0.24	1.99	0.04	0.00
	Constant	29.50	15.67	0.00	$R^2 = 0.14$, df =
	Landholding	3.12	3.06	0.00	95, $F = 5.21$, $p =$
Berseem	Agriculture+private employment	–14.46	–2.63	0.01	0.00

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1.15 Screening of *Brassica juncea* Genotypes for Salinity Tolerance at Seedling Stage

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Keywords: *B. juncea*; Chlorophyll; Germination; NaCl; Salt tolerance

1. Introduction

The abiotic stress of salinity, which interferes with plant growth and development and eventually lowers the potential yield of the crops, is inescapable and unexpected (Choudhary *et al*. 2019; Hussain *et al*. 2021). Approximately 800 million hectares of fertile agricultural land are affected by salinization globally (Quan *et al*. 2021). One of the greatest environmental stresses, especially in arid and semi-arid parts of the world, is salinity, which results in significant crop loss. According to some reliable estimates, more than 6% of the world's land is considered saline and of the total irrigated lands, 20% are saline soils, resulting in estimated agricultural losses of US$27.3 billion annually (Munns *et al*. 2020). The most serious problem is that the extent of saline agricultural lands continues to increase mainly due to poor management practices. In this situation, yield gaps between demand and production will certainly increase in the future. Moreover, several experts have claimed that agricultural output must increase to feed the world's population, which is expanding quickly (estimated to be 9.6 billion by 2050). It has been advocated that efficient utilization of marginal saline lands for crop production will solve the problem (Lone *et al*. 2017).

2. Materials and methods

The healthy seeds of 10 *B. juncea* cultivars were provided by the Oilseeds Research Institute, Faisalabad, Pakistan. After being surface sterilized with a 0.01% mercuric chloride solution, the seeds were rinsed two to three times with double-distilled water. The 25 days old plants were sampled to assess the morphological parameters, namely, plant height, shoot length, root length, fresh weight, dry weight, and chlorophyll content by SPADE meter. The experiment was conducted according to a complete randomized block design. The analysis of variance (ANOVA) was performed as described by Gomez and Gomez (1984).

3. Results and discussion

Various levels of salt concentrations showed significantly lower values for all the growth attributes over their respective controls at 25 days after sowing (DAS). Figure 1 illustrates how treatments at various NaCl concentrations, including 50, 100, and 150 mM, affected the 10 cultivars. The plant fresh weight in the non-saline control treatments varied. The fresh weight of the plant was generally affected by salt stress, although the effect ratio varied across the 10 genotypes. When compared to plants in the control condition, the fresh weights of plants under salt stress at the final harvest were considerably lower. Maximum damage was induced by the greatest salinity (NaCl) level, 150 mM, in all the types. Among the varieties (Figure 1) that showed different levels and their responses to the salinity, genotype KJ-284 was found to be the most resistant and had the maximum fresh weight of shoot, that is, 0.772 g, followed by RBJ-19008, which had 0.465 g, and RBJ-17003, which had 0.437 g. The highest values indicate the salinity tolerance in the genotypes. The analysis of variance indicates the significance of considered treatment on the nutrients in all cultivars for each passing day (Figure 1). At all stress levels, the genotype Faisal had extremely poor performance in comparison to other genotypes like RBJ-17078. The KJ-284 and RBJ19003 are more salt resistant and maintain their green color at low to high levels of salt stress. Our research supports the findings of Shahbazi *et al*. (2011) who found that all examined genotypes of *B. napus* are inhibited from germination in the early stages by high salt concentrations (50, 100, and 150 mmol). Thus, the present study's findings concluded that certain cultivars are more salt tolerant than others. It is clear that these *B. juncea* cultivars exhibit a significant degree of diversity in the traits related to salt tolerance, which is in line with the findings of Arzani and Ashraf (2016). To find more certain actual outcomes, further experiments utilizing new approaches should be conducted.

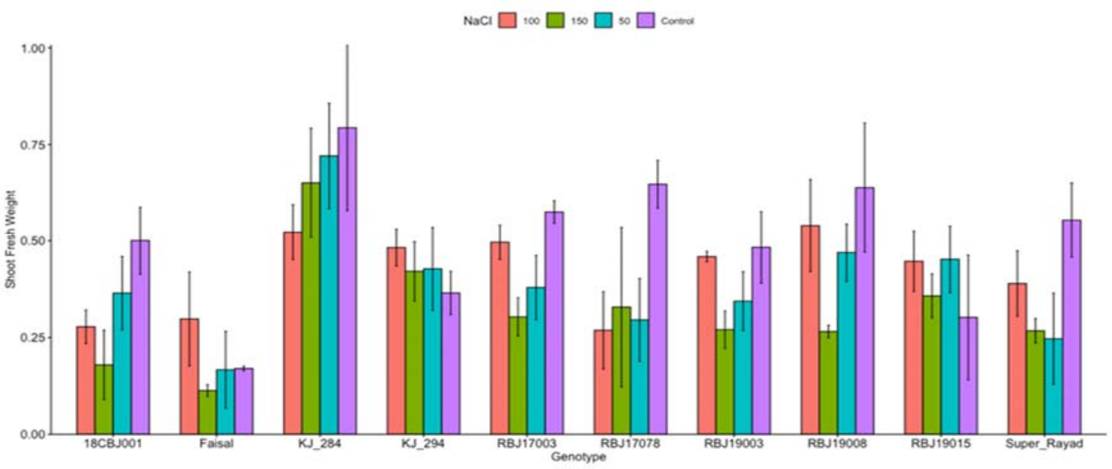

Figure 1 Effect of salinity stress on plants growth and development in comparison to control

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1.16 Physio-biochemical and Molecular Characterization of Gamma Irradiated Population of Guava (*Psidium guajava* L.)

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Keywords: Gamma irradiation; Physio-biochemical traits; SSR markers

1. Introduction

Guava (*P. guajava* L.) is a well-flourished fruit crop of the Indian subcontinent owing to its wider adaptability and the potential for higher productivity and nutritional quality. There is an urgent need to develop less vigorous or dwarf cultivars amenable to high-density planting (HDP) to improve guava production. In perennial crops, mutation breeding is a well acceptable strategy for induction and/or development of dwarfism trait(s) (improved architectural attributes) within a short span of time. Gamma-irradiation mutagenesis along with morphological markers is utilized to acquire and characterize the desired phenotypic variations in guava (Maan and Brar, 2021). Moreover, microsatellite markers are an extensively used tool to characterize genetic variations among mutant genotypes of different fruit crops (Sulu *et al*., 2020). Therefore, the present study aimed at the characterization of mutagenesis-induced genetic variability with physio-biochemical and molecular (SSR) markers.

2. Materials and methods

Stomata impression is prepared from the abaxial surface with the help of the dried nail polish method (Maan and Brar, 2021). Chlorophyll content and total phenolic content were measured using Minolta chlorophyll meter SPAD-502 and Folin-Ciocalteu assay, respectively. Leaf proline content was estimated with colorimetric assay from chromophore-containing toluene layer spectrophotometrically at 520 nm. SOD and POD activity was measured as units/g FW. Physio-biochemical data of 1-year-old mutagenic plants of guava cv. Punjab Pink were subjected to a two-way analysis of variance (ANOVA) using R studio statistical software (R Core Team, 2019) with P values ≤0.05 considered statistical significant. Total genomic DNA was isolated from young leaves using the CTAB method with minor modifications. PCR reactions for SSR primer pairs selected from the published literature were performed according to the published protocol. Genetic diversity parameters including the percentages of polymorphic loci (Pp), Nei's gene diversity (h), and Shannon index (I) were calculated.

3. Results and discussion

Maximal suppression of chlorophyll content with 250 Gy (10.61%) treatment followed by 150 Gy and the highest value of chlorophyll content was observed in non-mutagenized plants. Similarly, leaf stomatal density was significantly affected by different concentrations of gamma rays, with maximum reduction at 250 Gy. The hormetic response for stomata guard cell size with 50 Gy mutants [1.3–2.13% (stomata length) and 1.4–1.9% (stomata breadth)] was observed. Uplifted activities of antioxidant enzymes (SOD, CAT) and physio-biochemical characteristics (TPC and leaf proline content) were recorded with the mutated population as compared to the standard plant. 2.48-fold and 1.75-fold upregulated SOD and CAT activities, respectively, were observed with a significant difference from the rest of the mutated progenies under 250 Gy treatment and minimal upregulation in non-mutagenized type.

Table 1 Primer names and the total number of amplicons, sizes (bp), polymorphic amplicons, PIC, MI, and percentages of polymorphism (%) as revealed by SSR markers among the 27 mutated plants of guava

Locus	T (ºC)	Amplicon range (bp)	Total bands	Polymorphic alleles	PIC value	MI	RP	MRP
mPgCIR392	55	165–185	3	3	0.38	1.20	2.14	0.71
mPgCIR31	55	200–220	4	4	0.35	1.11	2.21	0.55
mPgCIR285	55	150–170	3	3	0.52	1.68	2.00	0.67
mPgCIR418	55	140–155	2	2	0.43	1.36	2.07	1.04
mPgCIR42	55	200–230	4	4	0.70	2.22	4.00	0.50
mPgCIR3	55	125–135	3	3	0.40	1.27	3.00	0.67
mPgCIR4	55	150–180	4	4	0.55	1.74	2.00	0.50
mPgCIR23	55	155–170	3	3	0.62	1.97	2.00	0.67
mPgCIR448	55	140–165	4	4	0.52	1.69	2.00	0.50
mPgCIR46	55	160–185	3	3	0.57	1.81	3.00	0.67
mPgCIR283	55	195–215	3	3	0.46	1.46	2.42	0.80
mPgCIR22	55	110–120	2	2	0.49	1.55	2.00	1.00
Average	–	–	3.17	3.17	0.49	1.59	2.40	0.69

T (ºC) = Annealing temperature, bp = Base pair, PIC= Polymorphism information contents, MI = Marker index, RP = Resolving power, and MRP = Mean resolving power.

Out of 40 SSR primers used for amplification, 12 markers produced 38 highly reproducible bands, and the number of amplified DNA fragments by each primer ranged from two to four fragments with an average of 3.17 alleles per locus. The size of the detected alleles ranged from 110 to 230 bp. The average PIC value (polymorphic information content), marker index (MI), and resolving power (RP) were 0.49, 1.59, and 2.40, respectively, for the amplified primers

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(Table 1). Similarly, UPGMA cluster analysis of genetic distances and PCO distinguish the mutated genotypes as separate taxonomic entities. To conclude, this study indicates that physio-biochemical and SSR markers can be successfully utilized for the characterization of a mutated population of guava with greater opportunity for early selection against different desirable traits in the era of climate change.

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Theme 2

Public Health, Food Security and Safety

2.1 Effect of Different Stabilization Methods on Proximate and Mineral Composition of Wheat Bran

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Keywords: Consumption; Fortification; Inactivation; Nutritional; Stability

1. Introduction

India is the third largest wheat producing country in the world corresponding to an annual production of approximately 109 million tons during the year 2021 (Anonymous, 2022). Germ (2–3%), endosperm (70–80%), bran (14–19%), and seed coat are major parts of the wheat kernel. Wheat bran, a by-product of the wheat milling industry, is usually stripped away during the milling process. On a rough basis, it is estimated that 796 thousand metric tons of wheat bran is produced, which could be a possible source of nutrition in food for human consumption, is either discarded or underutilized, or is used for feeding animals (Anonymous, 2019). Wheat bran contains protein, fat, ash, carbohydrates, polyphenols, phytic acid, dietary fiber, vitamins, and minerals (calcium, phosphorous, magnesium, iron, etc.) (Kumar *et al*., 2011). Wheat bran dietary fiber comprises mostly lignin, cellulose and hemicellulose, arabinoxylans, pentosans, and lignins. However, in addition to its rich and dense nutritional composition, the presence of lipase makes it unsuitable for the development of foods due to instability during storage. Lipase is primarily responsible for the hydrolysis of triglycerides into glycerol and free fatty acids and rendering it unsuitable for consumption by humans on account of its soapy taste, reduced pH, and rancid flavor. To overcome rancidification, inactivation of lipase is a must. Lipase inactivation in wheat bran can be achieved by stabilization after milling.

2. Materials and methods

The study was carried out in the Department of Food Science and Technology SKUAST-J using wheat bran purchased from Amar flour mills, Gangyal, Jammu. Samples were exposed to hot air oven, microwave, roasting, autoclave, and chemical and one sample was kept as such. Stabilized wheat bran samples were stored for a period of 3 months. The stabilization methods are summarized in Table 1.

Analysis of proximate composition: The crude protein, fat, ash, crude fiber, and moisture were determined according to AOAC 2005. After the ashing of samples, calcium, phosphorous, and magnesium content was determined according to the AOAC method. For determination of minerals, ashing was done followed by digestion using a solution of perchloric acid and nitric acid at a ratio of 1:4, followed by cooling. The solution was filtered using Whatman filter paper 42 and the volume of each sample was made to 25 mL using distilled water. Total dietary fiber and phytic acid were determined according to AOAC 2005 and the method suggested by Sadasivam and Manickam (2008), respectively.

Table 1 Experimental condition for thermal treatments

Stabilization method	Sample code	Operating conditions
Control	Raw	None
Microwave	MW	2450 MHz for 3 minutes
Hot air oven	HAO	120℃ for 20 minutes
Autoclave	AC	121℃ at 15 psi
Roasting	RO	190℃ for 20 minutes
Chemical	CH	Ethanol (5 mL/100 g)

3. Results and discussion

The results obtained were statistically analyzed at a 5% level of significance using a completely randomized design and through analysis of variance (ANOVA). Stabilization of wheat bran resulted in an increase of crude protein, crude fat, ash, crude fiber (Sudha *et al*., 2011), and mineral (calcium, phosphorous, and magnesium) content in comparison to raw wheat bran (Faria *et al*., 2012).

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2.2 Evaluation of Germplasm of *Cuminum cyminum* Linn.in Subtropics of Jammu

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Keywords:*Cuminumcyminum*; Correlation; Germplasm; Quantitative traits

1. Introduction

C.cyminum (Cumin), an industrially important seed spice crop, is cultivated for food, drugs, and essential oil due to the presence of metabolites (Heidari and Sadeghi, 2014). Seeds contain volatile oil (2.5–5%) composed of aldehydes and hydrocarbons. Owing to the diuretic, carminative, and antispasmodic properties of seeds, cumin has a role in traditional medicine to cure different diseases (Ravi *et al*., 2013). Being a cash crop, cumin has provided a wide alternative to the farmers. In Jammu and Kashmir, the *Kandi* area is 811 km^2, which stretches between longitude 74°21' and 75°45'E and latitude 32°22' and 32°55'N covering Jammu, Samba, and Kathua. Undulating topography, steep, irregular slopes, erodible, low water-retentive soils, badly dissected terrain, and marginal and fragmented land holding are making agriculture a nonprofitable venture in the present situation of unreliable weather conditions. Cumin, which is in large demand by the pharmaceutical and food industries, can be a better option for crop diversification in this area.

2. Material and methods

Seeds of eightgenotypes/varieties of cumin, procured from Sri Karan Narendra Agriculture University, Jobner, Rajasthan, were sown in Agroforestry farm, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu during 2018-19. The experiment was laidin RBD with eight genotypes, which were replicated thrice. Each genotype was sown in lines at a depth of 1.5cmin a raised bed of 1.5m×1.0m with a spacing of 30cm×5cminsandy loam soil on 16th November 2018 on an area of0.05 ha. At the time of sowing, basal doses of DAP, urea, and ammonium phosphate at the rate of 130.4, 101.15, and 66.66 kg/ha, respectively, were added. Seeds were first treated with Carbendazim and Mancozeb at the rate of 2 g/kg of seed before sowing. All cultural and plant protection practices were followed from sowing till harvesting and completed on 20^{th} March 2019. Agro-morphological traits were assessed during the growing season and determined by randomly choosing five plants of each genotype per plot and data about various characters were statistically analyzed using ANOVA.

3. Results and discussions

Seeds of all genotypes were germinated after 18 days of sowing. Flower initiation, 50% flowering, 100% flowering, and fruit maturity were observed at 63, 67, 69, and 105 days after sowing, respectively. Significant differences were detected among genotypes for all noted morphological characteristics based on mean performance. Although moderate seed germination percentage (48.60-74.37%) was recorded, the survival percentage of the crop was very poor (5.67-12.33%), resulting in low seed yield per plant (0.21-0.98g). This ultimately led to low yield per hectare (7.42-77.42kg), the highest being in genotype GC-4 (77.42kg/ha) (Table 1).

The interrelation between different traits was carried out by calculating correlation coefficients. All characters and combinations were positively and significantly correlated with each other except for trait pairs number of umbels per plant versus plant height, 1000 seed weight versus plant height, and 1000 seed weight versus the number of umbels per plant, which were positively correlated but nonsignificant. Seed yield per plant was significantly and positively correlated with the number of seeds per plant (r = 0.923, p = 0.01), number of seeds per umbel(r = 0.842, p = 0.01), survival percentage (r = 0.825, p = 0.01), the number of umbels per plant (r = 0.787, p = 0.01), germination percentage (r = 0.750, p = 0.01), and the number of branches per plant (r = 0.710, p = 0.01).An appraisal of data revealed that the overall performance of the crop was not good when compared with the standard yield of these varieties, which ranged from 550 to 1250kg/ha. Genotypes GC-4 and RZ-209 performed better than other genotypes due to their wider adaptability and appeared genetically distinct from the others as far as the characters of the plant contributing to economic yield are concerned.

Table 1 Mean performance of growth and yield parameters in different genotypes

Genotypes	Germin-ation %	Survival percentage (%)	Plant height (cm)	Number of branches per plant	Number of umbels per plant	Number of seeds per umbel	Number of seeds per plant	1000 seed weight (g)	Seed yield per plant(g)	Seed yield per plot (g)	Estimated seed yield (kg/ha)
RZ-341	56.01	6.33	26.47	2.42	6.88	13.33	90.92	2.95	0.25	1.64	10.93
RZ-345	48.60	5.67	25.59	2.23	6.61	11.20	74.95	2.82	0.21	1.11	7.42
GC-4	74.37	12.33	30.13	3.47	10.91	28.79	313.25	3.12	0.98	11.61	77.42
RZ-223	67.05	9.67	30.31	3.23	8.32	23.98	200.57	2.99	0.60	5.45	36.36
UC-231	57.41	8.00	28.31	2.66	7.12	15.89	113.78	2.97	0.33	2.47	16.49
RZ-209	81.98	11.67	29.99	3.33	9.62	25.14	240.20	3.02	0.73	8.57	57.10
UC-198	61.29	7.33	29.19	2.93	7.66	18.87	145.38	2.99	0.45	3.52	23.44
RZ-19	62.38	8.00	28.27	3.13	7.77	21.66	169.84	3.00	0.52	3.79	25.26
$CD_{0.05}$	12.57	2.95	NS	0.75	2.31	5.30	54.17	NS	0.14	1.37	9.97

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2.3 Farmers' Perception of Environmental Effects Owing to Transformation of Cropland into Industrial Uses: A Study of an Industry Dominated Area in Bangladesh

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Keywords: Environmental effects; Industrial uses; Perception; Transformation

1. Introduction

Environmental degradation has become a major global concern and the world's environment is gradually deteriorating. The degraded quality of the environment has created severe disturbances to the natural living of both flora and fauna. Agriculture contributes 13% to the GDP of Bangladesh. This is only possible from land resources. Needless to explain how significantly valuable is this in Bangladesh. Despite being so important in GDP growth, lands for growing crops are decreasing because of unplanned industrial growth and infrastructure development. The transformation of cropland into industrial uses is becoming very common in some areas of Bangladesh. It would be of interest to our agricultural and industrial planners to realize the effects of industrialization on the croplands. This will be understood by the actual users of croplands (Otter *et al*., 2013). The prime objectives of the study were to assess farmers' perception of environmental effects and explore the effect of some selected farmers' characteristics on their perception about the transformation of cropland into industrial uses.

2. Materials and methods

Three villages (Mouchak, Vannara, and Telir Chala) of Kaliakair Upazila of Gazipur district in Bangladesh were selected purposively as the study area. The huge transformation of cropland into industrial uses and its environmental effects in this area led the researchers to select these villages as the locale of the study. The farmers facing the possible consequences due to transformation and residing nearby the industries were the target population (565 farmers) of this study. A random sampling method was followed to select a sample of 113 farmers from the population. Data were collected using an interview schedule through personal interviews. To assess farmers' perceptions, the interview schedule consisted of 15 statements (both positive and negative) to cover the socioeconomic, political, and environmental conditions. To measure the perception, a 5-point Likert scale was used against a total of 15 statements and the responses were "strongly agree," "agree," "undecided," "disagree," and "strongly disagree" with scores of 5, 4, 3, 2, and 1, respectively, for positive statements while the reverse system was employed for the negative statements. Thus, the possible score of perception for a respondent could vary from 15 to 75. Finally, by adding all the frequency counts, the total score was calculated. Simple linear regression analysis was employed to explore the influence of some selected characteristics of farmers on their perceptions. For controlling the multicollinearity, the variance inflation factor (VIF) was used. The data were analyzed by SPSS Statistics 20.

3. Results and discussions

This study found that the area of cropland of farmers transformed to industrial uses ranged from 0% to 52.17% during the last 15 years. However, a higher proportion of the farmers (96.5%) reported that their land had been transformed to a low extent. The annual rate of transformation of cropland into industrial uses was 0.63%, which is significant enough for farmers to lose their way of life in the long run. The findings indicate that the overwhelming majority of the farmers (80%) had highly favorable perceptions followed by 14% with moderately favorable perception soft he detrimental effects of the transformation of cropland into industrial uses. Different characteristics of the farmers such as their "years of schooling," "extension media contact," and "organizational participation" influenced significantly to form the high perception of respondents regarding environmental effects caused by industry. Afrad *et al*. (2020) reported almost similarly. Regression analysis indicated that 64.5% of the total variation in the perception level of respondents was explained by three variables, namely, "extension media contact," "years of schooling," and "organizational participation" (1% level of significance). Among them, extension media contact alone could contribute the highest (53.5%) of the total variations, whereas years of schooling and organizational participation together could contribute 11% to the perception level of the respondents.

So, these three factors will provide important guidance to the agricultural and industrial planners in formulating policy for converting croplands into industrial land. In addition to these three factors, low price of the agricultural products, the high price of the land, and low productivity of cropland were identified as the three major reasons for the transformation of the farmers of this study. It is important to note that even though the farmers perceived the effects of industrialization on the environment, these three factors were more important to farmers. Therefore, converting croplands to industrial uses is of less concern. However, it remains to be explored how a balance could be made to preserve the farmers' way of livelihood and protect the environment and the valuable land resources for high GDP growth while the conversion of crop lands to industrial uses continues.

Table 1 Distribution of respondents according to their perception of environmental effects of transformation of cropland into industrial uses

Categories of perception based on the Likert scale (unit: rated score)	Percent of farmers
Highly unfavorable (15–29)	0
Moderately unfavorable (30–44)	6.2
Neutral (45)	0
Moderately favorable (46–60)	14.2
Highly favorable (61–75)	79.6
Total	100
Mean perception score attitude	61.43 SD=8.13)

SD, standard deviation.

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2.4 Perception of Farmers on National Food Security Mission Interventions in Wheat Crop in Jammu District of Jammu and Kashmir

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Keywords: Farmer; Improved technologies; NFSM; Perception; Productivity

1. Introduction

Recognizing stagnating food grain production and a steady rise in the demand for food grains by the growing population, the Central Government launched a massive programme 'National Food Security Mission' (NFSM) in Rabi 2007-08 to increase the food grain production in the country. The interventions envisaged in the programme are being launched in 15 states. The overall objective of this programme is to enhance the productivity and production of major cereals such as rice, wheat, and pulses in the country on a sustainable basis so as to ensure the food security of the country. The major pathway for achieving these objectives is to bridge the yield gap of these crops through the dissemination of improved technologies and farm management practices. The major goal of this programme is to increase the production of wheat by 8 million tons by the end of the eleventh plan. Besides increasing food grain production, the programme also envisages an increase in employment at the farm level significantly. This resolution is being implemented through the National Food Security Mission. NFSM-Wheat is implemented in five districts, namely, Jammu, Kathua, Poonch, Rajouri, Samba, and Udhampur (Anonymous, 2016). It was found that after the implementation of NFSM-Wheat, there was a significant increase in the area and productivity of the wheat crop from 2013-14 to 2017-18 (Lahmo *et al*., 2021).

2. Materials and methods

The present study was conducted in the Jammu district of erstwhile Jammu and Kashmir state. Presently, all districts are covered under the NFSM programme in Jammu and Kashmir. Jammu district comprises four agricultural subdivisions. Three subdivisions, namely, R.S. Pura, Marh, and Akhnoor, were selected because of the maximum number of wheat growers covered under NFSM in these subdivisions. From each selected subdivision, five villages were selected where a maximum number of NFSM beneficiaries were covered, thereby selecting a total of 15 villages. A list of NFSM wheat growing beneficiary farmers was procured from the concerned three subdivisions' chief agricultural officers. Forty NFSM beneficiaries from each subdivision were selected by applying random sampling without a replacement method, thus making a total sample of 120 NFSM beneficiaries. Data were collected from the respondents on the pretested interview schedule by contacting them personally in their fields and at their homes.

3. Results and discussion

Data presented in Table 1 revealed that 70% of respondents agree with the statement that the 'basic philosophy of NFSM is to increase productivity in wheat crop'. The majority of the respondents in R.S. Pura (70%), Marh (78%), and Akhnoor (65%) subdivisions agree with this statement. Further, 80% of respondents agree that the 'NFSM programme is well thought out for the upliftment of the socioeconomic status of the farmers'. With regard to the statement 'interventions selected in NFSM were according to the needs of the farmers', 49% of farmers have shown agreement. One-fourth of the respondents agreed with the statement (25%) that 'there is favoritism in the selection of beneficiaries'. Few respondents (6%) agree that the 'programme is more propaganda and less work for the welfare of the farming community'. Regarding the statement 'programme is an useless effort due to its ineffective working pattern', 55% agree with the statement. With regard to the statement 'there is no transparency in the distribution of interventions among farmers', 49% of respondents agree with it. However, 27% of respondents agree that 'illiterate farmers are not covered under the NFSM programme'. From the findings, it is concluded that the majority of the respondents had a favorable perception of National Food Security Mission interventions. It might be due to the reason that NFSM has resulted in an increase in area (10.47 ha) and production (1046.66 q) and productivity (15.04 q/ha) of wheat crop besides upliftment of the socioeconomic status of beneficiary farmers.

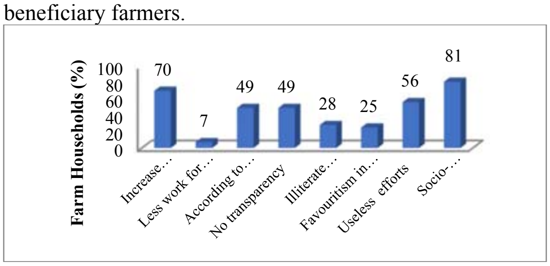

Fig 1. Respondents' perception of the NFSM programme

Table 1 Respondents' perception of the NFSM interventions (%farmer)

Perception of NFSM programme	R.S. Pura (*n*=40)	Marh (*n*=40)	Akhnoor (*n*=40)	Total (*N*= 120)
Basic philosophy is to 'increase productivity in wheat crop'	70	78	65	70
Programme is more propaganda and less work for the welfare of the farming community	8	5	8	7
Interventions selected according to the needs of farmers	16	75	58	49
There is no transparency in the distribution of intervention among farmers	93	38	15	49
Illiterate farmers are not covered under the NFSM programme	28	25	30	28
There is favoritism in the selection of beneficiaries	30	25	17	25
Programme is useless an effort due to its ineffective working pattern	58	61	50	56
Programme is well thought out for the upliftment of socioeconomic status of the farmers	75	88	81	81

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2.5 Effect of Agronomic Bio-fortification of Zn and Fe on Wheat Production and Economics

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Keywords: Bio-fortification; Economics; Growth; Yield

1. Introduction

Agriculture is undergoing a shift to not only producing more quantity of food crops but also producing nutrient-rich food crops in sufficient quantities. This will help in fighting 'micronutrient malnutrition', especially in poor and developing countries, where diets are dominated by micronutrient-poor staple food crops. 'Bio-fortification' refers to nutritionally enhanced food crops with increased bioavailability to the human and animal populations. There are various possible techniques to overcome hidden hunger and agronomic bio-fortification could be one of the major agricultural strategies to enhance the grain concentration of micronutrients as it is more economical, easily implemented, and more sustainable as compared to genetic engineering and other techniques. Bio-fortification is thus an upcoming, promising, cost-effective, and sustainable technique of delivering micronutrients to a population that has limited access to diverse diets and other micronutrient interventions (Garg *et al*., 2018).

2. Materials and methods

A field experiment was carried out at the Research Farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha during the *rabi* (winter) seasons of 2020-21 and 2021-22. The experiment was conducted in factorial RBD replicated thrice. The experiment comprised 18 treatment combinations with three varieties (WH-1105, HD-3086, and WB 02) and six Zn and Fe levels, namely, T_1: Rec. (recommended) NPK, T_2: Rec. NPK+soil application of chelated $ZnSO_4$ @ 20 kg/ha, T_3: Rec. NPK+soil application of chelated $ZnSO_4$ @ 20 kg/ha and foliar application of chelated $ZnSO_4$ @ 0.5% both at pre-anthesis and grain filling stages, T_4: Rec. NPK+soil application of chelated $ZnSO_4$ @ 20 kg/ha and foliar application of chelated $FeSO_4$ @ 1.0 % both at pre-anthesis and grain filling stages, T_5: Rec. NPK+soil application of chelated $ZnSO_4$ @ 20 kg/ha and foliar application of chelated $ZnSO_4$ @ 0.5% at pre-anthesis and chelated $FeSO_4$ @ 1.0% at grain filling stages, and T_6: Rec. NPK+soil application of chelated $ZnSO_4$ @ 20 kg/ha and foliar application of chelated $FeSO_4$ @ 1.0% at pre-anthesis and chelated $ZnSO_4$ @ 0.5% at grain filling stage. A full dose of P and K along with one-third of N was applied as a basal dose at the time of sowing through inorganic sources of nutrients, namely, DAP, MOP, and urea, respectively. The remaining two-thirds of N was applied in two equal splits at the crown root initiation (CRI) stage and pre-booting stage. Zn and Fe were applied as per the treatments. The soil of the experimental field was sandy clay loam in texture, slightly alkaline (7.4) in reaction, low in organic carbon (3.9), low in available nitrogen (218.8), low in potassium (102.0), but medium in available phosphorous (14.1). The DTPA extractable zinc (0.5 mg/kg) was found below the critical level, whereas iron (20.1 mg/kg) content was found sufficient in soil.

3. Results and discussion

Results revealed that wheat growth and yield showed an increase with soil as well as foliar application of chelated $ZnSO_4$ and $FeSO_4$ at pre-anthesis and grain filling stages. Significantly higher mean grain (4991.6 kg/ha) and straw (7276.5 kg/ha) yield were recorded in the variety WH-1105, which was at par with WB-02, while the lowest grain and straw yield were recorded with HD-3086. Among the levels of Zn and Fe, the treatment T_6: Rec. NPK+soil application of chelated $ZnSO_4$ @ 20 kg/ha and foliar application of chelated $FeSO_4$ @ 1.0% at pre-anthesis and chelated $ZnSO_4$ @ 0.5% at grain filling stages produced significantly higher grain and straw yield than other treatments and it was 19.5% and 13.6% higher than treatments T_1 and T_2.

Table 1 Effect of agronomic bio-fortification of Zn and Fe on wheat yield and economics

	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Factor A (variety)					
V_1-WH-1105 (non-fortified)	4991.64	7276.54	31,504.33	99,319.62	3.16
V_2- HD-3086 (non-fortified)	3890.12	5339.835	31,504.33	69,073.2	2.23
V_3-WB 02 (fortified)	4764.70	7032.91	31,504.33	93,743.0	2.94
SEm±	90.15	130.08			
C.D (0.05)	259.10	373.85			
Factor B (Zn and Fe levels)					
T_1: Rec. NPK	4183.20	5939.22	27,421	81,582.6	2.93
T_2: Rec. NPK+SA of ch $ZnSO_4$ @ 20 kg/ha	4401.95	6006.90	28,321	85,296.1	2.99
T_3: Rec. NPK+SA of ch $ZnSO_4$ @ 20 kg/ha and FA of ch $ZnSO_4$ @ 0.5% at PA and GF stages	4446.32	6161.44	28,881	86,294.2	2.99
T_4: Rec. NPK+SA of ch $ZnSO_4$ @ 20 kg/ha and FA of ch $FeSO_4$ @ 1.0% at PA and GF stages	4566.31	6592.34	37,761	81,683.8	2.05
T_5: Rec. NPK+SA of ch $ZnSO_4$ @ 20 kg/ha and FA of ch $ZnSO_4$ @ 0.5% at PA and Ch $FeSO_4$ @ 1.0% at GF stages	4696.02	7168.07	33,321	91,110.1	2.74
T_6: Rec. NPK+SA of ch $ZnSO_4$ @ 20 kg/ha and FA of ch $FeSO_4$ @ 1.0% at PA and ch $ZnSO_4$ @ 0.5% at GF stages	4999.14	7430.59	33,321	98,304.6	2.95
SEm±	127.50	183.96			
C.D (0.05)	366.43	528.70			

SA, soil application; FA, foliar application; Ch, chelated; PA, pre-anthesis; GF, grain filling.

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Similarly, maximum net returns (Rs. 98,304.6 per ha) and B:C ratios (2.99) were also recorded in T_6. This was followed by T_5: Rec. NPK+soil application of chelated $ZnSO_4$ @ 20 kg/ha and foliar application of chelated $ZnSO_4$ @ 0.5% at pre-anthesis and chelated $FeSO_4$ @ 1.0% at grain filling stages, which remained statistically at par with T_6. Hence, the best combination for getting higher yield and profitability of the wheat was found to be the treatment recommended NPK+soil application of chelated $ZnSo_4$ @ 20 kg/ha and foliar application of chelated $FeSO_4$ @ 1.0% at pre-anthesis and chelated $ZnSO_4$ @ 0.5% at grain filling stages.

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2.6 Effect of Leaf Color Chart and Chlorophyll Meter on Productivity of Wheat

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Keywords: LCC; Nitrogen; Productivity; SPAD; Wheat

1. Introduction

Nitrogen is a very important nutrient as it is intimately involved in the process of photosynthesis and thus directly related to total dry matter production. An adequate supply of nitrogen can increase the yield by as much as 60%. Top dressing by split application of N is needed when the crop has a great need for N and when the rate of N uptake is large (Zobermann and Fairhurst, 2020). Crop-demand-based N application is one of the important options to reduce N loss and increase the N use efficiency of a crop (Barad *et al*., 2018). Need-based N application through leaf color chart and soil plant analysis development (SPAD) can be used for adjustment of fertilizer N application based on actual plant N status (Meena *et al*., 2020). Leaf color chart LCC and SPAD meter can be reliable, quite simple, and useful tools to assist farmers in decision-making regarding top-dress N application to crops at right time.

2. Materials and methods

A field experiment was conducted at the research farm of the Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during *Rabi* 2018 and 2019. The experimental site was located at 32° 40' N latitude and 74° 82' E longitude at an elevation of 293 m above mean sea level. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction, and low in organic carbon and available nitrogen but medium in available phosphorus and potassium. The experiment was conducted in a randomized block design with four replications. The treatment consisted of control, nitrogen application based on LCC ≤ 3, nitrogen application based on LCC ≤ 4, nitrogen application based on LCC ≤ 5, sufficiency index based nitrogen application, and recommended dose of fertilizer (100:50:25:37.5 kg/ha N:P_2O_5:K_2O:S, respectively) along with one well-fertilized plot with 150% recommended dose of nitrogen (150:50:25:37.5 kg/ha N:P_2O_5:K_2O:S, respectively) as the reference plot for calculating sufficiency index

Table 1 Effects of LCC and SPAD on grain and straw yield and returns of wheat (pooled data of 2 years)

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Net returns (Rs/ha)
Control	2070	2953	27,427
Nitrogen application based on LCC ≤ 3	4641	5951	81,475
Nitrogen application based on LCC ≤ 4	4791	6097	84,300
Nitrogen application based on LCC ≤ 5	4845	6150	85,011
Sufficiency index based nitrogen application	4723	6027	83,288
Recommended dose of fertilizer	4272	5564	73,839
SEm(±)	149.43	152.80	–
CD (5%)	448.30	455.41	–
Well-fertilized reference plot (150% of recommended dose of nitrogen (RDN)	5270	6491	–

3. Results and discussion

Grain and straw yield of wheat was significant with the LCC and SPAD based nitrogen application. It is evident from the data presented in Table 1 that LCC≤5 based nitrogen application recorded significant enhancement in grain yield of wheat over that of control. LCC≤5 based nitrogen application recorded significantly highest grain yield (4958 kg/ha) and straw yield (6150 kg/ha) which was found to be statistically at par with the nitrogen application based on LCC≤4, sufficiency index based nitrogen application and LCC≤3. LCC≤5, LCC≤4, sufficiency index, and LCC≤3 based nitrogen application recorded 10.6%, 10%, 9.3%, and 7% higher grain yield of wheat, respectively, than the recommended dose of fertilizer, whereas an increment of grain yield by 109.2%, 108.1%, 106.8%, and 102.5% was observed in these treatments, respectively, over that of control. LCC≤5 based application of nitrogen recorded numerically higher net returns (Rs. 85,011/ha), which was closely followed by nitrogen application based on LCC≤4 (Rs. 84,300/ha). Hence, based on experimental results, it was concluded that LCC≤5 based nitrogen application is the most suitable and economical option for achieving higher productivity of wheat.

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2.7 Identification of Biofortified Genotypes of Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]

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Keywords: Biofortification; Food security; Genotypes; Pearl millet

1. Introduction

The pearl millet is climate-resilient and the most predominant food source for rural people. In order to deal with challenges like increasing population, there is a need of meeting the demand for food as well as the nutritional security of the country. Biofortification is one of the most important processes to avoid 'hidden hunger'. Biofortification is the process of increasing the micronutrient content of crops through selective breeding, genetic modification, and enriched agronomical cultivation practices. The deficiency of protein, zinc, and iron is affecting more than 2 billion people globally and the problem is common in pregnant women and children below the age of 5. Anemia is caused due to deficiency of iron (Fe) commonly found among people in poor countries who consume low-quality diet. Possibly it may cause child mortality and physiological disorder (Tako *et al.*, 2015). Zinc is also one of the important micronutrients which is required for proper growth. Zinc deficiency may cause stunting, increased susceptibility to many infectious diseases, mortality, and mental health problems.

2. Material and methods

The field experiment was conducted at the Bajra Research Scheme, College of Agriculture, Dhule, Maharashtra, India during *Kharif* 2021. The experiment was carried out under a randomized block design with two replications and 50 genotypes in each replication. The seed samples from each of the five selected plants per genotype were bulked and ground in a mixer grinder and 0.2 g of ground samples were analyzed in the laboratory for nitrogen content by the wet digestion method with the help of a hot plate; further iron and zinc content of all the genotypes of pearl millet was estimated by the atomic absorption spectro-photometer (AAS) method by using digested aliquot samples of grain as per protein content.

3. Results and discussion

The genotypes exhibited a population mean of 68.72 ppm in respect of iron content. The genotypes DHLB-36B (82.21 ppm), DHLB-21B (82.21 ppm), DHLB-31B (82.23 ppm), DHLB-27B (82.37 ppm), DHLB-28B (84.31 ppm), PBLN-2021-212 (85.38 ppm), DHLB-32B (86.16 ppm), DHLB-35B (86.81 ppm), PBLN-2021-209 (88.57 ppm), ICMB-10889 (105.84 ppm), and ICMB-13444 (114.13 ppm) exhibited the maximum limit of iron content. The population mean in respect of zinc content was 49.30 ppm. The maximum zinc content was observed in genotypes PBLN-2021-210 (56.25 ppm), DHLB-17B (57.19 ppm), PBLN-2021-204 (59.53 ppm), DHLB-23B (60.02 ppm), ICMB-10889 (60.13 ppm), and ICMB-13444 (62.32 ppm). The significantly highest iron and zinc content was recorded by the genotype ICMB-13444 while the highest protein content was observed in genotype DHLB-37B (20.91%). The results are in agreement with Anuradha *et al*. (2017). The genotype ICMB-13444 exhibited significantly superior iron and zinc content, and hence the genotype is suitable in view of nutritional security to overcome malnutrition problems, especially in females.

Table 1 Iron, zinc, and protein content in different genotypes

Genotype	Iron content mg/100 (g)	Zinc content mg/100 (g)	Protein content (%)	Genotype	Iron content mg/100 (g)	Zinc content mg/100 (g)	Protein content (%)
DHLB-10B	44.59	31.63	15.82	S-21/07	59.28	42.30	16.27
ICMB-13444	114.13	62.32	19.31	S-21/08	68.01	52.03	19.31
ICMB-10889	105.84	60.13	18.49	S-21/09	65.04	52.71	16.75
DHLB-8B	75.42	43.01	14.33	S-21/10	43.67	48.78	17.64
DHLB-14B	72.75	45.64	19.31	S-21/11	47.59	50.21	17.19
DHLB-15B	67.07	49.36	17.21	S-21/12	64.66	51.87	17.64
DHLB-16B	68.15	48.26	19.31	S-21/13	50.63	44.68	18.49
DHLB-17B	61.06	57.19	20.10	S-21/14	60.95	51.53	16.75
DHLB-21B	82.21	55.57	18.89	S-21/15	66.63	43.98	19.31
DHLB-23B	73.84	60.02	14.84	S-21/16	40.33	43.84	14.84
DHLB-24B	74.33	51.19	16.75	S-21/17	74.17	46.98	16.75
DHLB-27B	82.37	54.40	18.49	S-21/18	62.63	48.42	19.31
DHLB-28B	84.31	51.89	16.75	S-21/19	69.69	43.93	14.84
DHLB-31B	82.23	55.79	15.82	S-21/20	76.60	46.05	19.31
DHLB-32B	86.16	50.53	19.31	ICMB-9544	33.52	27.38	14.84
DHLB-8B33B	77.50	51.66	14.33	PBLN-2021-203	68.63	43.15	17.64
DHLB-35B	86.81	49.18	20.10	PBLN-2021-204	75.88	59.53	20.10
DHLB-36B	82.21	49.03	18.49	PBLN-2021-205	67.26	48.99	16.75
DHLB-37B	75.18	52.01	20.91	PBLN-2021-206	70.08	44.14	19.31
S-20/01	65.21	44.71	20.86	PBLN-2021-207	71.14	55.80	16.75
S-21/02	59.51	46.10	17.64	PBLN-2021-208	75.32	47.18	19.31
S-21/03	60.05	46.58	18.49	PBLN-2021-209	88.57	51.86	18.07
S-21/04	55.18	47.51	19.31	PBLN-2021-210	74.03	56.25	16.75
S-21/05	57.39	54.11	15.31	PBLN-2021-211	38.07	49.95	14.84
S-21/06	44.55	45.79	18.49	PBLN-2021-212	85.38	49.73	17.64
				Mean	68.72	49.30	17.70
				S.E.	1.74	1.41	0.48
				C.D. 5%	4.94	4.02	1.35
				C.V.	3.58	4.05	3.81

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2.8 Income Generated and Constraints Faced Under Wheat Seed Village Programme

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Keywords: Constraints; Income; Seed village programme; Wheat seed

1. Introduction

India is the world's second largest producer of wheat, rice, and other cereals. With a production of 133,596 MT, China is the world's largest wheat producer, followed by India (103,596.23 MT). VL-832, VL-804, HS-365, HS-240, HD-2781, HW-1085, and HW-741 are the main wheat varieties produced in India. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, and Gujarat are the major wheat growing states in India. The world's demand for Indian wheat is increasing. During the 2019-20 fiscal year, the country exported 217,354.22 MT of wheat valued at Rs 439.16 crore or USD 61.84 million (www.apeda.gov.in). The public sector's share of seed production in India decreased from 42.72% in 2017-18 to 35.54% in 2020-21, while the private sector's share increased from 57.28% to 64.46%, highlighting the private sector's growing role in the Indian seed industry. In the Jammu district, the seed village programme is laid out on wheat and paddy crop. The wheat seed village programme was laid out in three subdivisions of the Jammu district on 300.60 ha of land during 2019-20 (Department of Agriculture Production & Farmer's Welfare Jammu, J&K). We analyze the income generated and constraints faced by the farmers under Wheat Seed Village Programme in the Jammu district.

2. Materials and methods

The study was conducted purposively in the Jammu district of J&K during the year 2020-21. Two-stage sampling design was applied for the selection of samples. In the first stage, agricultural subdivisions of the Jammu district were selected and in the second stage villages in which the seed village programme was executed by the Department of Agriculture were selected randomly from irrigated and rainfed areas in equal numbers. Thus, the total sample selected for the study comprised 60 farmers (30 each from the irrigated and rainfed areas) from three subdivisions RS Pura, Marh, and Akhnoor.

Selection of dealers: All the 56 dealers in the Jammu district associated with the seed supply of wheat crops were selected to assess the contribution of private players in the seed chain. To work out the income generated under the wheat seed village programme, the data regarding the area under wheat crop and the availability of seeds were taken from the agriculture production department. Moreover, primary data were collected from the respondent farmers to calculate the wheat seeds produced by farmers under the programme. Besides, Henry Garrett ranking technique was used to identify and rank the constraints faced by the farmers.

3. Results and discussion

The quantity of seeds procured by the Department of Agriculture for the year 2020-2021 was 381.86 and 278.91 tons in the case of irrigated and rainfed conditions, respectively. Farmer sold rejected seeds as a grain in the market, which was 281.86 and 78.22 tons in the case of irrigated and rainfed conditions, respectively. Department of Agriculture procures seeds at the rate of Rs 24,750 per ton. The seed as a grain fetched less price (Rs 17,000 per ton). Gross income obtained from seeds sold to the Department of Agriculture was found to be Rs 9,450,911.25 for irrigated farmers and Rs 4,783,086 for rejected seeds. The average income per farmer was Rs 80,966.99 in irrigated areas and Rs 65,967.97 in rainfed areas, with an overall average of Rs 74,739.85 per hectare. The maximum number of farmers reported rejection of samples as a major problem followed by late release of funds, storage problems, lengthy procedures in procurement, price fluctuation, timely unavailability of fertilizers, late delivery of seeds, and insect pest and disease problems. The main reasons for the rejection of the sample were due to quality parameters set by the Department of Agriculture as the moisture content should be up to 12% for the cereal crops and the unacceptability of broken seeds.

Table 1 Gross income from procured seeds and rejected seeds of wheat under the seed village programme

Agro-eco conditions	Seed procured by the Department of Agriculture and total income			Rejected seed sold in the market as grain and total income			Gross income (Rs)	Avg. income per farmer (Rs)	Avg. income per ha
	Qty (tons)	Price/ton (Rs)	Total income (Rs)	Qty (tons)	Price/q (Rs)	Total income (Rs)			
Irrigated (*n* = 30)	381.86	24,750.00	9,450,911.25	281.36	17,000.00	4,783,086.00	1,423,3997.25	474,466.58	80,966.99
Rainfed (*n* = 30)	278.91	24,750.00	6,903,047.25	78.22	17,000.00	1,329,655.00	8,232,802.25	274,426.74	65,967.97
Overall (*n* = 60)	660.77	24,750.00	16,353,958.50	359.57	17,000.00	6,112,741.00	22,466,799.50	374,446.66	74,739.85

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2.9 Favorable Outcomes of Robotic Grafting in Bell Pepper (*Capsicum annuum* L. *var. grossum* Sendt.)

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Keywords: Bell pepper; *Ralstonia solanacearum*; Robotic grafting; Rootstocks

1. Introduction

Bell peppers are an off-season vegetable that generates income for farmers in Himachal Pradesh by being transported to far-off markets. Owing to biotic stress, specifically bacterial wilt brought on by *R. solanacearum*, its output in Himachal Pradesh saw a significant setback. Chemical control is ineffective, and resistant types and hybrids are less common. Vegetable grafting on resistant or tolerant rootstocks has gained popularity as a practical alternative strategy to solve a variety of issues. Controlling soilborne illnesses and increasing the yield of sensitive cultivars are both attainable through the grafting of scions onto resilient rootstocks. However, grafting is a highly labor-intensive operation and demands technically trained workers rather than ordinary laborers. Manual grafting has the problem of low production and poor graft quality, and it is hard to meet the requirement of production. Improved grafting methods to cut down the labor cost for grafting and subsequent handling of plug-grown grafted transplants will contribute further to the increased use of grafted vegetables worldwide. Therefore, developing a grafting robot is significant for the development of vegetable grafting production. When compared to robotic grafting, manual grafting is labor-intensive, slow, and has lower grafting success. Therefore, grafting robots are being employed in several nations to speed up the grafting process for vegetables. In this study, Helper Robotech Co. Ltd., purchased from South Korea (worth 27 lakh), was used which has the capacity to graft the plants at a rate of 600–700 per hour with more than 90% accuracy rate. Scion variety Indra mechanically grafted on rootstock Surajmukhi and scion Indra grafted on rootstock PBC-631 have been found to have significantly higher capsaicin content (%) and TSS (degree brix or %) than the other rootstocks and control. All the rootstocks were found to be resistant to bacterial wilt in bell pepper which generally causes a huge loss in the production in Himachal Pradesh. The robotic grafting involves no chemical treatment to control the bacterial wilt. It conserves soil health and causes no harm to public health and increases the production of bell pepper as compared to non-grafted plants, thus helping in the maintenance of food security in the HP region.

2. Materials and methods

The present investigation was undertaken in an open field condition at Experimental Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during the spring and summer seasons in 2018 under open field conditions. CSKHPKV-Palampur is the first agricultural university in the country to purchase a semi-automatic grafting robot for accelerating research and teaching work on vegetable grafting. This robot is supplied by Helper Robotech Co. Ltd., South Korea. The experiment was laid out in a factorial randomized block design with three replications and data were recorded on various horticultural and quality traits. The experimental material for the present study comprised five rootstocks, that is, AVPP0205 (Chilli), PI-201232 (Chilli), Pant C-1 (Chilli), Surajmukhi (Chilli), and PBC-631 (Chilli). The commercial hybrid 'Indra' was used as a scion. Three ages of seedlings were used, that is, 30 days old scion and 30 days old stock, 30 days old scion and 45 days old stock, and 45 days old scion and 45 days old stock.

3. Results and discussion

No incidence of bacterial wilt was found in the field among grafted plants, whereas only non-grafted (Control) plants, that is, Indra, showed wilting symptoms. All the rootstocks were found to be resistant to bacterial wilt. The pungency of capsicum is due to the presence of capsaicin content. Oleoresin in capsicum is made up of capsaicin which seems to reduce pain sensations when applied to the skin and helps in relieving muscle spasms, migraine headaches, and sinus infections. Table 1 depicts that the highest capsaicin content of 0.60% was recorded when RS4 (Surajmukhi) was used as rootstock. The highest capsaicin content of 0.52% was obtained when grafting was done with 30 days old scion and 45 days old rootstock (A2) through a machine which was statistically at par with A3 (45 days old rootstock and 45 days old scion) from which capsaicin content of 0.51% was obtained. High TSS affects the flavor and quality of bell pepper. Flavor is determined by the ratio of sugars and acids in the fruits. A higher percentage of sugar and acid contribute to the overall flavor and quality of fruits. The maximum TSS of 4.23° brix was recorded in plants grafted on RS5 (PBC-631). Grafted plants produced 0.55° brix higher TSS than the control. Maximum TSS (3.91° brix) was obtained from plants grafted with 45 days old scion and 45 days old rootstock (A3) with semi-automatic grafting robots.

Table 1 Effect of rootstocks and seedling age on capsaicin content (%) and TSS (degree brix or %) in bell pepper

Treatment	Capsaicin content (%)	TSS (degree brix or %)
A. Rootstock		
RS1 (AVPP0205)	0.49	3.82
RS2 (Pant C-1)	0.47	3.29
RS3 (PI-201232)	0.49	3.66
RS4 (Surajmukhi)	0.60	3.55
RS5 (PBC-631)	0.48	4.23
CD (P = 0.05)	0.01	0.03
B. Seedling age		
A1 (30-30)	0.49	3.60
A2 (30-45)	0.52	3.62
A3 (45-45)	0.51	3.91
CD (P = 0.05)	0.01	0.02
C. Control versus others		
Control	0.42	3.16
Others	0.51	3.71
CD (P = 0.05)	0.01	0.03

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2.10 Economic Analysis of Production and Marketing of Saffron

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Keywords: Cost-benefit ratio; Marketing; Net price; Saffron

1. Introduction

Saffron (*Crocus sativus*), popularly known as Kesar, is considered one of the world's best flavors. The total production of saffron in the world is about 300 tons/year, and Iran is at the top and produces about 88% of the world's saffron production. India ranks second with a share of about 7%. In India, it is cultivated in Jammu and Kashmir. Available data suggest that saffron production has declined over the past few years in the Kashmir and Kishtwar valleys due to severe drought, especially during the month of September 2020. The study was conducted in the Kishtwar district of J&K. About 120 ha of cultivable land is under saffron cultivation in the district.

2. Materials and methods

A multistage sampling was adopted for the selection of samples. Ten villages were selected on basis of the highest area under saffron cultivation. A total of 50 farmers were selected by the proportionate method of sampling. Fifteen intermediaries of different categories involved in the marketing and supply chain of saffron were selected.

Economic analysis: The cost and returns analysis was worked out using CACP cost concepts like cost A1, cost A2, cost B1, cost B2, cost C1, cost C2, and cost C3. Besides the modified formula given by Acharya was used for the marketing analysis of saffron.

3. Results and discussion

The year and operation-wise cost of cultivation per hectare of saffron is given in Table 1. It was observed that 80.11% (i.e. Rs 579,120) of the total cost of cultivation of saffron was incurred in 1st year, whereas it was 5.74% each during 2nd year and 3rd year and 8.41% during 4th year.

Table 1 Year and operation-wise cost of cultivation of saffron (Rs/ha)

S. No.	Name of operation	Ist year (Rs/ha)	IInd yr (Rs/ha)	IIIrd yr (Rs/ha)	IVth yr (Rs/ha)
1.	Land preparation	20,403	0.00	0.00	0.00
2.	Farmyard manure	13,699	0.00	0.00	0.00
3.	i. Cost of corms	381,145	0.00	0.00	0.00
	ii. Family labor	4,834	0.00	0.00	0.00
4.	Intercultural operations	37,518	37,518	37,518	37,518
5.	Picking	0.00	0.00	0.00	17,405
6.	Interest on working capital	12,963	2,626	2,626	3,844
A.	Total variable cost (1–6)	470,562	40,144	40,144	58,768
7.	Rental value of land	75,000	0.00	0.00	0.00
8.	Depreciation	5,621	0.00	0.00	0.00
9.	Interest on fixed capital	8,868	0.00	0.00	0.00
B.	Total fixed cost	89,490	0.00	0.00	0.00
10.	Total cost (A+B)	579,120 (80.11)	40,144 (5.74)	40,144 (5.74)	58,768 (8.41)

Note: Figures in the parenthesis are the percentage of the total value.

Three channels were identified in the study area for the marketing of saffron, namely, Farmer–Consumer; Farmer–Wholesaler (Kishtwar)–Wholesaler (Amritsar)–Retailer–Consumer, and Farmer–Retailer (Kishtwar)–Consumer. The price spread as percent of consumers' rupee for different marketing functionaries of saffron under different marketing channels was also calculated. It was found that saffron growers of Kishtwar received a net price of Rs 1995.00/10 g, Rs 1890.00/10 g, and Rs 1890.00/10 g, which were 99.75%, 75.60%, and 94.50% of the price paid by the consumer for channels I, II, and III, respectively. The producers' sale price of saffron was Rs 2000/10 g in the channel I, while it was Rs 1900.00/10 g in channel II and Rs 1900.00/10 g in channel III. The Kishtwar wholesalers' sale price to the Amritsar wholesaler was Rs 2000.00/10 g. The marketing cost incurred by a wholesaler in Amritsar was Rs 201.00/10 g, whereas the marketing loss was Rs. 50.00/10 g. The selling price to the retailer was Rs 2400.00/10 g.

Table 2 Price spread of saffron under different marketing channels (Rs/10 g)

Particulars	Channel 1	Channel 2	Channel 3
Net price received by the producer	1995.00	1890.00	1890.00
Marketing cost incurred by the producer	5.00	10.00	10.00
Marketing loss of the producer	0.00	0.00	0.00
Producers sale price/wholesaler's (Kishtwar) purchase price	2000.00	1900.00	1900.00
Marketing cost incurred by the wholesaler	0.00	0.00	0.00
Marketing loss of wholesaler (Kishtwar)	0.00	7.00	0.00
Marketing margin of the wholesaler (Kishtwar)	0.00	93.00	0.00
Wholesaler's (Kishtwar) sale price Wholesaler's (Amritsar) purchase price	0.00	2000.00	0.00
Marketing cost incurred by the wholesaler	0.00	201.00	0.00
Marketing loss of the wholesaler (Amritsar)	0.00	50.00	0.00
Marketing margin of the wholesaler (Amritsar)	0.00	149.00	0.00
Wholesaler's (Amritsar) sale price	0.00	2400.00	0.00
Marketing cost incurred by the retailer	0.00	41.00	25.00
Marketing loss of the retailer	0.00	10.00	5.00
Marketing margin of the retailer	0.00	49.00	70.00
Retailer's sale price	0.00	2500.00	2000.00
Price paid by the consumer	2000.00	2500.00	2000.00
Producer's share in consumer's rupee	99.75	75.60	94.50
Total marketing margin	0.00	291.00	70.00
Total marketing loss	0.00	67.00	5.00

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2.11 Melissopalynological and Physicochemical Analysis of Honey from Lower Hills of Himachal Pradesh, India

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Keywords: Honey; Melissopalynology; Multifloral; Unifloral

1. Introduction

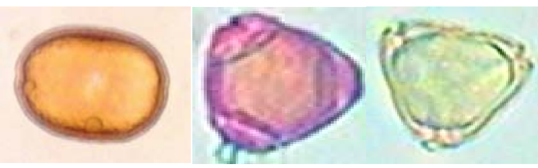
Honey is a natural sweet substance having a high nutritional value (330 kcal/100 g) (Abselami *et al*., 2018) and fast absorption of its carbohydrates upon consumption. Honey is a medicinal food which has antimicrobial, antioxidant, anti-inflammatory, antibacterial, and wound healing properties. The quality of honey is dependent on the type of flowers from which the bees collect the nectar, the climatic conditions under which plants grow, and the conditions of processing and storage of honey. While storing nectar in cells where previously pollens were stored, honey gets pollen gains. This is an important parameter for which the microscopical examination of these pollen grains (melissopalynology) in honey is important for confirmation of bee plants and helps to detect adulteration in honeys. Himachal Pradesh being in Himalayan foothills (350–2200 m amsl) has different agroclimatic zones. There is great variation in floral sources from these zones, so knowledge about pollen and nectar sources helps to provide better honey production and management during dearth periods and improve pollination.

2. Materials and methods

Melissopalynological and physicochemical analysis of six honeys (250 g each) of *Apis mellifera* collected from lower hills of Himachal Pradesh was done. Honey samples were prepared for analysis of pollen grains by using the method proposed by Louveaux *et al.* (1978). The prepared slides were observed under a trinocular microscope and microphotographs were taken by a camera attached to the trinocular microscope. Pollen size was measured in micrometer (µm) using 'Magnus pro' software. Identification of different pollen types was done on the basis of shape, size, aperture type, surface pattern, exine complexity, and aggregation pattern; and with the help of pollen slide collection of Department of Entomology Nauni, Solan. The analysis was done as recommended by International Commission for Bee Botany (ICBB) and various research publications. Honey was termed as unifloral (if single pollen type >45%) and multifloral (if several pollen types with less percentage). Quantitative melissopalynological analysis was done with the help of a haemocytometer after centrifugation. Further physicochemical analysis was performed by following standard procedures.

3. Results and discussion

Of various honeys analyzed, three samples were found unifloral in origin with predominant pollen grains of *Adhatoda* sp. (49.05%), *Dalbergia* sp. (46.59%), and *Eucalyptus* sp. (48.40%). *Adhatoda* sp. honey was identified from the Una region of Himachal Pradesh (Padiyola) based on the predominant flora (>45%). It was extra white in color and having pH, electrical conductivity (EC), moisture, optical density, density, and specific gravity 4.15, 0.33 mS/cm, 18.35%, 0.17, 1.48, and 1.46, respectively. Total suspended solids (TSS), glucose, fructose, F:G, sucrose, free acidity, lactonic acidity, total acidity, vitamin C, ash content, hydroxymethylfurfural (HMF), enzymes, phenols, amino acid, and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) were 78°B, 33.42%, 36.91%, 1.10, 4.37%, 32.85 meq/kg, 8.48 meq/kg, 41.33 meq/kg, 27.22 mg/100 g, 0.07, 29.17 mg/kg, 20.42, 25.81 mg/100 g, 19.96 mg/100 g, and 33.28 %, respectively (Table 1 and Figure 1). *Dalbergia* sp. honey was identified from the Una region (Haroli) based on the predominant flora (46.59%). It was amber in colour and having pH, EC, moisture, optical density, density, and specific gravity 4.88, 0.35 mS/cm, 16.79%, 1.39, 1.55, and 1.45, respectively. The chemical properties, namely, TSS, glucose, fructose, F:G, sucrose, free acidity, lactonic acidity, total acidity, vitamin C, ash content, HMF, enzymes, phenols, amino acid, and DPPH were 78.10°B, 29.71%, 39.99%, 1.35, 3.13%, 25.29 meq/kg, 8.27 meq/kg, 33.56 meq/kg, 29.63 mg/100 g, 0.10, 31.74 mg/kg, 18.39, 97.90 mg/100g, 37.96 mg/100 g, and 71.09%, respectively. *Eucalyptus* sp. honey was identified from the Kangra region (Baijnath) having *Eucalyptus* pollen grains as predominant pollens (48.4%). It was light amber in color and having pH, EC, moisture, optical density, density, and specific gravity 5.52, 0.66 mS/cm, 20.01%, 0.63, 1.50, and 1.42, respectively. Various chemical properties, namely, TSS, glucose, fructose, F:G, sucrose, free acidity, lactonic acidity, total acidity, vitamin C, ash content, HMF, enzymes, phenols, amino acid, and DPPH were 75.20°B, 29.68%, 36.45%, 1.22, 3.34%, 13.99 meq/kg, 5.57 meq/kg, 19.57 meq/kg, 22.79 mg/100 g, 0.45, 35.62 mg/kg, 18.40, 65.87 mg/100 g, 95.26 mg/100 g, and 55.98 %, respectively. *Dalbergia* sp. honey had the highest phenol and DPPH content indicating its antioxidant property. All physicochemical parameters were within the standard limits except for moisture content which was above the limit recommended by FSSAI (2020). Among the unifloral honeys, *Dalbergia* honey had the highest phenols and DPPH content indicating its good antioxidant properties for humans followed by eucalyptus.



a b c

Figure 1 Pollen grain of (a) *Adhatoda* sp., (b) *Dalbergia* sp., (c) *Eucalyptus sp*.

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Table 1 Physicochemical parameters of three unifloral honeys identified through melissopalynology

	Parameters	Honeys		
		Adhatoda sp.	*Dalbergia* sp.	*Eucalyptus* sp.
Physical parameters	pH	4.15	4.88	5.52
	EC (mS/cm)	0.33	0.35	0.66
	Moisture (%)	18.35	16.79	20.01
	Color	0.17	1.39	0.63
	Density	1.48	1.55	1.50
	Specific gravity	1.46	1.45	1.42
	TSS (B)	78.00	78.10	75.20
Chemical parameters	Glucose (%)	33.42	29.71	29.68
	Fructose (%)	36.91	39.99	36.45
	Sucrose (%)	4.37	3.13	3.34
	F:G	1.10	1.35	1.22
	Acidity (meq/kg)	41.33	33.56	19.57
	Vitamin C (mg/100 g)	27.22	29.63	22.79
	Fiehe's test	-ve	-ve	-ve
	HMF (mg/kg)	29.17	31.74	35.62
	Enzymes (DN)	20.42	18.39	18.40
	Amino acid (mg/100 g)	19.96	37.96	95.26
	Phenols (mg/100 g)	25.81	97.90	65.87
	Ash content	0.07	0.10	0.45
	DPPH content (%)	33.28	71.09	55.98

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2.12 Performance of New Wheat Cultivar JAUW-672 Under Different Sowing Dates, Fertility Levels, and Irrigation Regimes

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Keywords: Fertility levels; Irrigation regimes; Heat stress

1. Introduction

Wheat (*Triticum aestivum*) is one of the most important staple food crops of the world besides an important crop for Indian food security. The sowing time plays a crucial role in the productivity of the wheat crop by mitigating heat stress (Tomar *et al*., 2020). Further, the low yield of wheat is also due to insufficient irrigation and poor nutrition. The missing of irrigation during critical stages hampers yield. Also, the balanced application of NPK fertilizers improves growth indices, thus increasing wheat yield (Singh *et al*., 2018) Keeping the above points into consideration, the present investigation was undertaken to evaluate the performance of the new cultivar JAUW-672 suitable for restricted irrigations under different sowing dates, fertility levels, and irrigation regimes.

2. Materials and methods

The field experiment was conducted at Research Farm of Agronomy, Sher-e-Kashmir University of Sciences and Technology, Jammu during the *rabi* season of 2019-20 and 2020-21. The experiment consisted of 12 treatment combinations with two sowing dates, that is, 2nd week of November (D_1) and 4th week of November (D_2), three fertility levels, namely, 75% RDF (recommended dose of fertilizers) (F_1), 100% RDF (F_2), and 125% RDF (F_3), and two irrigation regimes, namely, pre-sowing (I_1) and crown root initiation+flowering (I_2) with three replications and laid out in factorial randomized block design. The sowing was done as per the technical programme by using 100 kg seed at a row spacing of 20 cm. The fertilizer dose was given on soil test basis and accordingly there was an increase in RDF. Half dose of nitrogen and a full dose of phosphorous and potassium (through urea, DAP, and MOP) were applied at the time of sowing, and the remaining half dose of nitrogen was top dressed in two equal splits, one each at the crown root initiation and just before the ear initiation stage. Owing to continuous rainfall from first week of November to mid-January, no artificial irrigation was used to trial during both the years. All other agronomic practices were kept normal. Observations were recorded using standard procedures. The data recorded for yield were subjected to statistical analysis, a procedure outlined by Cochran (1985). All the comparisons were worked out at a 5 % level of significance.

3. Results and discussion

There were no significant differences in sowing dates on grain and straw yields. Among the fertility levels, F_3, where 125% of RDF was applied, proved significantly superior in terms of grain (4.7 t/ha during 2019-20 and 4.5 t/ha during 2020-21), straw yield (5.6 t/ha during 2019-20 and 5.5 t/ha during 2020-21), and B:C ratio (2.51 during 2019-20 and 2.24 during 2020-21), followed by F_2, where 100% RDF was applied. This might be due to the application of a higher dose of nitrogen during ear initiation that helped in proper sink formation, thus enhancing production due to proper grain filling. Singh *et al*. (2018) also obtained similar results. Owing to continuous rainfall from the first week of November to mid-January, no artificial irrigation was applied to the trial, and thus irrigation regimes were statistically at par with each other.

Hence, wheat cv. JAUW-672 should be sown with 125% of the recommended dose of fertilizers (93.75 N:37.5 P_2O_5:25 K_2O kg/ha) on a soil test basis to enhance productivity under subtropical conditions of Jammu.

Table 1 Grain yield, straw yield, and economics of cv. JAUW-672 under different sowing dates, fertility levels, and irrigation regimes during 2019-20 and 2020-21

Treatments	Grain yield (t/ha) 2019-20	Grain yield (t/ha) 2020-21	Straw yield (t/ha) 2019-20	Straw yield (t/ha) 2020-21	Gross returns (Rs) 2019-20	Gross returns (Rs) 2020-21	Cost of cultivation (Rs) 2019-20	Cost of cultivation (Rs) 2020-21	Net returns (Rs) 2019-20	Net returns (Rs) 2020-21	B:C ratio 2019-20	B:C ratio 2020-21
D1	4.2	4.1	5.3	5.1	101,581.5	99,432	30,726	32,550	70,854	66,881	2.31	2.05
D2	4.1	3.9	5.0	4.9	98,404.5	95,607	30,726	32,550	67,677	63,056	2.20	1.94
SE(m)±	0.07	0.08	0.08	0.07	-	-	-	-	-	-	-	-
C.D.	NS	N.S	NS	NS	-	-	-	-	-	-	-	-
F1	3.7	3.6	4.7	4.6	88,470.5	87,090	29,918	31,742	58,551	55,348	1.96	1.74
F2	4.2	4.0	5.1	5.0	100,869	97,312	30,720	32,544	70,148	64,768	2.28	1.99
F3	4.7	4.5	5.6	5.5	110,639.5	108,145	31,541	33,365	79,097	74,779	2.51	2.24
SE(m)±	0.09	0.10	0.11	0.08	–	–	–	–	–	–	–	–
C.D.	0.26	0.31	0.31	0.25	–	–	–	–	–	–	–	–
I1	4.1	4.01	5.1	4.9	98,950.6	96,178	30,726	32,550	68,223	63,627	2.22	1.95
I2	4.2	4.12	5.2	5.1	101,063.7	98,861	30,726	32,550	70,336	66,310	2.29	2.04
SE(m)±	0.07	0.08	0.08	0.07	–	–	–	–	–	–	–	–
C.D.	N. S	N.S	N.S	NS	–	–	–	–	–	–	–	–

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2.13 Safety Standards and Assessment of Turmeric Quality Using Physicochemical Analysis

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Keywords: Physicochemical analysis; Safety standards; Turmeric

1. Introduction

Turmeric (*Curcuma longa*), being one of the most popular spices in the Indian subcontinent, plays a major role in imparting rich flavor and color to culinary dishes. Apart from its use as a spice, it is known for its medicinal properties such as wound healing, reducing inflammation, and treating various diseases (Prasad and Aggarwal, 2011). Owing to its increased demand, there have been cases of addition or removal of substances from turmeric in order to make it cheaper and more appealing for consumers. Consuming poor quality turmeric can lead to severe health problems (Abhirami and Radha, 2015). Since 2013, US FDA has been continuously detaining turmeric samples imported from India due to elevated levels of lead found in the samples (US Food and Drug Administration, 2022). Thus assurance of unadulterated and good quality turmeric has become a major food safety concern. Therefore, in this study, the quality standards for turmeric powder set by the Food Safety and Standards Authority of India (FSSAI) is discussed in detail. Moreover, different physicochemical parameters of turmeric samples were evaluated for quality analysis.

2. Materials and methods

Twenty turmeric samples were procured from the markets of the Ludhiana district of Punjab, India. Samples were divided into four categories (five samples in each category) based on their source of procurement, namely, national brands, local vendors, rural shops, and agro-processing complexes. Methanol, ethanol, and iodine were obtained from Molychem. De-ionized water having a resistivity of 18 MΩ-cm was used to prepare solutions. Color analysis was performed using Konica Minolta Sensing Inc. (Make CR-10, Japan) colorimeter. Yellowness index was checked for the presence of any coloring agents in the turmeric. Moisture content was measured in terms of weight loss percentage after heating the samples at 130°C for 2 h. Dry ash content was calculated as weight loss percentage after heating the samples in a muffle furnace at 600°C for 4 h. Starch content was estimated using a calibration curve obtained from UV-Vis spectra of different concentrations of starch in iodine solution. Curcumin and oleoresin content were measured using Soxhlet-based extraction methods.

3. Results and discussion

It was found that samples procured from national brands had moisture less than 10% (average value of 9.64%). This could be due to better packaging materials used. Ash content evaluated for the four categories was 5.09%, 4.95%, 5.89%, and 4.47% and hence was in accordance with the FSSAI safety standards. The starch content of loose samples (average value 62.78%) exceeded the safe limit of 60% w/w as set by FSSAI. Curcumin content for samples procured from national brands and agro-processing complexes was found in consistence with the BIS standards (3% w/w). However, for samples obtained from local vendors and loose samples, curcumin content was found to be 2.86% and 2.32%, respectively. Although the curcumin content is low in these two categories, the yellowness index is similar for all categories ranging from 104.68 to 107.79. This indicates the presence of synthetic coloring agents for imparting fake yellowness to the samples. Hence, it can be concluded that turmeric samples sold by local vendors and rural shops are of low quality, in spite of strict regulations being set by the regulatory bodies. We suggest the development of rapid and reliable testing procedures for the on-spot quality analysis of turmeric samples. Further, there should be increased vigilance of the regulatory bodies and consumers should be made aware of the fact that 'All that glitters is not gold', that is, even the best looking turmeric samples can be of poor quality and can pose serious health effects if consumed for longer periods.

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2.14 Awareness and Acceptance of Cultured Meat in J&K

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Keywords: Acceptance; Awareness; Cultured meat; Perception

1. Introduction

In the upcoming years, the world population is expected to grow and as it does, the demand for meat as a protein source is expected to grow with it (Lee, 2018). In the United States alone, meat consumption rose 5% in 2015 (Wilks and Phillips, 2017). Scientists are looking outside of the realm of traditional agriculture to solve the higher demand for animal protein sources while simultaneously lowering the environmental impacts present in agricultural production (Shapiro, 2018). Food is an integral part of everyday life. Of the available choices, we are going to probe meat consumption. Meat has many problems, and several of those problems are tied to technology. The industrialization of meat production has led to increased stress in animals, environments, and people (Galusky, 2014). The analysis of consumer perception toward meat attributes is important to understand and predict their behavior. Food production and technology generate ethical discomfort while providing material comfort, the technology that serves as the source of disaster and the promise of progress. For European consumers, the indication of meat origin is mandatory and is associated with product safety (Grunert, 2004). Owing to the current global health crisis caused by COVID-19, many people are introspecting the cause and effects of the same and changing habits, perceptions, and behaviors regarding their daily food choices. Understanding one such substitute is cultured meat and its acceptance, since the commercialization of this technology is growing interest and increasing greater feasibility. Yet it faces unforeseeable food disgust which could be positively tackled through awareness of the product and highlighting the modern-day conventional meat production technique. Overall this study aims to explore consumer awareness and acceptance of cultured meat.

2. Materials and methods

The study has been conducted in the Union territory of Jammu and Kashmir. A total sample size of at least400 respondents was selected. As per the objectives of the study, the literature was scanned. A well-structured questionnaire/ schedule was prepared containing all the variables. Suitable modifications were made in the questionnaire/schedule based on pretesting. Data was collected using a questionnaire/schedule. Keeping in view the objectives of the study, the data was compiled, suitably tabulated, and subjected to appropriate statistical analysis.

3. Results and discussion

Perception and response are considered Determinants of Acceptance of cultured meat tendency; assessing the collected demographical data, consumers' willingness to adopt the consumption of cultured meat seems to be unrelated to most demographical variables (i.e., education, age, gender). However, people with lower meat consumption (vegetarians and vegans) were generally more willing to consume products containing cultured meat. The output from the factor analysis of this study confirms Perception and Response to be separate but correlated concepts. This corresponds well with the assumptions derived from the 'two systems' or 'dual process model' approaches as discussed in the theoretical background, where Perception and Response were postulated as distinct effects that influence the acceptance decision. Following the data from this analysis, both Perception and Response have a moderate positive influence on Acceptance Tendency, which is in line with the theoretical background. The effect of Perception thereby seems to be slightly stronger. After the intervention involving providing information about cell-cultured meat's benefits, the number of respondents who said they were willing to try cell-cultured meat increased from about 25% to 43% and the number of those who were hesitant changed from two-thirds to 51%. There is a considerable shift in behavior and the participants seem to definitely be willing to try the product; 26.2% are still not sure about their stance toward the product and therefore doubtful of trying the product. There is almost no difference between the genders to try the product. It provides an objective report of the results and findings of customer acceptance of cultured meat. People who consider naturalness as important reported lower levels of perceived naturalness of cultured meat, which was in turn associated with lower consumption intentions. Consumers are unlikely to break their food habits unless they are aware of the problem and are motivated by the solutions, and with the positive feedback from various participants about the knowledge provided and time for introspection provided through the questionnaire, it may have pushed respondents toward a higher acceptance due to the sentiment toward human health, sustainability, and animal welfare.

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2.15 Clove Oil Fumigation for Enhanced Shelf Life of Button Mushroom (*Agaricus bisporus*)

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Keywords: Firmness; Mushroom browning; Oil fumigation; Shelf life

1. Introduction

A. bisporus (white button mushroom) is extensively consumed worldwide, owing to its medicinal, organoleptic, and nutritional properties. However, the shelf life of this mushroom is very short (3 or 4 days at 4°C) due to high respiration rate, loss of firmness, cap browning, gill opening, and so on. Chemical washing with citric acid, potassium, and metabisulphite is a commonly used practice for extending the shelf life of mushrooms. Besides, this essential oil of plant origin can also be used for extending the shelf life of horticultural products and preventing postharvest losses during storage under cold temperatures. Therefore, this study was planned to investigate the effect of clove oil fumigation on browning and the overall shelf life of button mushrooms.

2. Materials and methods

Freshly harvested, button mushrooms of uniform size (200 g per each replicate) were fumigated with an emulsion of clove essential oil (4 µl/L) for 24 h, packed in the PP bags (14 cm width×18 cm height×0.05 mm thickness) and stored at 4±1°C (85% RH) for 16 days. Tyrosinase enzyme activity (U/mg protein) was estimated spectrophoto-metrically at 420 nm using 40 mM catechol solution and the enzyme extract (Wu *et al*., 2013). Lipoxygenase activity (U/mg protein) was measured at 234 nm using linoleic acid solution (Borthakur *et al*., 1987) Total phenolic content (GAE/g FW) was estimated using gallic acid as standard, and firmness was measured using the texture analyzer TA-Hdi. The browning index (BI) was measured using L^* (for light/dark), a^* (for red/green), and b^* (for yellow/blue) values by the following formula: $BI = [100\,(x - 0.31)]/0.17$

where $x = (a^*+1.75L^*)/(5.645L^*+a^* - 3.012b^*)$

Malondialdehyde (MDA) content was measured as nmol/g FW spectrophotometrically at optical densities of 450, 532, and 600 nm using thiobarbituric acid (0.67%).

3. Results and discussion

During low-temperature storage, tyrosinase activity increased significantly over time and was found to be 56.85 U/mg protein on day 16 in control samples. However, in fumigated samples, the increase in activity was significantly lower with the progression of the storage period. Clove oil fumigation significantly inhibited the lipoxygenase activity as compared to the untreated control samples. On day 0, in freshly harvested mushrooms, the total phenolic content (TPC) was 1.74 GAE/g FW. TPC was observed to decrease in control and fumigated samples over time; however, clove oil fumigation significantly maintained the phenolic content of mushroom samples. On day 16 of storage, the TPC content of fumigated samples was 1.64 GAE/g FW, whereas control samples showed a TPC of 1.39 GAE/g FW. Color is the most important quality determinant in white button mushrooms. Change in the color was measured in terms of the browning index (BI). BI of the mushroom samples at day 0 was 12.68 and showed a rapid increase during the storage regardless of the treatment. In fumigated samples, the increase in BI was found to be significantly lesser as compared to the control samples. On days 8 and 16 in fumigated samples, BI was 28.34 and 40.26, respectively, while in control samples it was observed to be 32.34 and 44.85, respectively. Firmness at the time of harvest was 16.84 N, which showed an overall reduction during storage irrespective of treatment. Clove oil fumigation significantly reduced the loss in firmness up to day 16. Malondialdehyde (MDA) is an important marker of membrane integrity and is directly correlated to the lipoxygenase enzyme. During the postharvest period, MDA content increased from 1.13 to 5.13 nmol/g FW in control samples; however, in fumigated samples the increase in MDA was statistically lower and was found to be 3.66 nmol/g FW. During the storage period, fumigated mushrooms were acceptable up to day 10, while fruit bodies in control developed visible patches of browning on day 5. Clove oil fumigation enhanced the shelf life of mushrooms by 5 days. Thus, it can be used as an effective postharvest treatment to improve the overall shelf life of a button mushroom.

Table 1 Effect of clove oil fumigation on enzyme activities, total phenolic content, browning index, firmness, and MDA content in *A. bisporus*

Storage days	Treatment	Tyrosinase (U/mg protein)	Lipoxygenase (U/mg protein)	TPC (GAE/g FW)	Browning index	Firmness (N)	MDA (nmol/g FW)
0	–	9.64±0.16[g]	1.59±0.06[f]	1.74±0.09[c]	12.68±0.36[g]	16.84±0.59[a]	1.13±0.19[f]
4	Control	25.34±0.53[e]	6.27±0.33[d]	1.83±0.11[b]	24.54±0.85[e]	15.34±0.72[b]	1.88±0.47[e]
	Clove oil fumigation	19.46±0.85[f]	5.27±0.15[e]	2.08±0.13[a]	22.11±0.68[f]	16.23±0.60[a]	1.29±0.24[f]
8	Control	33.02±0.43[d]	8.88±0.24[bc]	1.78±0.14[c]	32.34±1.04[c]	12.22±0.52[d]	3.25±0.50[cd]
	Clove oil fumigation	27.04±0.66[e]	7.91±0.19[c]	1.87±0.08[b]	28.34±0.90[d]	14.87±0.77[bc]	2.23±0.28[e]
12	Control	47.11±0.69[b]	9.87±0.23[a]	1.54±0.15[e]	43.79±1.13[a]	11.11±0.80[e]	4.54±0.32[b]
	Clove oil fumigation	38.39±0.90[c]	8.64±0.18[bc]	1.63±0.20[d]	38.97±0.82[b]	14.08±0.63[c]	2.93±0.45[d]
16	Control	56.85±1.50[a]	9.19±0.22[b]	1.39±0.07[f]	44.85±1.10[a]	10.56±0.55[e]	5.13±0.61[a]
	Clove oil fumigation	46.11±1.17[b]	8.75±0.24[c]	1.64±0.15[d]	40.26±0.94[b]	13.67±0.48[c]	3.66±0.56[c]
CD(0.05)		1.89	0.62	0.09	1.31	0.85	0.56

Note: (i) Each value is a mean of three replicates±S.E. Significance level $p \le 0.05$.
(ii) Means with the same letter within an attribute are at a non-significant difference from each other.

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2.16 Comparative Lifetime Performance Analysis of Graded Sahiwal over Crossbred Cattle

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Keywords: Conservation; Indigenous breeds; Lifetime economics; Water use efficiency

1. Introduction

Indian agriculture is predominantly a smallholder mixed farming system composed of both crop and animal husbandry in integration. The livestock sector contributes 4.35% to the GDP of the country and 29.35% to the agricultural GDP at the constant price (Economic Survey Report 2021-22).Among the dairy animals, the milk production and productivity of indigenous breeds are lower as compared to crossbred and exotic breeds, but these breeds are still preferred by farmers because of their special characteristics such as adaptability, compatibility with socioeconomic conditions of the farmers, special taste and preferences for their milk and milk products along with religious considerations. Lifetime economics of a breed can be useful as it includes all aspects, which justify the rearing, propagation, and conservation of the indigenous breeds.

2. Materials and methods

Graded Sahiwal as an indigenous breed, the cross of Holstein-Friesian as crossbred, and Graded Murrah as a buffalo breed were selected for the study in the Central region of Bihar. Primary data were collected during January–March 2021 by using a pretested survey schedule. A sample size of 180 animals was selected from five age groups of each selected breed as: calf (<1 year age), Heifer (1 year to age at first calving), 1-3 lactation number, 4-6 lactation number, and ≥7 lactations (including unproductive life) to complete the life cycle of a breed. Twelve animals in each group were identified by following the snowball sampling technique. Lifetime productive and reproductive characteristics of the selected breeds were calculated and compared. The ease of rearing index was calculated using six indicators, for comparing the qualitative benefits, which determine the extent of easiness. The EoR index ratio was later used for finding the deflated lifetime costs and returns. The lifetime cost of milk production was calculated by the budgetary technique. Lifetime water consumption and water use efficiency for milk production for the selected breeds were estimated using the general technique used for estimating the water footprint.

3. Results and discussion

The lifetime lactation length of the Graded Sahiwal was estimated as 2804.20 days compared to 2654.97 days for crossbred and 2351.07 days for Graded Murrah. The productive days were also higher in the indigenous breed (4189.22 days), while it was 3308.43 days for crossbred and 3523.32 days for Graded Murrah. It shows that indigenous breeds can sustain in the agroecosystem for a longer duration as compared to exotic breeds. Lifetime milk production for crossbred was higher (19,550 L), while it was 12,539 L for Graded Sahiwal and 11,049 L for Graded Murrah. It indicated that crossbreds excel in lifetime milk production as compared to indigenous breeds. But it was observed that indigenous breeds were having higher persistency in milk production as compared to the crossbred in later lactation stages. In terms of reproductive parameters, the calf survival rate of Graded Sahiwal (91.41%) was higher as compared to crossbred (77.31%).

Table 1 Comparative lifetime parameters of the selected dairy animals

Parameters	Graded Sahiwal	Crossbred	Graded Murrah
Total lactation length (days)	2804.20	2654.97	2351.07
Total dry period (days)	1385.02	676.38	1172.25
Productive life (days)	4189.22	3308.43	3523.32
Lifetime milk production (litre)	12,539	19,550	11,049
Calf survival rate (%)	91.41	77.31	88.02
Conception rate	44.79	41.24	39.91
Major reproductive disorders	Anestrus	Repeat breeding, dystocia, uterine infection, abortion	Dystocia
EoR index (overall)	0.705	0.334	0.611
EoR index ratio (based on CB)	2.110	1.00	1.829
Net lifetime cost	536,886	617,236	641,387
Total lifetime return	503,055	692,259	580,084
Net lifetime return (Rs)	–33,831	75,023	–61,302
Deflated cost (Rs)	254,448	617,236	350,485
Derived benefit (Rs)	248,606	75,023	229,600
Total water consumption in lifetime (m^3)	12,080	13,216	14,548
Water use efficiency (L/m^3)	1.04	1.48	0.76

Reproductive disorders were also reported less in Graded Sahiwal which reduced the expenses on health. The ease of rearing index (EoR) was calculated using the indicators, namely, handling of the animal, feed requirement, fodder requirement, incidence of diseases, incidences of ticks and worms, and out-of-pocket expenses. The EoR index of Graded Sahiwal, Crossbred, and Graded Murrah was calculated as 0.705, 0.334, and 0.611, respectively. The EoR index ratio shows that Graded Sahiwal is 2.110 and 1.829 times easier to rear as compared to crossbred and Graded Murrah, respectively.Net lifetime cost of milk production for Graded Sahiwal, crossbred, and Graded Murrah was Rs 536,886, Rs 617,236, and Rs 641,387, respectively, which indicated that Graded Sahiwal was having approximately 15%lower cost than crossbred despite of having a higher productive life. The net lifetime return was found to be the highest for crossbreds as compared to the Graded Sahiwal and Graded Murrah. The cost after deflating with the EoR index ratio was estimated as Rs 254,448 for Graded Sahiwal, Rs 617,236 for crossbred, and Rs 350,485 for Graded Murrah. Lifetime water consumption

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was lower in Graded Sahiwal (12,080 m^3) as compared to crossbred (13,216 m^3) and Graded Murrah (14,548 m^3). It shows that indigenous breeds can be reared very easily in water deficit areas. These parameters show that these indigenous breeds are profitable if we are considering the all-lifetime characteristics. Though milk production is lower in indigenous breeds, the other factors which have been discussed make it a strong reason for the conservation and promotion of rearing of these indigenous breeds. Government and the dairy farmers need to think in this area for a sustainable development of the livestock industry without depleting the excess of our natural resources.

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2.17 Comparative Economics of Different Crops Under Natural Farming and Conventional Farming

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Keywords: Conventional farming; Cost of crop cultivation; Natural farming; Natural farming inputs

1. Introduction

Excessive use of agrochemicals during the past few decades has resulted in the degradation of soil and water, further affecting the microbial community. On the other hand, the high costs of agrochemicals caused indebtedness among farmers, and the inability to pay back loans led to the cases of farmers' suicides. In the recent past, natural farming has emerged as a farming tool to reduce the dependence of farmers on agrochemicals. In natural farming, nothing has to be purchased from outside. The inputs used for seed treatment and other inoculations are locally available in the form of cow dung and cow urine. The four basic pillars of natural farming are *Jeevamrit*, *Beejamrit*, *Acchadana*, and *Whapsa*. Other important principles are intercropping, furrow method of cropping, contour and bunds system, and using local species of earthworms. Various formulations for pest management are the *Agniastra*, *Brahmastra*, and *Neemastra*. Natural farming was first introduced by Padma Shri recipient Subhash Palekar. Earlier it was also called Zero Budget Natural Farming. The present study examined the costs and returns involved in crop production under natural farming. The same was compared with the conventional system of farming in order to examine the comparative profitability.

2. Material and methods

The study pertained to CSK HPKV, Palampur farm as natural farming in Himachal Pradesh started with the inauguration of a pilot project on natural farming at CSK HPKV, Palampur where 25 acres of land has been dedicated solely to practicing the natural farming model. The project aims to increase the agricultural produce and income of the farmers. The government is also promoting natural farming in order to achieve the desired goal of doubling farmers' income by 2022. Various nutrient enrichment inputs, namely, *Jeevamrit* and *Ghanjeevamrit*, as well as pest control inputs, namely, *Neemastra*, *Agniastra*, and *Brahmastra*, were being prepared on the farm. All are liquid while *Ghanjeevamrit* is a solid formulation. The cost of preparation of all these formulations was worked out. Then a list of different crops being cultivated with natural farming techniques using natural farming formulations was prepared. Data on various costs of cultivation and returns involved in the cultivation of these crops were collected. Data regarding crop production costs under conventional farming techniques were also collected for the same crops from the university farms. The data were analyzed by employing appropriate mathematical and statistical tools.

3. Results and discussion

The total area of the natural farm at CSK HPKV, Palampur was 10 ha of which 50% area was cultivable. Out of the total cultivable area, 3 ha area was rainfed. The cost of *Jeevamrit* and *Beejamrit* prepared on the farm was Rs 2.36 and Rs 8.99 per litre, respectively, while that of *Ghanjeevamrit* was Rs 9.87 per kg. Per liter costs of pesticide formulations like *Neemastra*, *Agniastra* and *Brahmastra* were found to be Rs 18.42, Rs 12.69, and Rs 14.46, respectively. Thus, the cost of preparation of natural formulations was very low. The preparation technique was also very simple and required almost no inputs from outside. Therefore, the farmers should be encouraged to prepare these formulations and use them on their own farms. According to Bala *et al*. (2011), the cost of production of organic inputs, namely, Vermicompost, Nadep compost, Vermiwash, Matka khad, BD compost, CPP compost, Compost tea, Agnihotra ash, and Truimbecum ash, at CSK HPKV farm was calculated as Rs 1.91, Rs 1.51, Rs 4.43, Rs 1.85, Rs 2.18, Rs 10, Rs 1.11, Rs 116.13 and Rs 717.79, respectively. Vermiwash, Matka khad, and Compost tea were in liquid form, so the costs were in Rs per liter while the other formulations were solid and the costs were in Rs per kg.

Crops selected for the study were maize, pea, wheat, gram, and soybean and the per hectare total cost of cultivation for these crops was Rs 31,686, Rs 47,555, Rs 36,914, Rs 38,280, Rs 39,267, Rs 25,711, and 21,872, respectively. A comparison of these costs with the costs of crops grown under conventional farming showed that the total costs were comparatively less under natural farming. Further, it was also found that the yields, and hence the gross returns of crops under natural farming, were less than the crops grown under conventional farming. Despite lower yields, B:C ratios were higher under natural farming due to low cultivation costs. Cox *et al*. (2019) found out that organic compared with conventional soybean had higher returns despite lower yields. It was inferred that natural farming can provide higher net returns but the yield/total production may go down risking food security. Therefore, some efforts are needed in the direction to ensure equivalent yields under natural farming before advocating it on large scale.

Table 1 Economics of different crops under natural and conventional farming

Particulars	Costs/returns (Rs/ha) Maize		Costs/returns (Rs/ha) Pea		Costs/returns (Rs/ha) Wheat		Costs/returns (Rs/ha) Gram		Costs/returns (Rs/ha) Soybean	
	NF	CF	NF	CF	NF	CF	NF	CF	NF	CF
Total variable cost	28,923	49,121	46,134	67,521	32531	46,076	36,819	49,303	36,806	43,603
Total fixed cost	2763	2763	1421	1421	4383	4383	1461	1461	2461	2461
Total cost	31,686	51,884	47,555	68,942	36,914	50,459	38,280	50,764	39,267	46,064
Gross returns	45,335	49,750	27,2250	39,0000	53,667	60,750	62,500	65,200	74,250	78,000

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Particulars	Costs/returns (Rs/ha) Maize		Costs/returns (Rs/ha) Pea		Costs/returns (Rs/ha) Wheat		Costs/returns (Rs/ha) Gram		Costs/returns (Rs/ha) Soybean	
Returns over the total cost	13,649	–2134	22,4695	321,058	16,753	10,291	24,220	14,486	34,983	31,936
Returns over total variable cost	16,412	629	22,6116	322,479	21,136	14,674	25,681	15,947	37,444	34,397
Total cost of production (Rs/kg)	13.98	15.64	7.86	7.07	13.76	12.46	30.62	35.01	23.80	23.62
Variable cost of production (Rs/kg)	12.76	14.81	7.63	6.93	12.12	11.38	29.46	35.22	22.31	22.36
B:C ratio	1.43	0.96	5.72	5.66	1.45	1.20	1.63	1.29	1.89	1.69

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2.18 Genetic Divergence Studies in Local Cucumber (*Cucumis sativus* L.) Under Subtropical Plains of Jammu

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Keywords: Cucumber; Divergence; Mahalanobis D^2 clustering

1. Introduction

Cucumber (*C. sativus* L., 2n = 2x = 14), also called 'Khira', belongs to the family Cucurbitaceae and is one of the most important summer vegetable crops grown both under open field and protected conditions throughout India and the world. Cucumber has tremendous economic and dietic importance. It is grown for its tender fruits, which are consumed raw as salad, cooked as a vegetable, or as pickling cucumber in its immature stage.

Genetically diverse parents are likely to produce high genetic diversity effects and desirable traits tool in quantifying the degree of divergence among the biological populations. Generally, diverse plants are expected to give high hybrid vigour, and hence it necessitates the study of genetic divergence among the existing varieties and germplasm collection for the identification of more heterotic parents for the hybridization programme. The information on the genetic divergence of various traits particularly of those that contribute to yield and quality would be most useful in planning the breeding programme. It is a well-known fact that genetic diversity plays a role in the manifestation of heterosis. Mahalanobis D^2 method is the most powerful tool used to measure the diversity in the germplasm with respect to the aggregate of characters. Grouping of genotypes based on D^2 analysis will be useful in choosing suitable parental lines for heterosis breeding. Clustering in the germplasm is done in such a way that the variation within the cluster is minimum and it is maximum between the clusters. This method helps to compare the genetic diversity and geographic diversity as well as in the choice of appropriate parents for a successful hybridization programme. Hence, the present investigation was made to determine the relationship between genetic diversity and heterosis in local cucumbers.

2. Materials and methods

The experimental material comprised 21 diverse genotypes of local cucumber collected from different areas of J&K. The study was carried out under subtropical conditions of Jammu at Vegetable Experimental Farm-I, Division of Vegetable Science & Floriculture, SKUAST-Jammu during summer 2018-19. The nursery was sown in the month of January 2019 in polybags under protected structures. Healthy seedlings were transplanted in a randomized complete block design with three replications in March 2019. Observations were recorded on various traits, namely, days to 50% flowering, days to first female flowering, node number at which first female flower appears, days to the first harvest, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits/vine, vine length (m), number of seeds/fruit, 1000 seed weight (g), total soluble solids (°brix), fruit yield/vine (kg), and fruit yield/hectare (q/ha) from selected plants of each plot in each replication and were subjected to D^2 analysis as per the standard method of Mahalanobis (1936). Grouping of the genotypes was done using Tocher's method.

3. Results and discussion

On the basis of Mahalanobis D^2 statistics, the data of 21 parental lines on 14 different characters were grouped into four clusters (Table 1). The resultant four clusters showed sufficient genetic diversity. Similar results were earlier reported by Ahirwar *et al.* (2017). The perusal of data depicted that cluster I had a maximum number of genotypes (16) followed by cluster II (3) and clusters III and IV (1 each). The clustering of genotypes into different groups did not follow any specific pattern, and therefore grouping of genotypes into different clusters was observed to be independent of their geographical origin. The clustering pattern of 21 genotypes of cucumber based on D^2 values indicated sufficient genetic diversity for selecting superior and diverse parents which can be exploited for any breeding programme. Maximum intra cluster distance was found in cluster I, that is, 827.53, suggesting that crossing among the genotypes of the cluster with maximum intra cluster value (cluster I) will result in maximum heterosis. The parents within the cluster can be chosen for the hybridization programme. The relative inter cluster distance showed a maximum divergence between clusters II and III (4684.41) suggesting that crossing between the genotypes of these clusters will result in more heterosis. Genotypes belonging to clusters separated by genetic distance may be used in a hybridization programme to obtain a wide spectrum of variation among the segregants.

Table 1 Clustering of 21 genotypes of local cucumber (*C. sativus* L.) based on D^2 statistics

Cluster	No. of genotype(s)	Genotype(s)	Characters
I	16	Cucumber Selection-2, Cucumber Selection-11, Cucumber Selection-9, Cucumber Selection-7, Cucumber Selection-14, Cucumber Selection-4, Cucumber Selection-21, Cucumber Selection-17, Cucumber Selection-15, Cucumber Selection-19, Cucumber Selection-5, Cucumber Selection-12, Cucumber Selection-10, Cucumber Selection-1, Cucumber Selection-6, Cucumber Selection-13	Days to first female flowering, days to the first harvest
II	3	Cucumber Selection-16, Cucumber Selection-18, Cucumber Selection-20	Fruit diameter, average fruit weight

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III	1	Cucumber Selection-3	Days to 50 % flowering, node number at which first female flower appears, fruit length, vine length, number of seeds per fruit, 1000 seed weight
IV	1	Cucumber Selection-8	Number of fruits per vine, total soluble solids, fruit yield per vine, fruit yield per hectare

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2.19 Detection of Nontuberculous Mycobacterial Species in Mastitic Milk Samples from Cattle and Buffaloes by PCR and PCR-restriction Fragment Length Polymorphisms (PRA)

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Keywords: *M. kansasii; M. smegmatis*; Nontuberculous mycobacteria (NTM); PCR; PRA

1. Introduction

Nontuberculous mycobacteria (NTM) are ubiquitous organisms that cause disease in animals and humans and are of zoonotic importance. The transmission to humans from the environment can occur by ingestion of contaminated milk, food, water, and so on (Konuk *et al.*, 2007). Advanced techniques for rapid identification of NTM such as PCR-restriction enzyme pattern analysis (PRA) methods have been developed. Keeping in view the possible role of NTM in causing mastitis this study was undertaken.

2. Materials and methods

Milk samples (*n* = 30) from cattle (*n* = 18) and buffaloes (*n* = 12) with a history or incidence of mastitis were collected from dairy farms in Ludhiana. DNA from the milk samples was extracted using a PowerFood Microbial DNA isolation kit (MoBio) and then amplified using specific primers for *Mycobacterium kansasii*, *M. smegmatis*, *M. vaccae*, *M. fortuitum*, *M. intracellulare* (Table 1) and the reaction volume of 25 µL was made for PCR. Thermocycling conditions of initial denaturation at 94°C for 5 min, followed by 30 cycles of denaturation at 94°C for 1 min, annealing of primers at 60°C for 1 min, extension at 72°C for 1 min, and final extension at 72°C for 10 min were used. A highly conserved *hsp*65 portion gene of *Mycobacterium* was amplified for PRA as per Telenti *et al*. (1993) (Table 1). The amplified PCR product (439 bp) was then digested with *BstEII* and *HaeIII* as per Telenti *et al*. (1993).

Table 1 Primer sequences of different NTM species and *hsp*65 gene

Organism	Primer	Primer sequence	Size (bp)
M. kansasii	Forward	5′-GCAAAGCCAGACACACTATTG-3′	152
	Reverse	5′-AAGAACACGCTACCCGTAGG-3′	
M. smegmatis	Forward	5′-ACCATGTCTATCTCAGTGTGCT-3′	628
	Reverse	5′-ACGCTCGAGGTCCACTACAA-3′	
M. fortuitum	Forward	5′-GACTGCCAGACACACTATTGG-3′	172
	Reverse	5′-GTGAGACCACACGATTCTGC-3′	
M. intracellulare	Forward	5′-CCT TTA GGC GCA TGT CTT TA-3′	450
	Reverse	5′-ACC AGA AGA CAT GCG TCT TG-3′	
M. vaccae	Forward	5′-CGAAGCCAGTGGCCTAACCC-3′	500
	Reverse	5′-TGGATCCTGCCAAGGCATCCACCAT-3′	
*hsp*65	Forward	5′-ACCAACGATGGTGTGTCCAT-3′	439
	Reverse	5′-CTTGTCGAACCGCATACCCT-3′	

3. Results and discussion

In the present study, 30 mastitic milk samples were subjected to PCR for the detection of NTM. Out of these, three samples were positive. *M. kansasii* (*n* = 1) and *M. smegmatis* (*n* = 2) were detected (Figure 1). Three out of 30 mastitic milk samples (10%) were positive for the *hsp*65 gene (Figure 2). Among three positive samples for *hsp*65 gene, one sample was identified as *M. kansasii* having the RFLP pattern as 245/220 bp when digested with *BstEIII* and 140/105/70 bp when digested with *HaeIII* and two samples were identified as *M. smegmatis* having the RFLP pattern as 245/145/85 bp when digested with *BstEIII* and 160/130 bp when digested with *HaeIII* (Figure 3). Prior research on raw milk and dairy products suggested that some developing nations have high levels of NTM species (Konuk *et al*., 2007).

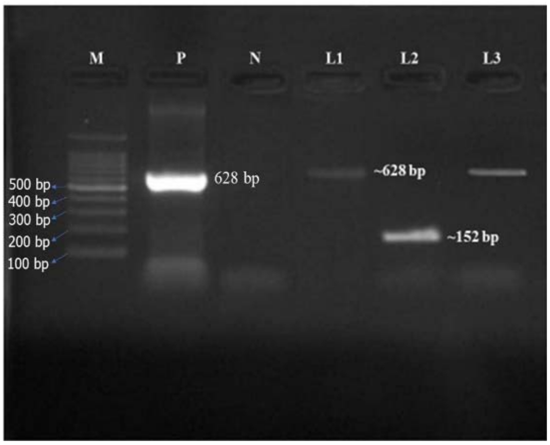

Figure 1 Agarose gel electrophoresis showing an amplicon of ~ 628 bp of *M. smegmatis* and *M. kansasii* ~ 152 from milk samples. M: marker (100 bp DNA ladder), P: positive (*M. smegmatis*), N: negative, L1 and L3: positive sample for *M. smegmatis* from milk samples, L2: positive sample for *M. kansasii* from milk sample

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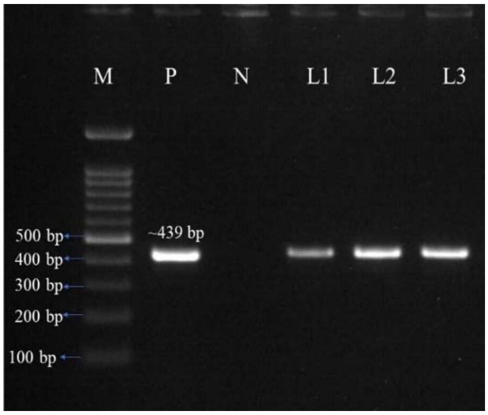

Figure 2 Agarose gel electrophoresis showing an amplicon of ~ 439 bp from milk samples. M: marker (100 bp DNA ladder), P: positive, N: negative, L1, L2, L3: positive for *hsp*65 gene PCR (439 bp) milk samples

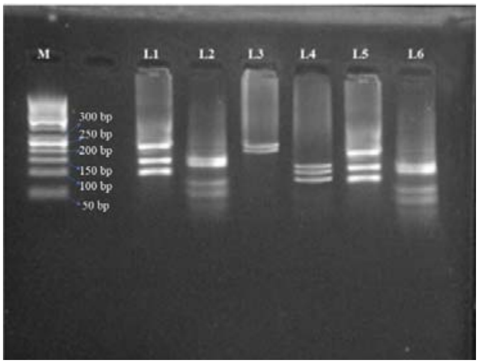

Figure 3 Agarose gel electrophoresis showing RFLP pattern of NTM species in milk. M: marker (50 bp DNA ladder), L1: *M. smegmatis* (*BstEIII*) (235/130/85), L2: *M. smegmatis* (*HaeIII*) (145/125/60), L3: *M. kansasii* (*BstEIII*) (245/220), L4: *M. kansasii* (*HaeIII*) (140/105/70), L5: *M. smegmatis* (*BstEIII*) (235/130/85), L6: *M. smegmatis* (*HaeIII*) (145/125/60)

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2.20 Factors Driving Changes in Agricultural Land Use Pattern Over Time in Kathua District of Jammu & Kashmir (UT)

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Keywords: Food crops; Land use pattern; Non-food crops; Total cropped area

1. Introduction

Agriculture plays an important role in the overall economic and social well-being of our country. India has experienced remarkable land use and land-cover changes including deforestation, cropland changes, and urban expansion (Roy *et al*., 2015). The change in land use has taken place in conformity with the shifting of land toward non-agricultural uses (Singh and Swain, 2016). The Jammu and Kashmir is facing many problems related to land use and its distribution/allocation due to rapid urbanization and infrastructural development. The study in Jammu and Kashmir has revealed a major shift of land from the desirable to undesirable land use classes (Wani *et al*., 2009). An analysis of factors driving changes in the land use pattern over a period of time provides scope for understanding the present scenario of agricultural land utilization. Proper measures can be taken accordingly to have a balance between remuneration to the farmers along with a sustainable environmental and production system. Therefore, we analyzed the 'Factors driving changes in agricultural land use pattern over time in Kathua district of Jammu & Kashmir (UT)'.

2. Materials and methods

For the purpose of analyzing factors driving changes in agricultural land use pattern over time, the Kathua district of Jammu and Kashmir was purposively selected. There are 19 blocks in the Kathua district. In the first stage, four blocks were selected purposively, which were on the roadside, as roadside blocks were more vulnerable to changes in agricultural land use patterns. In the second stage, three villages were selected randomly without replacement from each selected block. Thus, a total of 12 villages were selected randomly for the study. In the third stage, 10 respondents were selected randomly without replacement from each selected village. Thus, in all 120 respondents were selected for the present study.

Multiple linear regression was carried out on the time series data for the period from 2015-16 to 2017-18 in order to identify the factors affecting the land use pattern.

The functional form of this type of regression used is as follows:

$$y = b_0+b_1x_1+b_2x_2 \dots b_kx_k$$

where y represents the continuous dependent variables whose values had been modelled, b_0 is the y intercept, and x_1 to x_k represent k independent variables.

3. Results and discussion

In the present study, to test which socioeconomic variable influences area under food crops, non-food crops, and total cropped area during the study period, a multiple linear regression model was used. The results showed that in the year 2015-16 the value of R^2 was estimated to be 0.89 and the independent variables which are affecting changes in the area under food crops were Age (X_1), Family size (X_4), Owned land (X_5), On-farm income (X_{12}), Rabi season cultivation expenditure (X_{15}), Rabi season fertilizer expenditure (X_{17}), Net irrigated area (X_{18}), and Area sown more than once (X_{20}). Area sown more than once had decreased and affected the land use pattern (Amin *et al*., 2018).

In the year 2016-17, four independent variables, that is, Owned land (X_5), On-farm income (X_{12}), Net area sown (X_{18}), and Area sown more than once (X_{20}), were significantly affecting the changes in the area under food crops. The chemical fertilizers affected the area under food crops (Rachmina et al., 2014). In the year 2017-18, in the case of the area under food crops, On- farm income (X12), Net irrigated area (X18), Net area sown (X19), and Area sown more than once (X20) were affecting the changes in the area under food crops.

The land use pattern of the study area from 2015-16 to 2017-18 had shown that fallow land other than current fallow, land under food crops, net area sown, area sown more than once, and area under total cropped area had decreased. There was a great variation in land under non-food crops which had increased during the study period. Conversion for non-agricultural purposes appears to be the most important threat to the common property land resources such as cultivable wastelands, land under miscellaneous tree crops, and groves and grazing lands. Therefore, policy and research focus are needed to conserve and manage the common lands in a better manner to ensure rainwater harvesting, provide livelihood, fodder, and fuel security to rural poor, and sustain the ecological balance.

Table 1 Socioeconomic variables determining changes in land use pattern from 2015 to 2018

Year 2015-16				
Factors affecting area under food crops				
Coefficient				
Model	B	Std. error	t-value	Sig.
(Constant)	0.001	0.512	0.001	0.999
Age (X_1)	0.018	0.006	2.965	0.004
Family size (X_3)	–0.166	0.060	–2.785	0.006
On-farm income (X_{12})	4.57	0.001	6.526	0.001
Owned land (X_5)	–0.510	0.152	–3.359	0.001
Net irrigated area (X_{18})	1.241	0.260	4.480	0.001
Area sown more than once (X_{20})	0.745	0.105	7.064	0.001
Rabi season cultivation expenditure (X_{15})	–9.45	0.001	–2.699	0.008

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Rabi season fertilizer expenditure (X_{17})	9.78	0.001	3.189	0.002
R^2= 0.898 and adjusted R^2 = 0.880				
Year 2016-17				
Factors affecting area under food crops				
Coefficient				
Model	B	Std. error	t-value	Sig.
(Constant)	–0.074	0.293	–0.251	0.802
On-farm income (X_{12})	1.78	0.001	1.142	0.001
Owned land (X_5)	–2.36	0.089	–2.636	0.010
Net area sown (X_{18})	1.327	0.090	14.708	0.001
Area sown more than once (X_{20})	0.297	0.070	4.266	0.001
R^2 = 0.965 and adjusted R^2 = 0.961				
Year 2017-18				
Factors affecting area under food crops				
Coefficient				
Model	β	Std. error	t-value	Sig.
(Constant)	–0.004	0.276	–00.159	0.874
On-farm income (X_{12})	1.36	0.001	3.36	0.001
Net irrigated area (X_{18})	–0.346	0.162	–2.137	0.035
Net area sown (X_{19})	1.38	0.089	15.572	0.001
Area sown more than once (X_{20})	0.273	0.066	4.153	0.001
R^2 = 0.969 and adjusted R^2 = 0.965				

Note: All figures are significant.

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2.21 Study on the Biofortification of Brinjal with Micronutrients Fortified Organics on the Performance of Brinjal in Coastal Soil

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Keywords: FYM; VC; MNFFYM; MNFVC; Coastal soil; Micronutrients; Salinity

1. Introduction

In the coastal areas of Tamil Nadu, the deficiency of both macro and micronutrients especially zinc and iron is the most common in coarse textured coastal soils. Soil micronutrient availability is a limiting factor in crop productivity and quality in coastal salt affected soils. Brinjal fruit contains high zinc and iron minerals, but these minerals are limited due to low micronutrients status in soil and by this way increasing the nutrient in soil through agronomic biofortification that enhances the nutrient content of soil and concordantly brinjal fruit. Hence, the present investigation was carried out to study the effect of the application of zinc and iron fortified organic manures and micronutrients fertilization on the productivity of brinjal and restoration of soil fertility in coastal soil.

2. Materials and Methods

A field experiment was carried out in a farmer's field at Perampattu coastal village, near Chidambaram Taluk, Cuddalore district, Tamil Nadu, from February to May 2022. The characteristics of the experimental soil were as follows: low (135.56 kg ha-1), low (9.45 kg ha-1), and medium (157.30 kg ha-1) NPK status, respectively. The available zinc (0.69 mg kg^{-1}) and iron content (3.87 mg kg^{-1}) of soil is below the critical level, respectively. The various treatments, namely, T_1 – Control (100% NPK/RDF alone), T_2 – RDF+FYM @ 12.5 t ha^{-1}, T_3 – RDF+Vermicompost (VC) @ 12.5 t ha^{-1}, T_4 – RDF+FYM+$ZnSO_4$ @ 25 kg ha^{-1}+$FeSO_4$ @ 25 kg ha^{-1} SA (soil application), T_5 – RDF+VC+$ZnSO_4$ @ 25 kg ha^{-1}+$FeSO_4$ @ 25 kg ha^{-1} SA, T_6 – RDF+FYM+$ZnSO_4$ @ 0.5%+$FeSO_4$ @ 0.5% FA (foliar application), T_7 – RDF+VC+$ZnSO_4$ @ 0.5%+$FeSO_4$ @ 0.5% FA, T_8 – RDF+Zn+Fe Fortified FYM (MNFFYM) @ 6.25 t ha^{-1}, T_9 – RDF+Zn+Fe Fortified VC (MNFVC) @ 6.25 t ha^{-1}, T_{10} – RDF+MNFFYM @ 6.25 t $ha^{-1+}$$ZnSO_4$ @ 0.5%+$FeSO_4$ @ 0.5% FA, and T_{11} – RDF+MNFVC @ 6.25 t $ha^{-1+}$$ZnSO_4$ @ 0.5%+$FeSO_4$ @ 0.5% FA with three replications were studied under randomized block design (RBD) using brinjal var. Annamalai brinjal. Required quantities of NPK, $ZnSO_4$, and $FeSO_4$ fertilizers and different organics, namely, FYM and vermicompost, as per the treatment schedule were incorporated into the soil. Calculated quantities of micronutrients were fortified with organics MNFFYM and MNFVC applied to the soil as per treatment schedule. Foliar application of $ZnSO_4$ @ 0.5% and $FeSO_4$ @ 0.5% twice was applied as per the treatment schedule.

3. Results and Discussion

The application of recommended dose of fertilizer (RDF)+micronutrients fortified vermicompost (MNFVC) @ 6.25 t ha^{-1} through soil application along with foliar application of $ZnSO_4$+ $FeSO_4$ @ 0.5% at pre flowering stage (PFS) and flowering stage (FS) recorded the highest growth, yield characters, quality characters and yield of brinjal at harvest stages, respectively. This was followed by the treatments arranged in descending order $T_{10} > T_8 > T_7 > T_6 > T_5 > T_4 > T_3 >$ and T_2. These treatments were also statistically significant. The lowest growth, quality, yield parameters, and yield of brinjal were noticed in control. Addition of micronutrients fortified organic manures through soil and foliar spray of $ZnSO_4$+$FeSO_4$ along with RDF significantly increased the growth, and yield attributes which may be ascribed to better nutrient availability of soils (Mahesh *et al.*, 2017). Hence, the results of the study clearly concluded that the application of RDF+MNFVC @ 6.25 t ha^{-1} through soil along with foliar application of $ZnSO_4$ @ 0.5%+$FeSO_4$ @ 0.5% twice was superior in increasing the growth, yield, quality, nutrients availability, and uptake by zinc and iron biofortification of brinjal in coastal soil.

Table 1 Effect of biofortification of brinjal with zinc and iron fortified organic manures on growth, yield characters, yield, and quality of brinjal

Treatments	Plant height (cm)	Dry matter production (kg ha^{-1})	No. of fruits per plant	Single fruit weight (g)	Fruit yield (t ha^{-1})	Stover yield (t ha^{-1})	Ascorbic acid (mg 100 g^{-1})	Crude protein (%)
T_1	91.36	701.55	13.38	33.48	9.92	4.48	4.74	3.286
T_2	97.35	715.48	14.47	34.63	10.89	4.77	5.34	3.426
T_3	101.22	728.43	15.32	35.62	11.88	5.02	6.03	3.576
T_4	104.55	741.37	16.31	36.53	13.03	5.22	6.73	3.756
T_5	107.05	755.23	17.33	37.62	14.13	5.43	7.44	3.946
T_6	109.51	768.50	18.44	38.77	15.18	5.68	8.19	4.076
T_7	112.50	781.56	19.32	39.86	16.15	6.03	8.81	4.226
T_8	115.37	805.11	20.27	40.85	16.97	6.35	9.53	4.406
T_9	118.04	819.47	21.36	41.73	18.06	6.64	10.19	4.566
T_{10}	120.97	831.51	22.48	42.84	19.01	6.86	10.94	4.716
T_{11}	123.56	844.25	23.37	43.79	19.89	7.11	11.56	4.876
SEd	**1.11**	**5.50**	**0.30**	**0.35**	**0.36**	**0.08**	**0.27**	**0.05**
CD (*p*=0.05)	**2.35**	**11.55**	**0.65**	**0.74**	**0.76**	**0.17**	**0.58**	**0.11**

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2.22 Exploring the Antioxidant Potential of *Grewia asiatica* and Development of Ethnic Cheese: Kaladi and Its Functional Validation on Wistar Rat Animal Model

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Keywords: Antioxidant; *Grewia asiatica*, Kaladi; Oxidative stress; Wistar rats

1. Introduction

Kaladi is a traditional ripened dairy product indigenous to the Jammu and Kashmir state of the Republic India. It is a pastoral cheese popular in the form of street food called kaladi kulcha among jammuites and widely cherished. But the status of kaladi outside UT isn't available. Being rich in fats and proteins, it is vulnerable to lipolysis and proteolysis. The extract of *Grewia asiatica* fortification in kaladi was optimized and standardized for its preparation and subjected to *in vitro* antioxidant profile, that is, total phenols and total flavonoids content, DPPH (2,2-diphenyl-1-picrylhydrazyl), ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid), FRAP (ferric reducing ability of plasma) assays, and product storage profile. The value added kaladi was evaluated on oxidative stressed induced Wistar rats following 30% replacement in ad-lib feeding for 30 days and were subjected to *in vivo* antioxidant profile, namely, LPO (lipid peroxidation), SOD (superoxide dismutase), CAT (catalase), and GPx; biochemical profile, namely, glucose, total protein, total cholesterol, and triglycerides; and estimation of serum liver marker enzymes, namely, ALT (alanine transaminase) and AST (aspartame transaminase).

2. Materials and methods

Hygienically milked full fat buffalo milk with 6% milk fat and 9% SNF was procured from the local market of Jammu in pre-sterilized utensil and was stored in the laboratory at 4^0C until it was pre-warmed. Highly acidic coagulant mixture called Mathar, which was a combination of curd whey and buttermilk, was used for coagulation. A total of 40 male wistar rats were procured from the Indian Institute of Integrated Medicine, CSIR (IIIM), Jammu.

Based on the sensory evaluation and storage life of the value added functional kaladi produced, the extract of *Grewia asiatica* (0.7%) fortification in kaladi was optimized and standardized for its preparation and subjected to *in vitro* antioxidant profile, that is, total phenols and total flavonoids content, DPPH, ABTS, FRAP assays, and product storage profile. The value added kaladi were evaluated on oxidative stressed induced Wistar rats following 30% replacement in ad-lib feeding for 30 days and were subjected to *in vivo* antioxidant profile, that is, LPO (Hafeman *et al*., 1974), biochemical profile, that is, glucose, total protein, total cholesterol, and triglycerides, and estimation of serum liver marker enzymes, namely, ALT and AST.

3. Results and discussion

The processing condition for preparation of *Grewia asiatica* extract fortified kaladi was characterized, optimized, and standardized to 0.7%, which exhibited significant antioxidant capacity in vitro as well as in kaladi with respect to total phenolic and flavonoid content. Its antioxidant potential further strengthens its radical scavenging effect with respect to DPPH, ABTS, and FRAP assays. It was found to have the shelf life of more than 28 days. The value added kaladi ameliorated by decreasing liver marker enzyme (ALT and AST), decreasing lipid peroxidase level, increasing catalase level, increasing superoxide dismutase level, increasing glutathione peroxidase level, increasing glucose, increasing total proteins, increasing total cholesterol, and increasing body weight with declining relative liver and spleen weight. Thus, we can conclude to say that functional kaladi can be prepared with fortification of lyophilized extract 0.3% *Grewia asiatica*.

Table 1 *In vitro* antioxidant profile of lyophilized herbal extract (Mean±S.E.)

Parameters	*Grewia asiatica*
TPC (mg GAE/g)	45.4±2.64
TFC (mg QE/g)	23.75±2.46
DPPH (µg ascorbic acid/mL)	89.42±5.7
ABTS (TEAC µmol/g)	98.60±3.2
FRAP (% of $FeCl_3$/mg)	18.73±0.55

Note: *n*=6 for each treatment.

The lyophilized extract of *Grewia asiatica* exhibited significant antioxidant capacity in vitro as well as in kaladi with respect to total phenolic and flavonoid content. Its antioxidant potential is further strengthening its radical scavenging effect with respect to DPPH, ABTS, and FRAP assays. The value added kaladi prepared with fortification of lyophilized extract 0.7% *Grewia asiatica* was found to be having shelf life of more than 28 days. The value added kaladi ameliorated by decreasing liver marker enzyme (ALT and AST), decreasing lipid peroxidase level, increasing catalase level, increasing superoxide dismutase level, increasing glutathione peroxidase level, increasing glucose, increasing total proteins, increasing total cholesterol, increasing body weight with declining relative liver and spleen weight. Thus, we can conclude to say that functional kaladi can be prepared with fortification of lyophilized extract 0.7% *Grewia asiatica.*

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2.23 Production and Purification of L-asparaginase Obtained from *Enterobacter asburiae* Isolated from Black Gram Rhizospheric Soil Sample

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Keywords: Asparaginase; Optimization; Production; Purification

1. Introduction

L-asparaginase, an important biopharmaceutical, has been a boon to cancer patients, especially for the therapeutic treatment of acute lymphoblastic leukemia. However, asparaginase formulations from *Escherichia coli* and *Erwinia* species currently being used are associated with potential side effects causing hindrances toward a successful therapeutic treatment. Therefore, optimization and production of asparaginase obtained from varied microbial sources have been the aim of several studies to overcome the hypersensitive and toxicological responses associated with presently used drug formulations. In this study, the possibility of using *Enterobacter asburiae* strain R16C1/MT93543 isolated from black gram rhizospheric soil sample as an L-asparaginase production source of industrial importance was investigated. Different parameters were optimized for the production of the enzyme using Response Surface Methodology (RSM) and the enzyme was purified using anion exchange chromatography on fast protein liquid chromatography (FPLC) column.

2. Materials and methods

Response Surface Methodology (RSM) is a statistical modeling and optimization method to study the combined and interactive effects of a given quantitative data using appropriate experimental designs. RSM was employed to study the interaction between temperature, rpm, and inoculum size in optimized M9 medium using Minitab14 to identify optimized conditions required for enzyme production. Fifteen experiments were conducted for the identification of the best combinations of three different parameters to obtain maximum enzyme activity. Therefore, the parameters selected were temperature, rpm, and inoculum size. Enzyme activity against a different set of combinations was determined using a standard plot. Experimental data obtained from 15 experiments were used to determine the optimum point of process parameters using Box–Behnken Design (Managamuri *et al*., 2017). The design was used to optimize and study individual as well as interactive effects of rpm, inoculum size (%), and temperature for asparaginase activity. Comparable values for enzyme activity were obtained from experimental results and software predicted values.

Enzyme purification was carried out by anion exchange chromatography using a Mono-Q 5/50 mm polystyrene/ divinyl benzene GL anion exchange column attached to BioLogic DuoFlow FPLC system. Extracellular enzyme extraction was done by centrifugation at 10,000 rpm for 10 min; the pellet was then disposed of and the supernatant was taken. The powdered ammonium sulfate with saturation range fractions of 30%, 60%, and 90% was added in order to perform precipitation. Supernatant acquired from the high-activity fraction was dialyzed and the crude enzyme mixture was then loaded into the column and washed with the same equilibration buffer (Husain *et al*., 2016). L-asparaginase was eluted with a ramp of 0–100% 1 M NaCl in 50 mM Tris buffer (8.6 pH). The presence of L-asparaginase in the fractions showing the main peak was determined by measuring the catalytic activity.

3. Results and discussion

As per interaction data obtained for the selected fermentation parameters, rpm, size of the inoculum, and temperature showed significant effects at interactive levels, thus showing the effect on the production of enzymes. A significant improvement in enzyme activity was obtained after optimization as the contour plots designed showed the region of eligibility for maximum enzyme activity. The point prediction obtained from the analysis of variance (ANOVA) for the response surface cubic model for asparaginase activity (40.17 U/mL) was 30 °C, 180 rpm, and 10% inoculum size in M9 medium, which was 4.4-fold higher than the initial activity of the enzyme. On purification, 44.23 IU of asparaginase enzyme units were sequentially precipitated by the addition of ammonium sulfate (powdered) in a saturation range of 30%, 60%, and 90% fraction. Maximum activity of enzyme 41.61 IU was obtained in 60–90% fraction, yielding 3.7 mg/mL of protein with a specific activity of 11.25 mg/mL. Dialysate of this fraction was loaded on pre-equilibrated Mono-Q column with the elution of protein in 0–100% NaCl ramp. Fraction nos. 80–119 showing single protein peak were eluted with 60–80% NaCl gradient. Highest-activity asparaginase fractions were concentrated and stored at –80 °C. The specific activity yield of the enzyme was calculated to be 20.87 IU/mg using asparagines as substrate under optimum enzyme conditions. Table 1 summarizes the asparaginase purification results.

Table 1 Summary of various steps involved in the purification of asparaginase

Purification yield step (%)	Total enzyme activity (IU/mL)	Total protein (mg/mL)	Specific activity (U/mg)	Relative purification fold	Yield (%)
Crude CFE	44.23	6.8	6.50		
Ammonium sulfate precipitation	41.61	3.7	11.25	1.73	94.10
Dialysis	35.75	2.8	12.78	1.87	80.82
FPLC	31.00	1.5	20.70	2.85	70.10

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2.24 Effect of Organic Nutrient Management on Yield Potential of Greengram

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Keywords: Biofertilizer; Soil health; Yield

1. Introduction

India is the major pulse growing country in the world, accounting about 33%, 25%, 27%, and 14% area, production, consumption, and import of pulses in the world, respectively (Rawal and Navarro, 2019). Greengram is the third important pulse crop of India after chickpea and pigeonpea and one of the most important leguminous crops grown in arid and semi-arid regions of India. Greengram is an excellent source of high-quality protein (25%) and has the ability to symbiotically fix atmospheric nitrogen in association with *Rhizobium*. Long-term application of synthetic chemical fertilizers causes adverse effects on the environment such as chemical accumulation, increases salinity, and disparity in soil nutrients and harms the soil health. Consequently, biofertilizers and organic manures were opted to somehow reduce the adverse impact of low soil fertility, and environmental and biotic stresses, by improving the rhizospheric conditions for achieving sustainability in the crop production.

2. Materials and methods

A field experiment was conducted during *Kharif* 2020 at the research area of Deendayal Upadhyay Center of Excellence for Organic Farming, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India, comprising 13 treatments involving biofertilizers (*Rhizobium*, phosphate solubilizing bacteria [PSB], and *Trichoderma harzianum*) and different organic manures on loamy soil having moderately alkaline pH and 0.67% organic carbon with low, medium, and high available nitrogen, phosphorus, and potassium status, respectively. Different organic nutrient management practices adopted for evaluation were seed treatments, either alone or in combination, and farmyard manure (FYM) or vermicompost application @ 50%, 75%, and 100% recommended dose of nitrogen (RDN) (20 kg/ha) with combined seed inoculation. These treatments were replicated three times and allocated randomly to different plots of variety MH 1142 of greengram. The experimental field was irrigated thrice by providing sprinkler irrigation to avoid the consequences of dry spell and harvested manually. Data recorded for growth and yield parameters were statistically analyzed by Fisher's analysis of variance technique. Significance of differences in effects of treatments was tested by 'F' test and critical difference (CD) was computed at the 5% level of significance using the following formula:

$$\mathrm{CD} = \frac{\sqrt{2 \times \text{Error mean sum of square}}}{N} \times t\ (\text{error df } 5\%)$$

where CD denotes critical difference, N is the number of total observations, and t is the value of t-distribution for error degree of freedom at 5% level of significance.

3. Results and discussion

Integrated application of organic manures and biofertilizers in greeengram improved the soil nutritional status and production of growth-promoting substances, which ultimately increased the plant vigor and yield. At 30 days after sowing (DAS), *Rhizobium*+PSB+*Trichoderma harzianum*+75% RDN through vermicompost recorded significantly higher dry matter accumulation (5.0 g per plant) followed by 100% RDN through vermicompost (4.9 g per plant), whereas *Rhizobium*+PSB+*Trichoderma harzianum*+ 100% RDN through FYM resulted in maximum dry matter accumulation at 45 and 60 DAS (12.5 and 19.9 g per plant, respectively). The maximum number of seeds per pod and test weight was observed with *Rhizobium*+ PSB+ *Trichoderma harzianum*+100% RDN through vermi-compost (9.8 and 34.4 g, respectively). Significantly superior results were obtained with the addition of organic manures owing to optimum rhizospheric conditions and recorded maximum seed and straw yield of 855 and 2949 kg/ha, respectively, with *Rhizobium*+PSB+*Trichoderma harzianum*+ 100% RDN through vermicompost (Table 1). Dual inoculation of *Rhizobium* and PSB significantly improved the yield pertaining to enhanced mineralization and solubilization of nutrients (Verma *et al*., 2017). Application of various levels of FYM and vermicompost significantly improved the harvest index and reported the highest harvest index of 22.7% with *Rhizobium*+ PSB+*Trichoderma harzianum*+75% RDN through vermicompost, which was significantly superior over control (17.0%). Enhanced nutrient availability could be the reason for the increase in yield potential due to improved aeration along with the slow release of nutrients and prolonged soil moisture availability owing to the incorporation of organic manures. The greengram production may be recommended with *Rhizobium*+ PSB+ *Trichoderma*+100% RDN through vermicompost at Hisar conditions, although application of vermicompost and FYM @ 75 and 100% RDN gave statistically similar results and can be practiced for optimizing resources.

Table 1 Effect of organic nutrient management practices on growth and yield of greengram

Symbol	Treatments	Dry matter accumulation (g/plant)			Number of seeds per pod	1000 seed weight (g)	Yield (kg/ha)		Harvest index (%)
		30 DAS	45 DAS	60 DAS			Seed	Straw	
T_1	Control	3.4	10.1	13.1	6.9	32.0	453	2211	17.0
T_2	*Rhizobium*	3.9	10.5	15.0	8.3	32.9	565	2627	17.8
T_3	PSB	3.8	10.3	14.2	7.8	32.7	517	2432	17.7
T_4	*Trichoderma harzianum*	3.7	10.3	13.8	7.7	32.6	516	2411	17.7
T_5	*Rhizobium*+PSB	4.0	10.9	16.9	8.4	33.1	639	2633	19.5
T_6	*Rhizobium*+*T. harzianum*	3.9	10.6	15.4	8.3	33.0	614	2649	19.0
T_7	*Rhizobium*+PSB+*T. harzianum*	4.3	11.0	17.9	8.6	33.4	690	2735	20.1

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T_8	T_7+50% RDN FYM	4.7	11.6	18.8	8.9	33.7	747	2760	21.5
T_9	T_7+75% RDN FYM	4.8	11.9	19.5	9.1	34.0	802	2806	22.2
T_{10}	T_7+100% RDN FYM	4.9	12.5	19.9	9.5	34.2	834	2908	22.4
T_{11}	T_7+50% RDN Vermicompost	4.6	11.4	18.6	8.9	33.8	786	2831	21.9
T_{12}	T_7+75% RDN Vermicompost	5.0	11.7	19.1	9.4	34.1	840	2863	22.7
T_{13}	T_7+100% RDN Vermicompost	4.9	12.0	19.5	9.8	34.4	855	2949	22.5
	SE (m)±	0.15	1.17	1.94	0.32	0.50	28.64	120.11	1.01
	CD (p = 0.05)	0.45	0.40	0.66	0.94	NS	84.09	352.67	2.96

NS = Nonsignificant at 5% level of significance.

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2.25 Molecular Characterization of Plant Growth Promoting Bacteria Associated with Rhizosphere of Basmati Rice in Jammu Region

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Keywords: PGPB; PGP; Characterization; IAA; Rhizosphere; Microbial fertilizers

1. Introduction

Rice is currently the most important food crop in the world. It is important to perform screenings of the core rice microbiota to develop an understanding of the function of its microbiome. Plant growth promoting bacteria (PGPB) present in the rhizosphere play an important role to support plant growth on a sustainable basis. In order to begin to address this aspect, we have performed the isolation of bacterial isolates from bulk soil, rhizosphere, and endorhizosphere of Basmati rice. The preliminary characterization of bacteria for different plant growth promoting (PGP) traits such as siderophore, phytohormone, hydrolytic enzymes production, and phosphate solubilization was assessed and it led to the selection of 11 PGPB for further identification. Based on 16S rRNA gene sequence analysis, these bacterial isolates belonged to different genera, that is, *Bacillus*, *Pseudomonas*, and *Streptomyces*. All bacterial isolates were able to produce indole acetic acid (IAA) and five were able to solubilize inorganic phosphate *in vitro*. We believe this approach can be useful in the development of potential microbial fertilizers and can be used to improve the yield of rice crop to reduce synthetic fertilization.

2. Materials and methods

The soil samples, consisting of bulk soil and rhizosphere, of three plants were collected from Basmati rice growing areas of Jammu district during the flowering stage. The sampling was done as per the method of Luster *et al.* (2009). The isolation of bacteria from soil samples was done by serial dilution method (Stotzky *et al*., 1966). The isolation of endorhizosphere bacteria was performed by the method of Moronta-Barrios *et al*. (2018). *In vitro* assays of these bacterial isolates were performed for their ability to produce IAA and siderophore and to solubilize inorganic phosphate (P). The bacteria showing most of these activities were selected for 16S rRNA amplification. The total genomic DNA of bacterial strains was extracted by standard method with slight modifications. The 16S rRNA region was amplified from the bacteria isolated from different samples of rice using the universal 16S rRNA gene primers 27F (5’-AGAGTTTGATCCTGGTCAG-3’) and 1492R (5’-GGTTACCTTGTTACGACTT-3’). The 16S rRNA amplicons were custom sequenced at Agri-genome Labs Private Ltd., Cochin, Kerala, India. The obtained gene sequences were compared with others in the GenBank databases using the NCBI BLAST at http://www.ncbi.n1m.nih.gov/blast/Blast.cgi. Sequences were submitted to NCBI GenBank database and accession numbers were obtained.

3. Results and discussion

Bacteria were obtained both from rhizospheric portion and root interior of rice. The 16S rRNA sequencing classified the bacterial isolates into different genera as *Bacillus*, *Pseudomonas*, and *Streptomyces* (Table 1). *In vitro* PGP traits of the bacteria are described in Table 2. All bacterial isolates were able to produce IAA. The production of IAA by bacteria isolated from rhizosphere of different crops are already reported in a number of studies. Auxin production by the isolates is proposed as a major means of attaining growth promotion. Five bacteria were able to solubilize phosphate. The solubilization of P is an important characteristic under conditions where it is a limiting factor for crop production. All these characteristics are considered as important PGP traits and may be considered a positive indicator of utilizing the microbes as biofertilizers for crop production. Further studies should be focused on the detailed molecular and functional characterization of these PGPB for practical applications in the field.

Table 1 Identification of PGPB from different samples on the basis of 16S rRNA sequencing

Samples	Isolate code	16S rRNA identity	Percent identity	Accession no.
Bulk	CB 1	*Bacillus subtilis*	99.77%	MT361595
	CB 32	*Bacillus aryabhattai*	87.20%	MT361596
	CB 80	*Bacillus proteolyticus*	99.87 %	MT361597
	CB 94	*Bacillus cereus*	100%	MT361598
	CR 1	*Streptomyces* sp.	99.6%	MT361599
Rhizosphere	CR 14	*Pseudomonas mosselii*	100%	MT361600
	CR 42	*Bacillus tequilensis*	100%	MT361601
	CR 48	*Pseudomonas* sp.	97.4%	MT361602
	CR 55	*Bacillus pacificus*	99.89%	MT361603
Endo-rhizosphere	CE 19	*Bacillus* sp.	99.89%	MT361604
	CE 29	*Bacillus velezensis*	99.88%	MT361605

Table 2 *In vitro* assays of PGPB isolated from rhizosphere of Basmati rice in Jammu district

Isolate no.	Protease	Cellulase	Amylase	Phosphate	Siderophore	Ammonia	Catalase	IAA
CB 1	–	–	–	+	+	+	+	+
CB 32	+	+	+	+	–	+	+	+
CB 80	+	+	+	–	+	+	–	+
CB 94	+	+	+	–	–	+	–	+
CR 1	–	+	+	–	+	+	+	+
CR 14	+	+	+	–	+	+	+	+

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Isolate no.	Protease	Cellulase	Amylase	Phosphate	Siderophore	Ammonia	Catalase	IAA
CR 42	+	+	+	–	+	+	+	+
CR 48	+	–	–	+	+	+	+	+
CR 55	+	–	–	+	–	–	+	+
CE 19	+	+	+	–	+	+	+	+
CE 29	–	+	+	+	+	+	+	+

Note: "+" stands for positive activity and "–" stands for no activity for the tests in the above table.

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2.26 Effect of Edible Coatings on Quality of Walnut Kernels

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Keywords: Edible coating; Pea starch; Peroxide value; Soy protein isolate

1. Introduction

Nuts have gained considerable interest because of their advantageous nutritional and nutraceutical benefits. One of the commonly consumed tree nuts is 'walnut' (*Juglans regia* L.). India holds the eighth rank for walnut production around the world. In terms of area and walnut production, Jammu and Kashmir is the largest contributor of about more than 98% in India. In Jammu and Kashmir, around 89,000 ha of the area is under walnut production with an annual production of 2.66 lakh metric tons (Ministry of Statistics, Planning and Implementation, 2018). Deshelled nuts are very easy to consume, but after deshelling the main issues that arise are fungal decomposition and unwanted rancid taste making the walnut unacceptable to consumers as well as lessening their market value. In the past few years, different innovative techniques like packaging technology have been used for the enhancement of the shelf life of walnuts. Edible coatings are used as a better alternative to synthetic packaging materials which work tremendously for the improvement of both quality and stability of the food product.

2. Materials and methods

Green walnuts were purchased from the local market, Jammu. Then they were hulled and shelled followed by drying in a cabinet drier (38°C, 3 days). After drying, kernels were coated with coatings made of pea starch and soy protein isolate in different concentrations. Glycerol as a plasticizer and butylated hydroxyl toluene (BHT) as an antioxidant were also added in the same coatings as per the treatment detail given in Table 1. Coatings were prepared by dissolving pea starch and soy protein isolate separately in distilled water containing glycerol. Kernels after coating were dried in a cabinet drier (25°C, 24 h) and then packed in low-density polyethylene packaging material and stored at room temperature. Coated and uncoated walnut kernels were then analyzed for their physicochemical (moisture content, peroxide value, and thiobarbituric acid) and sensory attributes in terms of their color and taste in triplicate during storage at an interval of two months.

Table 1 Edible coatings used for the study

Treatments	Treatment detail
T_1	Uncoated (without coating)
T_2	7% Pea starch+3.5% Glycerol
T_3	7% Soy protein isolate+3.5% Glycerol
T_4	7% Pea starch+3.5% Glycerol+0.02% BHT
T_5	7% Soy protein isolate+3.5% glycerol+0.02% BHT
T_6	3.5% Pea starch+3.5% Soy protein isolate +3.5% Glycerol
T_7	3.5% Pea starch+3.5% Soy protein isolate+3.5% glycerol+0.02% BHT

3. Results and discussion

The lowest initial moisture content of 4.25% was recorded in treatment T_1 (control) while the highest initial moisture content of 5.54% was recorded in treatment T_7 (PS:SPI:GLY:BHT). The moisture content of treatments decreased after two months of storage. This might be due to the evaporation of excess of water added while coating. Among edible coated kernels, treatment T_2 showed the lowest mean moisture content of 5.36% while the highest mean moisture content of 6.24% was reflected by treatment T_1 (uncoated) (Naji and Davoodi, 2018). Also, a significant increase was observed in peroxide and the thiobarbituric acid value of uncoated and coated kernels. The increase was greater in uncoated kernels corresponding to a value of 0.17–5.76 mg MDA/kg and 1.28–6.29 meq O_2/kg oil after 180 days of storage while the least increase was observed in treatment T_7 (PS:SPI:GLY:BHT) corresponding to a value of 0.16–1.42 mg MDA/kg and 1.27–3.26 meq O_2/kg, respectively (Chatrabnous *et al*., 2018). In the case of color, coated kernels of the seventh treatment recorded the second highest score (7.45) followed by uncoated kernels (7.20). This is due to the masking of the natural color of walnut kernels by coating color. After 180 days of storage, treatment T_7 (PS:SPI:GLY:BHT) recorded the highest score of 7.50 for taste factor showing a higher rate of acceptability of edible coated nuts as compared to other coated and uncoated kernels.

Table 2 Effect of edible coatings and packaging on thiobarbituric acid value (mg MDA/kg) of coated walnut kernels

	Storage period (days)				
Treatment	0	30	60	90	Mean
T_1	0.17	2.91	3.52	5.76	3.09
T_2	0.18	1.90	2.65	3.89	2.16
T_3	0.17	1.82	2.54	3.32	1.96
T_4	0.18	1.21	1.69	2.42	1.38
T_5	0.16	0.84	1.23	1.87	1.03
T_6	0.16	1.64	2.48	3.02	1.83
T_7	0.16	0.69	1.11	1.42	0.85
Mean	0.17	1.57	2.17	3.10	

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2.27 Effects of Germination on Mineral Content and Functional and Bioactive Characteristics of Oat Flour

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Keywords: Bioactive components; Functional properties; Germination; Minerals; Oats

1. Introduction

Oat (*Avena sativa* L.) is a minor cereal consumed at lower rates as compared to other cereals all over the world. It can be used in the form of flour, bran, meal, and flakes as breakfast cereals and as ingredients in other foodstuffs. Oats are one of the most nutritious cereals that are high in protein and fiber and contain a high amount of minerals and vitamins (Ahmad *et al.*, 2014). Oats contain many essential amino acids necessary for the human body and high antioxidant activity components such as tocopherols, tocotrienols, and flavonoids. Oat products are mostly known for their unique profile of lipids that is two or three times more than other cereals and a high protein content comprising valuable amino acids. Owing to their high fiber content, oats are beneficial for the health of the digestive tract, due to their contribution to the increase of fecal mass. In addition to β-glucans, a soluble fiber, food products prepared from oats possess significant amounts of phenolic compounds and other antioxidants (Inglett and Chen, 2012). Oat β-glucan can also be used as a stabilizer in milk and meat products sensitive to oxidation of fat during storage. The nutritional value of oat is mainly sustained by dietary fibers (DF), which represent an essential part of the human diet (Duda *et al.,* 2021). The main objective of this investigation was to assess the mineral content and functional and bioactive properties of oat flour. Germination of cereal grains has been used for centuries for the purpose of softening the kernel and improving its nutritional value (Sharma *et al.*, 2016).

2. Materials and methods

Oats grains were procured from the local market of Jammu and were analyzed for minerals content and functional and bioactive properties. The grains were soaked in water twice their volume for 12 h at room temperature (28–30°C). After soaking, grains were evenly spread on germination sheets and covered with the same sheets. The grains were germinated at 25±2°C for 72 h at 40–45°C in a BOD incubator (Super-Deluxe York Scientific Industry). The germinated grains were washed and subjected to drying at 60°□C till the moisture reached 10%. The dried grains were milled into flour, sieved, packed in aluminum laminates, and stored under ambient conditions for further use. Minerals were determined by AOAC (2007) method while the bulk density of oat flour was determined by the method suggested by Kaur and Sandhu (2010). The water absorption capacity of flour was determined by the method described by Al-Khuseibi *et al*. (2005). The oil absorption capacity of the flour sample was determined by the method described by Elkhalifa *et al*. (2010) with modifications. Total phenols were determined by the Folin-Ciocalteu assay (Ahmed and Abozed, 2015). The free radical scavenging activity of samples was determined by using a stable DPPH (1,1-diphenyl-2-picrylhydrazyl) radical (Arab *et al*., 2011).

3. Results and discussion

Oat grains subjected to germination were analyzed for mineral content and the results are depicted in Table 1. Magnesium content increased from 169.55 to 187.25 mg/100 g, phosphorus from 429.61 to 454.61 mg/100 g, calcium from 4.70 to 7.72 mg/100 g, and iron from 4.70 to 7.72 mg/100 g. Our results are consistent with the findings of Refai *et al.* (2012) who reported higher values of magnesium, calcium, zinc, and iron content in oats and barley grain subjected to soaking and germination (48 and 72 h). Further, the functional properties of oats flour were also affected after germination: bulk density decreased from 0.76 to 0.38 g/mL, water absorption capacity from 68.80% to 108.28%, and oil absorption capacity from 186.33% to 199.92 %. Bioactive components of oats flour also increased after the germination process: antioxidant activity value increased from 45.20% to 58.17% and the total phenolic content of oats flour increased from 200.70 to 229.00 mg GAE/100 g.

Table 1 Minerals composition of oat flour

Minerals	Non-germinated oat flour	Germinated oat flour
Magnesium (mg/100 g)	169.55±3.19	187.25±2.17
Phosphorus (mg/100 g)	429.61±5.20	454.61±4.19
Calcium (mg/100 g)	47.99±0.41	58.00±0.19
Iron (mg/100 g)	4.70±0.02	7.72±0.01
Zinc (mg/100 g)	5.68±0.05	3.61±0.03

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2.28 WhatsApp for Creating Awareness of Food Adulteration

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Keywords: Adulteration; Awareness; Food; Message; WhatsApp

1. Introduction

In contemporary times, a mobile phone can be seen as the most essential instrument for communication. It is a revolutionary step in the field of telecommunication which has become the most common and convenient way of communicating and transmitting data. The advent of smartphones has given new meaning to mobile phones. They are not only a means of communication but are also a source of information and entertainment. WhatsApp application is one such application that can be used not only for many convenient functions but being user interactive and text based also provides a good corpus of language. In light of the ever-increasing use of adulterants in food and their effect on health, there is an urgent need to create awareness regarding adulteration and dissemination of knowledge on the use of practices to check adulteration. Since WhatsApp is relatively a new phenomenon, Punjab having high penetration of mobile telephony points toward its potential for creating awareness which should be harnessed. Keeping this in view, the present study was aimed at investigating the awareness regarding food adulteration.

2. Materials and methods

To select one practice, for the present study, a list of 10 selected topics was given to experts from the Department of Family Resource Management for ranking from 1 to 10 on the basis of their importance for the family based on the need hierarchy. The data available in the Department of FRM on the identified practice was collected. The content was also updated through the appropriate available literature. The selected content was validated by the three experts from the Department of FRM for its completeness and correctness. The suggestions were incorporated and the finalized content was accepted for developing WhatsApp package. The final content was appropriately sequenced to provide information from the basic concept to its application. For these 38 different messages were prepared and transformed into appropriate delivery modes, that is, text messages, pictures, or video clips on the basis of suitability. The study was conducted in the Ludhiana district of Punjab. Thirty women from each from urban, peri-urban and rural areas were selected based upon the criteria like the age between 20 and 40 years, access to an android or any other more advanced handset with internet availability, and regular users of WhatsApp. The existing level of awareness was assessed with the help of an interview schedule. A total of 38 messages for WhatsApp package in four sets were developed and shared on daily basis for 38 days. After the gap of 10 days, after the completion of messages, all the respondents were interviewed to measure the post-intervention level of awareness using the same interview schedule. Depending upon the nature of the data and needs of the present exploration, frequency distribution, percentage, mean scores, and paired t test were employed.

3. Results and discussion

It was found that the percentage of respondents aware of food adulteration and its types increased after intervention given over a period of 30 days. All of the respondents were aware of adulteration and about 95.00% of respondents were aware of its types after the intervention. The data in Table 1 reveal that there was an increase in the percentage of respondents who were aware after the intervention in relation to both reasons for intentional food adulteration (68.5% to 97.8%) and reasons for unintentional food adulteration (42.9% to 97.8%). It can be clearly seen that the increase in the percentage of respondents was more in case of unintentional food adulteration. This shows that a lesser percentage of respondents were aware of unintentional adulteration before the intervention. The percentage increased from 66.6% to 98.9% in urban, 63.3% to 97.7% in peri-urban, and 75.5% to 96.6% in rural areas regarding intentional adulteration. More than 50.00% of the respondents became aware of the source of incidental adulteration after the intervention. The messages in the form of text, pictures, and videos were found highly effective in terms of creating awareness of different types, sources, and reasons for adulteration in food items. A similar study conducted by Mittal (2018) found that there was extensive use of different mobile applications for varied purposes which included information seeing also. ICT is the key to the mass dissemination of information on different aspects of adulteration. What's App can be considered an important tool for the dissemination of information and creating awareness (Jayade, 2014).

Table 1 Awareness regarding reasons for food adulteration before and after intervention

Items		Urban (n_1 = 30)		Peri-urban (n_2 =30)		Rural (n_3 = 30)		Total (n = 90)	
		Before %	After %	Before %	After %	Before %	After %	Before %	After %
Reasons for intentional adulteration	Increase quantity	66.6	100	70	93.3	70	93.3	68.9	95.6
	Earn more profit	80	100	76.7	100	90	100	82.2	100
	Market competition	53.3	96.7	43.3	100	66.7	96.7	54.4	97.8
Mean		66.6	98.9	63.3	97.7	75.5	96.6	68.5	97.8
Reasons for unintentional adulteration	Carelessness	66.7	10	43.3	96.7	33.3	96.7	47.8	97.8
	Improper storage facilities	36.7	96.7	30	100	26.7	90	31.1	95.6
	Uncovered food	90	100	66.7	100	60	100	72.2	100
	Animals around food	40	100	36.7	100	33.3	93.3	36.7	97.8
	Growing vegetables along dirty water	6.6	96.7	20	100	53.3	96.7	26.7	97.8
Mean		48	98.68	39.34	99.34	41.32	95.3	42.9	97.8

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Theme 3

Pest Management Innovations

3.1 Efficacy of New Generation Herbicides for Weed Control in Maize

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Keywords: Herbicides; Weed control efficiency; Weed flora; Weed index

1. Introduction

Maize (*Zea mays* L.) is one of the most important multipurpose cereal crops in the world. Maize, being a rainy season crop and sown at wider spacing, results in heavy weed infestation. Besides hand weeding, there is another way to control weeds by the use of newly released herbicides. Newly released herbicides such as tembotrione and topramezone are postemergence herbicides with broad-spectrum weed control in maize. These herbicides inhibit 4-hydroxyphenylpyruvate dioxygenase (4-HPPD) and the biosynthesis of phytoquinone with the subsequent carotenoid pigment formation, membrane structure, and chlorophyll disruption. Tank mix application of these herbicides with atrazine was found more effective. Hence, the present investigation was conducted with pre- and postemergence herbicides as well as their combined use for weed control in maize.

2. Materials and methods

An agronomic experiment entitled "Efficacy of new generation herbicides for weed control in maize" was carried out during *Kharif* 2019 at AICRP on Maize, MPKV, Rahuri, Dist. Ahmednagar, Maharashtra (India). The experiment was laid out in a randomized completely block design with three replications and eight weed management treatments, namely, T_1 – tembotrione 120 g/ha+atrazine 250 g/ha (tank mix) at 20 DAS, T_2 – topramezone 35 g/ha+atrazine 250 g/ha (tank mix) at 20 DAS, T_3 – atrazine 1000 g/ha (PE), T_4 – pendimethalin 1000 g/ha (PE), T_5 – atrazine 750 g/ha+pendimethalin 750 g/ha (tank mix) (PE), T_6 – 2,4-D amine salt 58% SL @ 0.5 kg/ha at 20 DAS, T_7 – weed free, and T_8 – weedy check. The volume of water used for spraying was 500 L/ha. The soil of the experimental site was clayey in texture, medium in available nitrogen (210.11 kg/ha) and phosphorus (17.40 kg/ha) and high in available potassium (460.2 kg/ha), and moderately alkaline in reaction (pH 8.3). The maize variety Uday (DMR-248) was dibbled at 75 cm×20 cm spacing. The recommended dose of fertilizer used was 120:60:40 kg NPK/ha. Weed dry weight, control efficiency, and index were calculated at harvest.

3. Results and discussion

The predominant monocot weed species observed in the experimental site were Cynodon dactylon, Dinebra retroflexa, Echinochloa colonum, and Brachiaria eruciformis and dicot species such as Euphorbia hirta, Convolvulus arvensis, Commelina benghalensis, Amaranthus polygamus, Parthenium hysterophorus, and Cyperus rotundus as sedges.

Among the herbicidal treatments, lower weed density and weed dry weight and weed index and higher weed control efficiency were observed at harvest on the application of tembotrione @ 120 g/ha+atrazine @ 250 g/ha (tank mix) at 20 DAS (Table 1). However, it was at par with T_2. Decrease in weed density and dry weight with tank mix application of atrazine with tembotrione or topramezone might have been due to foliar absorption of herbicides by the target weeds and the application of pre- and postemergence herbicides has controlled all categories of weeds resulting in reduced yield losses. The results are similar to that reported by Sweta et al. (2015).. Weed-free treatment recorded significantly higher grain and straw yields that were at par with T_1 and T_2. The highest gross monetary returns were recorded in T_7, while the highest net monetary returns and benefit:cost ratio were recorded in T_1. These results corroborate that of Sanodiya *et al.* (2013). Among herbicidal treatments, grain yield, straw yield, additional net monetary returns, and B:C ratio were obtained significantly higher with T_1. Hence, under labor constraint situation, the application of tembotrione @ 120 g/ha+atrazine 250 g/ha (tank mix) at 20 DAS is suggestive of weed control in maize for higher remuneration.

Table 1 Effect of different weed control treatments on weed studies, yield, and economics of maize

Treatment	Total weed density	Weed dry weight (g)	Weed control efficiency (%)	Weed index (%)	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (Rs/ha)	Gross monetary return (Rs/ha)	Net monetary return (Rs/ha)	B:C ratio	Additional net returns over control (Rs/ha)
T_1-Tembotrione @ 120 g/ha+Atrazine @ 250 g/ha (tank mix) at 20 DAS	7.10 (50)	43.01	72.52	5.52	8015.62	9310.12	47238	174799	127561	3.70	51854
T_2-Topramezone @ 35 g/ha+Atrazine @ 250 g/ha (tank mix) at 20 DAS	7.31 (53)	45.00	70.87	6.62	7921.87	9040.00	47488	171936	124488	3.62	48781
T_3 - Atrazine @ 1000 g/ha PE	9.61 (92)	125.40	48.35	23.84	6460.93	7740.00	44663	142060	97397	3.18	21690
T_4 - Pendimethalin @ 1000 g/ha PE	9.35 (86)	116.40	52.74	23.38	6504.50	8005.00	44988	144089	99101	3.20	23394
T_5-Atrazine @ 750 g/ha+Pendimethalin @ 750 g/ha (tank mix) PE	8.61 (67)	105.93	63.18	15.28	7190.40	8760.00	44613	158840	114227	3.56	38520
T_6-2,4-D amine salt 58% S @ 0.5 kg/ha at 20 DAS	10.02 (100)	132.40	45.05	28.45	6070.31	7360.00	45788	140864	95076	3.07	19369

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Treatment	Total weed density	Weed dry weight (g)	Weed control efficiency (%)	Weed index (%)	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (Rs/ha)	Gross monetary return (Rs/ha)	Net monetary return (Rs/ha)	B:C ratio	Additional net returns over control (Rs/ha)
T_7 – Weed free	0.71 (00)	00.00	100	00.00	8484.37	9720.40	58583	184349	125763	3.14	50056
T_8 – Weedy check	13.50 (182)	232.80	00	35.95	5440.00	6250.00	42583	118290	75707	2.77	–
±SEm	1.85	5.13	2.07	1.02	289.36	313.16	–	4959	1290	0.20	–
CD at 5%	5.60	15.56	6.27	3.10	877.79	949.88	–	15043	3913	0.61	–

Values are $\sqrt{x+0.5}$ transformed. Original values are in parenthesis. PE – preemergence, DAS- Days after sowing

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3.2 Relative Abundance of Mustard Aphid *Brevicoryne brassicae* (Homoptera: Aphididae) on Mustard, *Brassica juncea* (L.)

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Keywords: *Brevicoryne brassicae*; Coccinellid predators; Population dynamics; Weather parameters

1. Introduction

Mustard, *Brassica juncea* (L.), is an important oilseed crop and constitutes a major source of edible oil. The crop is known to be damaged at various stages of plant growth by more than a dozen of insect pests, and mustard aphid (*B. brassicae*) (Homoptera: Aphididae) is the most serious and destructive pest and major limiting factor for mustard cultivation. This pest causes substantial losses in many crops and accounts for about 35–75% reduction in the yield of mustard. Owing to continuous desapping, yellowing and the subsequent drying of leaves take place, ultimately leading to the formation of weak pods and undersized grains. For ensuring the effective and economical management of this serious pest, a study was conducted to provide an opportunity to overcome the pest challenges.

2. Materials and methods

The field experiment on mustard was conducted on Entomology Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology, Wadura, Kashmir (SKUAST-K), India, during *rabi* 2018-19 and 2019-20. KS 101 "Gulcheen" variety was sown on the second week of October @ 5 kg/ha on a plot of size 10×12 m^2. The meteorological data prevailed during the infestation period of aphids, *rabi* 2018-19 and *rabi* 2019-20, were procured from the meteorological observatory, SKUAST-K. The aphid population was recorded on 20 randomly tagged plants at weekly intervals. Initially, at the pre-bloom stage, the population of aphids was recorded on the whole plant as one single unit. At the flowering/bloom stage, the aphids were counted from the upper 10 cm twig. At the post-bloom stage, the aphids were recorded on the upper, middle, and lower pods of plants on five randomly selected plants. The population of coccinellids was also recorded at pre-bloom, bloom, and post-bloom stages at weekly intervals. The data generated during 2018-19 and 2019-20 on the aphid population were pooled and correlated with the weather parameters and with the population of coccinellids. The regression coefficient (R^2) and regression equation ($Y = a+bx$) were computed by standard statistical methods.

3. Results and discussion

The data pertaining to temperature, rainfall, and relative humidity (Table 1) revealed that the maximum and minimum temperatures did not favor the aphid population; however, rainfall and relative humidity favored the aphid population. Significant correlation was observed between morning relative humidity ($r = 0.60$) and evening relative humidity ($r = 0.58$). A significant positive correlation was exhibited by aphids with coccinellid predators namely *Coccinella septempunctata* ($r = 0.95$) and *Hippodamia variegata* ($r = 0.96$). Dharavat *et al*. (2016) observed a negative correlation of aphids with maximum and minimum temperatures and a significantly positive correlation with humidity. Varmora *et al.* (2009) reported that the aphid population exhibits a positive correlation with rainfall and relative humidity. Ali and Rizvi (2012) revealed a positive correlation between aphids and coccinellid predators. Practically in another way, the predator population has a positive correlation with the aphid population. Rainfall and humidity during the susceptible stage of the crop are important factors affecting the aphid population. Thus, manipulation of the sowing time prevents overlapping of the insect pest and favorable conditions with the susceptible stage of the crop. Our study also provides proper timing and selection of pesticide applications besides other management practices. Natural enemies also play a key role in reducing the population of insects below invasion pests, and therefore their conservation and augmentation are of great importance.

Table 1 Correlation and regression analysis

Parameters		2018-19 and 2019-20 (pooled)		
		Regression equation		Correlation coefficient
Abiotic factors		**Aphid population/plant**		**(r)**
1	Maximum temperature	$y=-0.025x+22.92$	$R^2 = 0.066$	–0.26
2	Minimum temperature	$y=-0.002x+7.570$	$R^2 = 0.001$	–0.05
3	Rainfall	$y=0.012x+21.36$	$R^2 = 0.003$	0.06
4	Morning RH	$y=0.067x+72.81$	$R^2 = 0.360$	0.60^{*}
5	Evening RH	$y=0.077x+56.16$	$R^2 = 0.334$	0.58^{*}
Biotic factors				
1	*C. septempunctata*	$y=0.031x+0.105$	$R^2 = 0.894$	0.95^{**}
2	*H. variegata*	$y=0.018x-0.011$	$R^2 = 0.922$	0.96^{**}

Note: Correlation significance at 0.01^{**} and 0.05^{*} levels

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3.3 Survey of Myceliophagus Nematodes Associated with Commercially Cultivated Button Mushroom (*Agaricus bisporus)* in Jammu

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Keywords: *A. bisporus; Aphelenchoides sp.; Ditylenchus myceliophagus*; Identification

1. Introduction

Myceliophagus nematodes are highly destructive and are known to cause damage ranging from 41% to 100% crop loss in mushrooms, depending on the nematode species involved, its population density, and the cropping stage at the time of infestation. These nematode infestations reduce crop duration and lead to extremely poor flushes in the initial stage followed by total crop failure (Kumar *et al.*, 2008).

2. Materials and methods

A survey was conducted to study the incidence of nematodes on mushrooms (*A. bisporus*) by collecting compost and casing soil samples from different mushroom farms in Jammu, Samba, and Udhampur districts during the cropping season of 2019-20. The samples procured were thoroughly processed and the population of nematodes was determined by using Cobb's sieving and decanting method using 20, 60, and 100 mesh sieves (Cobb, 1917) followed by the modified Baermann funnel technique (Staniland, 1954). The catch of the suspension was collected in a beaker from the Petri-plate (after keeping suspension over tissue paper overnight) and was subjected to preliminary investigation for the presence of myceliophagus nematodes based on the presence of style and other significant visible characters with the help of stereoscopic binocular microscope at AICRP Nematology laboratory, SKUAST-Jammu. Two milliliters of suspension of each sample was also pipetted out into a counting dish and the nematode population was counted under a stereoscopic microscope. The total nematode count 250/g sample was obtained by multiplying the average of 3 counts of nematode population per mL. The frequency of the occurrence of nematodes was worked out based on the number of samples infested out of the total samples collected.

3. Results and discussion

Data presented in Table 1 regarding the survey of 66 mushroom farms of the district Jammu revealed a population of *D. myceliophagus* and *Aphelenchoides* sp. in button mushroom crop. *D. myceliophagus* was found to be more predominant with 71.42% frequency of occurrence with an average population of 63.28. However, nematodes *Aphelenchoides* sp. showed the percentage of occurrence of 57.14% with an average population of 48.42. A survey of 71 mushroom farms of the district Samba revealed the mean population of *D. myceliophagus* was predominant with 62.50% occurrence with an average population of 48.50, while *Aphelenchoides* sp. was recorded with 37.00% occurrence with an average population of 23.12. In the Udhampur district, 46 mushroom farms were surveyed that revealed the *Ditylenchu myceliophagus* was most frequent with 56.00% frequency of occurrence and an average population of 40.12. However, nematodes *Aphelenchoides* sp. showed an occurrence of 33.54% with an average population of 26.33. The result is in accordance with the findings of Bajaj and Kanwar (2011) who also reported that the fungal feeding nematodes such as *Aphelenchoides* sp. and *D. myceliophagus* are common in mushrooms.

Table 1 Occurrence frequency and population of myceliophagus nematodes associated with button mushroom in Jammu division

Locations	No. of samples collected	Myceliophagus nematode population (per 250 cc compost)	
		D. myceliophagus	*Aphelenchoides* sp.
Jammu	66	63.28	48.42
Frequency of occurrence		**71.42**	**57.14**
Samba	71	48.50	23.12
Frequency of occurrence		**62.50**	**37.00**
Udhampur	46	40.12	26.33
Frequency of occurrence		**56.00**	**33.54**

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3.4 Long-term Impact of Insecticide Resistance Management Programme of Cotton on Pesticide Use in Punjab, India

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Keywords: Cotton; Evaluation; IRM; Pesticide use

1. Introduction

An insecticide resistance management (IRM) based integrated pest management (IPM) programme was launched in 10 cotton-growing states of India in 2002, coinciding with the commercialization of Bt cotton in Western and Southern regions of the country. In Punjab, the IRM programme for rationalizing insecticide use was implemented from 2002 to 2013. The focus of an IRM programme was on rationalizing insecticide use. IRM is a component of IPM, and it aims to delay/retard the development of resistance in insects and to manage their populations by using as few as possible applications of any insecticide. The IRM strategy included spraying only when economic threshold levels (ETL) are reached, using selective insecticides that are less harmful to the insect pests' natural enemies, and rotating between different insecticide classes to overcome the development of resistance in insect pests and their resurgence. We analyzed the long-term impact of the IRM programme on reducing pesticide use on cotton in Punjab.

2. Materials and methods

Under the IRM project, Bathinda, Mansa, and Fazilka districts, covering 72% of cotton-growing areas, were selected for the field study in 2003–2004. A field study was conducted in 2003 and 2004 for finding the immediate outcomes of the IRM programme in cotton. A sample of 150 cotton farmers trained under the IRM programmes and a control group of 60 cotton farmers were surveyed and the results were published in a peer-reviewed journal (Peshin *et al*., 2009). For assessing the long-term impact of the IRM programme, the sampled farmers were revisited in 2016-17. Because of sample attrition, only 172 of them could be contacted, and of the total contacted farmers, only 121 were cultivating cotton (IRM 92 and non-IRM 29) and rest had shifted from cotton to rice cultivation and a few had given up farming and leased out their farms. An additional sample of 83 cotton farmers was drawn from six villages from the list of IRM and non-IRM cotton farmers prepared in 2003 and 2004. The new additions were from the same test and control villages as in 2003–2004. The sample size comprised 27 villages and 204 farmers. We employed with and without IRM intervention methodology to quantify the differences in pesticide use by applications and active ingredients applied per ha, seed cotton yield/ha, and percent area under Bt cotton in 2004 and 2016. Besides, a modified difference-in-differences (DD) methodology (Eq. 1) was also adopted to quantify the impact.

$$\Delta Y_{t} - \Delta Y_{c} = (Y_{t2} - Y_{t1}) - (Y_{c2} - Y_{c1}) \quad (1)$$

where Y_{t1} and Y_{t2} denote the observations of IRM farmers in 2004 and 2016, respectively, and Y_{c1} and Y_{c2} indicate the status of the non-IRM farmers in 2004 and 2016, respectively. The equation $\Delta Y_t - \Delta Y_c = (Y_{t2} - Y_{t1}) - (Y_{c2} - Y_{c1})$ indicates difference-in-differences (with sample attrition) impact of IRM programme over time.

3. Results and discussion

In 2003, there was no significant difference in the mean frequency of pesticide use between IRM and non-IRM farmers, and after the intervention of the IRM programme, the IRM farmers reduced the use of insecticide applications by 2.36 in 2004 (Peshin *et al*., 2009). In 2004, the average number of insecticide applications in the IRM villages was 13.1 compared to 15.1 in non-IRM villages, with a significant difference of 15.3% (t = 2.1, $p \leq 0.05$). The pesticide use (a.i.) in the IRM and non-IRM villages was 5.602 and 8.032 kg /ha, respectively, a difference of 30.25%. The mean insecticide applied per ha per farm by the IRM and non-IRM farmers was 5.455 and 6.083 kg, respectively. After the withdrawal of IRM intervention, the difference in insecticide use frequency between these two groups in 2016 was 1.0, which was not significant (Table 1). Besides, there were no significant differences in seed cotton yield and active ingredients of pesticides applied by the IRM and non-IRM farmers. But if we analyze the data using the modified difference-in-differences (DD) model, the differences in pesticide applications and active ingredients of pesticide applied were 2.9 applications and 0.746 kg/ha, respectively. DD methodology eliminates the seasonal and widespread adoption of Bt cotton effects to work out the actual impact of the IRM programme. In the DD test, the control group had a statistically greater drop than the test group. It could be because the percent area under Bt cotton in the control (95%) was more than treatment. The reduction in pesticide applications and pesticide use (a.i.) by weight in absolute terms from 2004 to 2016, among both the IRM and non-IRM farmers, is driven by an increase in area under Bt cotton (Table 1) and *Helicoverpa armigera* not being a key pest of cotton in 2016 (Peshin *et al*., 2020). However, the long-term benefits of the IRM training programme on pesticide applications have fleeted after the withdrawal of IRM intervention in 2013 making farmers overdependent on Bt technology and the pesticide industry outreach programmes. There should be a reinforcement of farmers' training in integrated pest management for sustaining the long-term impact of the IPM/IRM programme in reducing pesticide use for having sustainability and resilience of agrifood systems. Otherwise, the quantifiable principal objective of reducing pesticide use on a long-term basis will not be achieved.

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Table 1 Impact of IRM programme (with sample attrition)

Parameter	2004			2016			DD
	IRM	Non-IRM	Difference	IRM	Non-IRM	Difference	
Mean pesticide applications (No.)	13.1(6.58)	15.1(6.55)	–2.0	9.2(3.57)	8.3(2.95)	0.9	2.9
Mean pesticide use by weight (a.i.)	5.455(3.08)	6.083(3.42)	–0.628	1.863(1.06)	1.745(1.04)	0.118	0.746
Mean yield (kg/ha)	2243(849.1)	2296(636.6)	53	2099(25.2)	1922(578.4)	117	230
Percentage area under Bt cotton	34.7	25.2	9.5	91.2	96.8	–5.6	15.1

Note: Figures in the parenthesis are standard deviations. DD = difference-in-differences.

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3.5 Effects of Postemergence Herbicidal Combinations Tank Mixed with Zinc and Iron Sulfate on Growth and Straw Yield of Wheat Crop (*Triticum aestivum* L.)

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Keywords: Growth parameters; Herbicidal combinations; Iron; Straw yield; Wheat; Zinc

1. Introduction

Wheat (*T. aestivum* L.) plays a very important role in attaining food security. The Green Revolution led to the complex problem of both grassy and broad-leaved weeds. Diverse type of weed flora attacks wheat due to different growing conditions and cultivation practices. Weed reduces the wheat yield by 30–40% (Khan and Haq, 2002). Among various weed management methods, chemical weed control is more efficient and less time-consuming. Other factors affecting wheat growth and yield are imbalanced fertilization and deficiency of nutrients. Zn and Fe are essential micronutrients for plants. They play a very crucial role in nitrogen fixation, energy transfer and protein synthesis, photosynthesis, and so on. The time of spray of micronutrients in standing field crops mostly coincides with the time of application of postemergence herbicides. But very little information is available about the compatibility of herbicidal combinations with zinc and iron sulfate. Keeping in mind the role of these micronutrients, this study was carried out.

2. Materials and methods

A field experiment was conducted at Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Regional Research Station, Bawal (Rewari), India during the *Rabi* season of 2018-19. The experiment was laid out in randomized block design (RBD) having 18 treatments, each replicated thrice. Treatments consist of the sole application of four herbicidal combinations, namely, clodinafop+ metsulfuron (60 g/ha), sulfosulfuron+metsulfuron (32 g/ha), mesosulfuron+iodosulfuron (14.4 g/ha), and pinoxaden+ carfentrazone (50+20 g/ha); tank-mixed application of above herbicidal combinations with $FeSO_4$ (0.5%); tank-mixed application of above herbicidal combinations with $ZnSO_4$ (0.5%)+urea (2.5%); and tank-mixed application of above herbicidal combinations with $ZnSO_4$ (0.5%)+urea (2.5%)+$FeSO_4$ (0.5%).The rest two were weedy check (no weed management) and weed free.

3. Results and discussion

A significant increase in growth parameters such as plant height, dry matter accumulation, and the number of tillers per plant was observed with the application of herbicidal combinations with micronutrients. All weed management treatments employed in the present study had a significant effect on straw yield of wheat in comparison to weedy check and gave straw yield statistically equal to that of weed free. The addition of Zn or Fe individually to the herbicides improved the straw yield over the sole application of herbicides. The combined application of herbicides with Zn and Fe (Zn+Fe) further augmented the straw yield. The straw yield achieved under the treatment of herbicides with the sole application of Zn or Fe was statistically similar to the straw yield under the application of herbicides+Zn+Fe. Weeds compete with the crop for the applied inputs and space, resulting insignificant yield losses. The synergistic effect of tank mixing of herbicidal combinations with Zn and Fe increased the yield of wheat. The herbicidal combinations exhibited their worth against weeds through a selective mechanism while micronutrients (Zn and Fe) enhanced the efficacy of herbicidal combinations by improving the growth of wheat plants directly through their physiological and biochemical effects and improving their competitive ability against weeds. The harvest index also followed the same trend. Similar compatibility of herbicides and micronutrients was reported by Sabeti (2015).

Table 1 Effects of herbicidal combinations and their tank mixtures with zinc and iron sulfateon straw yield of wheat

Treatment	Dose (g/ha)	Straw yield (kg/ha)
Clodinafop+metsulfuron	60	7918
Sulfosulfuron+metsulfuron	32	8052
Mesosulfuron+iodosulfuron	14.4	8064
Pinoxaden+carfentrazone	50+20	8062
Clodinafop+metsulfuron+$ZnSO_4$+urea	60	8223
Sulfosulfuron+metsulfuron+$ZnSO_4$+urea	32	8292
Mesosulfuron+iodosulfuron+$ZnSO_4$+urea	14.4	8353
Pinoxaden+carfentrazone+$ZnSO_4$+urea	50+20	8302
Clodinafop+metsulfuron+$FeSO_4$	60	8176
Sulfosulfuron+metsulfuron+$FeSO_4$	32	8284
Mesosulfuron+iodosulfuron+$FeSO_4$	14.4	8298
Pinoxaden+carfentrazone+$FeSO_4$	50+20	8296
Clodinafop+metsulfuron+$ZnSO_4$+urea+$FeSO_4$	60	8548
Sulfosulfuron+metsulfuron+$ZnSO_4$+urea+$FeSO_4$	32	8678
Mesosulfuron+iodosulfuron+$ZnSO_4$+urea+$FeSO_4$	14.4	8705
Pinoxaden+carfentrazone+$ZnSO_4$+urea+$FeSO_4$	50+20	8689
Weedy check	–	6673
Weed free	–	8433
C.D. (p=0.05)		620

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3.6 Quantification of Spray Drift of Wheel Operated Boom Sprayer for Assessing Environmental Risk

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Keywords: Dropleaf; Spray drift;Water-sensitive paper; Wheel sprayer

1. Introduction

Pesticides have substantially aided in the enhancement of agricultural yields by controlling pests and diseases. However, their sporadic use is leading to significant consequences not only to public health but also to food quality resulting in an impact load on the environment. Traditional agriculture demands pesticides use in bulk with conventional sprayers resulting in high drift potential. The drift of spray from the pesticide applications can expose people, plants, animals, and the environment to pesticide residues that can cause health and environmental effects and property damage.

2. Materials and methods

A wheel operated sprayer developed at the SKUAST-Jammu (Zaffar, 2020)was evaluated in terms of the spray drift in the vegetable field of the knol khol crop. During the experimental study, the wind speed recorded was 1.2±1 m/s. Thespray drift was measured for three types of nozzles, that is, flat fan, hollow cone, and flood jet,and also the effect of the heightof the nozzle, that is, 40, 50, and 60cm, and the number of the nozzles on the boom, that is, two, three, and four nozzles, were also evaluated. The study involved the use of water-sensitive papers, which were laid on the leaves of the knol khol crop at a distance of 50 cm from the extreme end of the boom of the sprayer. The sprayed water-sensitive papers werethen analyzed using mobile-based software "Dropleaf," which was provided by the Federal University of Mato Grosso do Sul, UFMS, Brazil. The software gave the drift coverage (%) from the target area. The data obtained were statistically analyzed using RBD design to check the significance of the sprayer with respect to the height of nozzle, the type of nozzle, and the number of nozzles on the spray drift.

3. Results and discussion

The data on the effect of the type of nozzle, the number of nozzles, and the height of the nozzle on the spray drift are presented in Table 1 and the spray drift was found maximum for hollow cones(9.1%) and minimum for flood jet nozzles (0.2%). The minimum spray drift for the flood jet nozzle was due to the design features forming large-sized droplets as compared to the flat fan and hollow cone nozzles, which produced finer droplets that were more prone to the drift. With the increase in the number of nozzles on the boom, the spray drift decreased. A decrease of 33.3%, 47.1%, and 67.8% in spray drift was observed when the number of flat fan nozzles was increased from two to four at the height of 40,50, and 60 cm, respectively. In the case of hollow cone and flood jet nozzles, adecrease of 36.7%, 76%,and 59% and25%, 83%, and 70%, respectively, in spray drift was observed with anincrease in the number of nozzles from two to four at the height of 40, 50, and 60 cm, respectively. The decrease in the spray drift with an increase in the number of nozzles was due to the decrease in atomization of liquid producing large droplets, which are comparably less prone to the drift than the smaller droplets. In terms of the effect of the height of the nozzles, the spray drift increased with an increase in height of the nozzles. The increase of 49.4%, 53.9%, and 3.4%in spray drift was observed when the height of flat fan nozzles was increased from 40 to 60 cm for two, three, and four nozzle booms, respectively. In the case of hollow cone and flood jet nozzle, the increase of 46.1%, 39.3%, and 16.2% and 93.7%, 90.9%, and 84.2%, respectively, in spray drift was observed with an increase in the height from 40 to 60 cm for two, three, and four nozzle booms, respectively. The increase in the spray drift with an increase in the height of boom may be due to more time span for water droplets to remain suspended in the air, which resulted in more drift due to the flow of wind (Nordby and Skuterud, 2006). The main effects of the nozzle type, height of spraying, and the number of the nozzles were not statistically significant at a 5% level of significance. However, nozzles type, the height of nozzle, and the number of nozzles were significant in first-order and second-order interactions at a 5% level of significance.

Table 1 Effect of the nozzle type, numberof nozzles, and height of nozzle on the spray drift

Nozzle type	No. of nozzles	Spray drift (%)		
		H_1 (40 cm)	H_2 (50 cm)	H_3(60 cm)
	B1 (two nozzles)	4.4	5.3	8.7
Flat fan nozzle (N_1)	B2 (three nozzles)	4.1	5.0	8.9
	B3 (four nozzles)	2.8	2.8	2.9
	B1 (two nozzles)	4.9	5.5	9.1
Hollow cone nozzle (N_2)	B2 (three nozzles)	4.0	4.3	6.6
	B3 (four nozzles)	3.1	3.1	3.7
	B1 (two nozzles)	0.4	4.2	6.4
Flood jet nozzle (N_3)	B2 (three nozzles)	0.2	0.4	2.2
	B3 (four nozzles)	0.3	0.7	1.9

Note: H_1, H_2, and H_3refer to the height of the nozzle from the target area.

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3.7 Standardization and Evaluation of Different Coloured Sticky Traps and Their Height Against Onion Thrips (*Thrips tabaci* L.)

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Keywords: *Allium cepa*; Colored sticky traps; Evaluation; Onion; Standardization; *Thrips tabaci*

1. Introduction

Onion (*A. cepa*), being an important horticultural crop, suffers an indispensable loss in quality as well as quantity due to various insect pests. Among different insect pests, thrips (*T. tabaci* L.) alone cause significant yield loss in onion accounting for more than 50% (Gupta *et al*., 1984). Farmers make repeated applications of insecticides to manage thrips, which leads to concerning issues such aspest resistance, secondary pest outbreak, biomagnification of pesticide residues, and disturbance in ecosystem functioning. Therefore, nonchemical management of pests should be adopted to avoid emerging pesticide problems and this could be done by the reliance of farmers on management practices that are nontoxic to nontarget organisms and are eco-friendly at the same time. Therefore, keeping in view the importance of the onion crop and the ill effects of pesticide application to control onion thrips, the present research was carried out to evaluate the effect of sticky traps in managing *T. tabaci*population on onion.

2. Materials and methods

A fieldexperiment was conducted at Entomology Farm, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) inrabi 2019-20. Seedlings of onion variety "Yellow Globe" were transplanted in the field in November 2019 in a plot size of $2\times1m^2$ spaced at 15×30cm. There were four treatments, each replicated five times. In the first experiment, four sticky traps(yellow, green, blue, and white) of size 12×10cm were installed 70 cm above the ground in an onion field in the 15th standard week to evaluate the attractiveness of thrips to different trap colors. In the second experiment, four different colored sticky traps (yellow, blue, green, and white) were installed at four different heights (25, 50, 75, and 100 cm) above ground to evaluate the appropriate height for sticky trap installation for checking *T. tabaci* population. The data were collected at weekly intervals till the harvest of the crop. The number of thrips/card/week was recorded as the total catch per card. The thrips stuck on the traps were counted using a 10× lens at weekly intervals. Ten such counts were made during the entire cropping period. The data collected were statistically analyzed to obtain the value of the critical difference so that the efficacy of different treatments could be accurately compared against the target insect pest. Following ANOVA, differences between data sets were determined using the least significant difference at p=0.05 in all instances.

3. Results and discussion

The data collected from the first experiment revealed that maximum *T. tabaci* population was attracted to yellow sticky traps (32.38 thrips/trap) after 70 days of trap installation. It was followed by blue, green, and white colored traps, which recorded a cumulative mean population of 21.64, 15.02, and 8.66 thrips/trap, respectively (Table 1). Our results are supported by Gharekhani *et al*. (2014) who reported that *T. tabaci* population was maximum attracted to yellow traps followed by blue and white traps. The efficiency of the height of different sticky traps against *T. tabaci* during 2019-20 is presented in Figure 1. The perusal of the data revealed that yellow sticky traps installed at 75cm from the ground had maximum effectiveness in attracting *T. tabaci* (32.48 thrips/trap) after 70 days of trap installation. It was followed by 100, 50, and 25cm which recorded a cumulative mean population of 30.28, 27.42, and 23.54 thrips/trap, respectively, after the 70th day of installation of yellow sticky traps. Similarly, blue sticky traps recorded a maximum population of thrips (21.38 thrips/trap) when installed at 75 cm above the ground. A similartrend was observed in green and white sticky traps wherein traps installed at 75 cm above ground attracted a maximum number of thrips. All the treatments were significantly different from each other. Our results corroborate with the findings of Macintyre-Allen *et al*. (2005) who reported that sticky traps installed between 0.7 and 0.95m above ground had the highest efficacy in attracting the *T. tabaci* population.

Table 1 Efficacy of different colored sticky traps against *T. tabaci* during rabi 2019-20

Sticky trap	Thrips population/trap* (no.)									
	7DAI	14DAI	21DAI	28DAI	35DAI	42DAI	49DAI	56DAI	63DAI	70DAI
White	0.40	1.80	3.20	4.80	9.60	12.80	17.80	14.80	12.00	9.40
Green	2.20	4.60	8.40	11.20	15.80	19.20	27.40	23.80	19.80	17.80
Yellow	4.60	12.60	17.80	26.00	37.40	42.60	52.40	47.00	43.20	40.20
Blue	2.40	3.80	9.60	16.60	23.00	28.60	40.60	35.40	29.40	27.00
C.D.($p\leq0.05$)	1.10	2.99	1.73	2.01	2.65	2.92	1.99	2.47	2.31	2.71

*Mean of five replications; DAI, days after trap installation.

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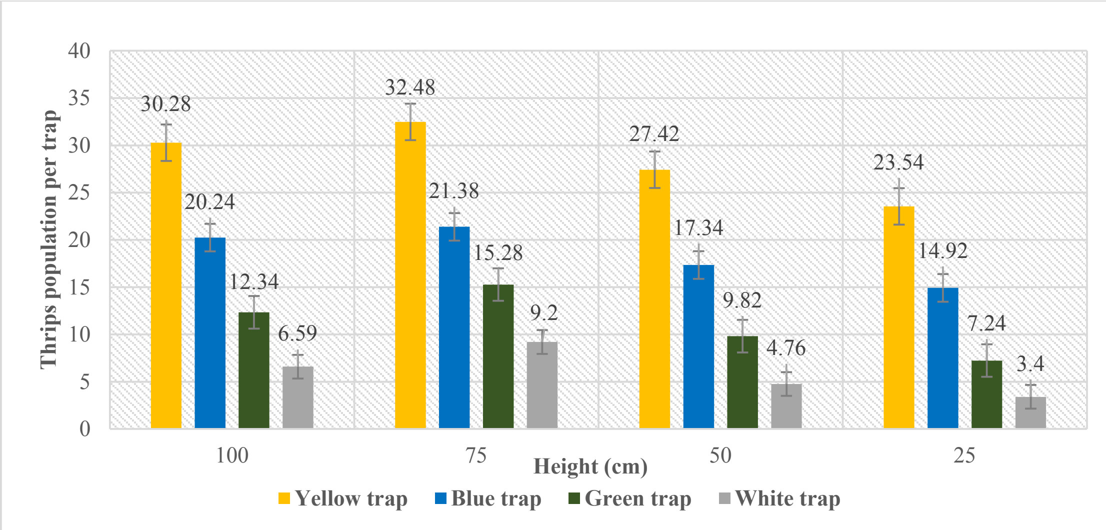

Figure 1: Efficacy of height of sticky traps against *T. tabaci* on onion

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3.8 Biocontrol of *Alternaria* Leaf Blight of Wheat by Endogenous Rhizobacteria

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Keywords: *Alternaria*; Biocontrol; Biofertilizer; Rhizobacteria

1. Introduction

Isolation of PGPR (plant growth promoting rhizobacteria) was carried out from the rhizosphereand roots of wheat (*Triticumaestivum* L.) from fouragroclimaticzones of Himachal Pradesh. A total of 67 bacterial isolates (36 rhizospheric and 31endophytic) were morphologically and physiologically characterized and tested for multifarious PGP (plant growth promoting) traits, namely, phosphate solubilization (390.2–412.17 µg/mL), HCN production, growth on nitrogen-free medium (3–6 mmcolony diameter), auxin production (27.78–33.41 µg/mL) and siderophore production (16.5–29.4% siderophore unit), and antagonism against *A. Triticina* (50-69% inhibition) under *in vitro* conditions. The strain B2 was characterized as *Serratiamarcescens* basedon morphological, biochemical, and partialgenesequence analysis of 16SrRNA. It has exhibited maximum growth in hibition against *A. Triticina* (69%). Seed bacterization with the isolate registered a significant reduction in disease incidence (26.67%) after 45 days of inoculation. The result envisages the potential of *S. Marcescens* as a biofertilizer and biocontrol agent for wheat in the North-Western Himalayan region.

2. Materials and methods

The biocontrol efficacy of selected bacterial isolate(s) against the test fungal pathogen *A.triticina* was carried out by adopting a standard methodology by taking seven treatments (Table 1) under completely randomized design (CRD). Observations on various plant parameters were recorded.

3. Results and discussion

A significant effect on seed germination and plant growth parameters of wheat with a minimum of disease incidence was recorded by the application of selected endophytic bacterial isolates. The present findings are in accordance with those Siddiqui (2007)in wheat with inoculation of bacterial isolate(s). The significant improvements in nutrient uptake by inoculated plants are in conformity with the findings of Akhtar *et al*. (2009) and Zaidi and Khan (2005).

Table 1 Effect of liquid bacterial inoculum and fungicides on the seed germination and plant parameters of wheat under net house conditions

Treatments	Seed germination (%)	Disease incidence percentage	Total chlorophyll content (mg/g FW)	Shoot parameters		Root parameters	
				Shoot length(cm)	Shoot biomass (g/plant)	Root length (cm)	Root biomass (g/plant)
T1 (Absolute Control)	86.67(68.83)*	0.00(0.00)*	0.20	39.80	1.15	4.93	0.16
T2 (*A.triticina*)	66.67(54.76)*	76.67(61.90)*	0.10	36.87	1.02	4.48	0.09
T3 (Fungicide+*A.triticina*)	73.33(59.19)*	33.33(35.00)*	0.14	40.79	1.63	4.60	0.17
T4 (*A. triticina*+ BIS1)	86.67(68.83)*	53.33(46.90)*	0.20	39.35	2.16	7.00	0.20
T5 (*A.triticina*+HAR1)	73.33(59.19)*	33.33(35.00)*	0.14	39.55	2.27	5.73	0.23
T6 (*A.triticina*+SHS1)	73.33(58.98)*	40.00(39.22)*	0.21	41.37	1.70	5.55	0.30
T7 (*A. triticina*+ B2)	86.67(68.83)*	26.67(30.78)*	0.26	41.90	2.22	6.37	0.34
T8 (*A.triticina*+SHS2)	80.00(63.90)*	26.67(30.78)*	0.11	37.37	2.10	6.08	0.30
CD0.05	9.85	11.84	0.024	39.80	1.15	4.93	0.16

*Figures in parentheses are angular trans formed values. FW-Fresh weight

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3.9 Evaluating the Efficacy of Fenoxaprop+Metribuzin on *Rumex* spp. in Wheat (*Triticum aestivum* Linn.)

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Keywords: Chlorophyll fluorescence; Herbicide combination; Weed management

1. Introduction

Rumexdentatus is a major weed of irrigated wheat, particularly in the rice-wheat cropping system. It is reported to cause yield loss in wheat cropsup toan extent of 55% (Balyan and Malik, 2000). The cultural and mechanical methods of weed control are generally burdensome, fatiguing, and arduous. In chemical methods, employing the usage of metsulfuron, sulfonylurea herbicide has been recommended for the control of this weed for a longer period. But continuous usage results in the poor efficacy of this herbicide (Chhokar *et al.*, 2017). At present, the herbicide combinations of herbicides such asfenoxaprop+ metribuzin have shown improved weed control efficiency against broadleaf weeds such as *Rumex* spp. and *Cronopus didymus*. Keeping in view the above facts and the paucity of research on the above aspects, the present investigations were planned to evaluate the response of fenoxaprop+ metribuzin against *Rumex* spp. in wheat.

2. Materials and methods

A pot experiment was carried out in the Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University under CRD (completely randomized design) with three replications using seeds of four populations of *Rumex* spp., namely, HHH (HAU, Hisar), UPH (Ujha, Panipat), JHH (Jind), and JJH (Jhajjar), collected from farmers' fields of Hissar, Panipat, Jind and Jhajjar districts. Seeds collected from the research farm, CCSHAU, Hisar were used as a standard check for comparison. Fenoxaprop+metribuzin was taken as treatment and applied at three doses (0.5X, X, and 2X) to evaluate its efficacy against *Rumex* spp. Soil from the research farm area of the agronomy department was used for filling pots. The potting mixture was prepared in the ratioof 2:3:1 (soil:sand:vermin-compost).Spraying was done with the help of a knapsack sprayer with flat fan nozzles having a 300 L/ha spray volume capacity. Plant height, chlorophyll fluorescence, electrical conductivity, percent mortality, fresh weight, and dry weight were recorded.

3. Results and discussion

The data on the effect of fenoxaprop+metribuzin on plant height, chlorophyll fluorescence, percent control, electrical conductivity, and dry weight of *Rumex* biotypes is given in Table 1. Among the four biotypes, the least efficacy of fenoxaprop+metribuzin combination was observed in UPH as revealed by significantly higher plant height (22.7 cm), higher chlorophyll fluorescence (0.27), and lower EC (0.27 dS/m). The herbicide efficacy improved with the increase in dose from 0.5X to 2X. The mean data over herbicide doses revealed that significantly lower mortality was recorded in UPH (44%) followed by JHH (58%), HHH (60%), and JJH (67%) at 4 WAT. The percent control of weed achieved at X and 2X dose was statistically at par in all biotypes, but the reduction in the dose from X to 0.5X resulted in 7.8% lower mortality. The fresh weight recorded as g/pot at 120DAS was significantly higher in UPH (3.94), followed by JHH (2.44), HHH (2.18), and JJH (1.18). A similar trend was observed with respect to dry weight.

The mortality achieved in JHH (78%), HHH (79%), and JJH (89%) at X dose is good enough to recommend this herbicide for field-level application, but its efficacy is quite low in UPH (60%). Comparatively lower values of chlorophyll fluorescence and fresh and dry weight were observed in all biotypes upon the application of fenoxaprop+metribuzin due to inhibition of acetyl CoA carboxylase that causes leaf chlorosis and necrosis. These results are in line with the findings of Chhokar *et al.* (2015). Fenoxaprop+metribuzin (X dose = 275g a.i./ha) gave efficient control of most of the biotypes. The combinations may be recommended after validating at field-level experimentations for enhancing the productivity of wheat.

Table 1 Plant height, chlorophyll fluorescence, electrical conductivity, per cent control,and dry weight of *Rumex* biotypes as influenced by the application of fenoxaprop+metribuzin

Bio-types	Plant height (cm) at 4 WAT					Chlorophyll fluorescence (Fv/Fm) at 7 DAT					Electrical conductivity (dS/m) at 4 WAT					Mortality percentage at 4 WAT					Dry weight at 120 DAS				
	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean	0	0.5X	X	2X	Mean
HHH	26.3	20.3	18.3	16.7	20.4	0.85	0.06	0.04	0.02	0.24	0.02	0.38	0.45	0.49	0.34	0 (0)	73 (92)	79 (95)	85 (98)	60 (71)	2.47	0.33	0.23	0.13	0.79
UPH	27.3	23.3	21.0	19.0	22.7	0.91	0.09	0.05	0.04	0.27	0.03	0.20	0.39	0.45	0.27	0 (0)	48 (55)	60 (75)	67 (85)	44 (54)	3.23	1.37	0.77	0.53	1.48
JHH	27.7	22.7	20.0	18.0	22.1	0.91	0.06	0.04	0.03	0.26	0.03	0.36	0.40	0.48	0.32	0 (0)	72 (90)	78 (93)	81 (97)	58 (70)	2.83	0.33	0.33	0.17	0.92
JJH	21.7	13.3	12.3	11.7	14.8	0.84	0.04	0.01	0.01	0.23	0.03	0.55	0.60	0.60	0.44	0 (0)	89 (100)	89 (100)	89 (100)	67 (75)	2.40	0.33	0.27	0.17	0.79
Mean	25.8	19.9	17.9	16.3		0.88	0.06	0.04	0.02		0.03	0.37	0.46	0.51		0 (0)	71 (84)	77 (91)	81 (95)		2.73	0.59	0.40	0.25	

	CD (*P*=0.05)	±SEm	CD (*P*=0.05)	SEm	CD (*P*=0.05)	SEm	CD (*P*=0.05)	±SEm	CD (*P*=0.05)	±SEm
Biotypes	0.8	0.29	0.02	0.006	0.01	0.003	4	1.4	0.13	0.044
Herbicide	0.8	0.29	0.02	0.006	0.01	0.003	4	1.4	0.13	0.044
Biotypes × herbicide	NS	0.58	NS	0.012	0.02	0.006	8	2.8	0.25	0.088

Note: Original figures in parenthesis were subjected to angular transformation. X dose is 275 g/ha; WAT, weeks after treatment; DAT, days after treatment; DAS, days after sowing.

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3.10 Evaluation of Different IPM Modules for Management of Fruit Fly *Bactrocera cucurbitae* (Coquillett) in Summer Squash (*Cucurbita pepo* L.)

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Keywords: *Bactrocera cucurbitae*; Methyl Eugenol; IPM;Spinosad; Summer squash

1. Introduction

The unique agro-ecological situation of the Jammu region encourages the cultivation of diverse categories of vegetables that providea direct source of employment opportunities and livelihood to the rural farming community. Among these vegetable crops, summer squash (*Cucurbita pepo* L.) a cucurbitaceous crop, is one of the popular cash cropsdue to its short duration. Like other vegetables, insect pests are the major limiting factors in its production causing significant damage to the crop at different stages from nursery raising to the harvest. The most effective and popular way to control insect pests is the use of chemical insecticides. However, the indiscriminate application of chemical insecticides has led to several problems such aspest resurgence, development of resistance in insects, ecological imbalance by killing natural enemies, and environmental and human health hazards. These problems associated with chemical applications led to the formulation of Integrated Pest Management (IPM) modules for the management of fruit flies in summer squash with an objective to develop effective, safe, and eco-friendly pest control methods aimed at enhancing sustainable crop production. Therefore, an experiment was carried out to evaluate different IPM modules for the management of fruit flies and to validate and popularize these eco-friendly IPM management modules among the farmers in the Jammu region.

2. Materials and methods

The experiment comprised six treatments(Table1) and was conducted ina randomized block design(RBD) with four replications in a plot size of 5×4 m^2atthe experimental farm ofthe Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology Chatha, Jammu (SKUAST-Jammu). The summer squash variety “DON 17” was sown in polybags in February 2018 and transplanted in the main field in March 2018. All cultural practices recommended as per the package of practices of SKUAST-Jammu were followed. Observations on percent fruit damage and yield in each module were recorded to calculate the benefit-cost ratio based on increased yield over control. Data were statistically analyzed for analysis of variance(ANOVA) by SPSS software calculating critical difference (p=0.05) and means were compared with Tukey’s HSD test at $p \leq 0.05$.

Table 1 Details of treatments

MODULE-I	MODULE-II	MODULE-III
• Weekly clipping of infested fruits • **Low-cost methyl eugenol trap with spinosad** • Maize as a trap crop • Spraying as spot application with spinosad+Gur	• Weekly clipping of infested fruits • **Low-cost methyl eugenol trap with spinosad** • Maize as a trap crop • Spraying as spot application with imidacloprid+Gur	• Bait spray 0.1 % malathion and sugar i.e. 40 ml of malathion and 200g of sugar in 20 lit of water per ha.
MODULE-IV (Package of Practice)	**MODULE-V (Farmer’s Practice)**	**MODULE-VI (Control)**
• Spraying as spot application with deltamethrin+Gur	• Spraying of profenophos @ 1000 mL/ha	• Sole crop (water spray)

3. Results and discussion

Among the six IPM modules, the module I was found to be superior and showed the least percent damage in summer squash on a number basis (16.15%) and a weight basis(11.69%). Also, the module I was found to be superior with the highest adult fruit fly mortality (87%)with spot application of spinosad for the whole cropping period. Thus, the descending order of performance of modules was Module I>Module II > Module III >Module IV > Module V>Module VI. Our findings are similar to the of Birah *et al.* (2015) who found that the IPM moduleconsisting of the installation of cue-lure baited traps was most effective for managing fruit flies (*B.cucurbitae*) in cultivated cucurbits. For each module, an increase in fruit yield over control plots was worked out based on which the monetary value of the additional quantity of summer squash for each module was estimated at the market rate of Rs. 10,000/ton for the year 2018. The results revealed that the treatments were having significant positive differences with control and among each other in the average yield which resulted in the highest cost-benefit ratio obtained in the case of Module I (i.e., 1:3.96). The least C:B ratio was in the module V (i.e.,1:1.22) (Table 2).

Table 2 Economics of different IPM modules for management of fruity fly in summer squash

Treatment	Average yield(t/ha)	Increase over control (t)	Value of additional yield (Rs/ha)	Cost of treatment (Rs/ha)	Net profit (Rs)	Benefit-cost ratio
Module I	35.00[a]	27.00	270,000.00	54,450.00	215,550.00	1:3.96
Module II	32.00[b]	24.00	240,000.00	50,732.00	189,268.00	1:3.73
Module III	26.00[c]	18.00	180,000.00	42,500.00	154,345.00	1:3.63
Module IV (PoP)	22.00[d]	14.00	140,000.00	40,000.00	100,000.00	1:2.5

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Treatment	Average yield(t/ha)	Increase over control (t)	Value of additional yield (Rs/ha)	Cost of treatment (Rs/ha)	Net profit (Rs)	Benefit-cost ratio
Module V (Farmers practice)	16.00^{e}	8.00	80,000.00	36,000.00	44,000.00	1:1.22
Module VI (Control)	8.00^{f}	_	_	_	_	_
S.Em±	0.494	_	_	_	_	_
C.D at 5%	1.504	_	_	_	_	_

In a column means followed by different alphabets (a,b,c,d,e and f) are significantly different from each other by Tukey's HSD (0.05).

The cost of summer squash in 2018 was Rs. 10,000/ tonnes.

Labour charges @ Rs. 300/labour/day

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3.11 Biology of Dried Fruit Beetle *Carpophilus hemipterus* (L.) on Peanut and Its Preference for Various Processed Nuts

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Keywords: *Carpophilus* spp.; Edible nuts; Storage product insects

1. Introduction

Among the common insect pests observed in nut processing factories, *C. hemipterus* (L.) is the most important with its cosmopolitan distribution. As the infested nuts can be difficult to identify and reject during processing and sorting, the beetles pose a significant risk to export markets. They are classified as secondary pests; however, their presence indicates damp and moldy conditions. Louw *et al*. (2009) documented that the dried fruit beetle bred prolifically in fermenting fruits, with the adults sheltering under the decaying, moist cladodes that have dropped from the plant. Rain triggered hull rot, *Carpophilus* beetle trap catches, and nut damage in almonds with higher damage levels in wetter areas of Australia is of common occurrence (Hossain, 2018). Thus, moisture and humidity are very important for the development of dried fruit beetles. Andhra Pradesh is located in the coastal region of India and there are several industries involved in the processing of various nuts. Understanding the biology and preferences of this particular pest is essential to taking necessary preventive measures.

2. Materials and methods

Detailed biology and duration of different stages of the insect were studied on peanuts. The preference of *C. hemipterus* for various processed nuts, namely, peanuts (*Arachis hypogea*), cashew nuts (*Anacardium occidentale*), pistachios (*Pistacia vera*), almonds (*Prunus dulcis*), and walnuts (*Juglans*) was assessed under free-choice conditions during 2021 and 2022 at Post Harvest Technology Centre, Bapatla, Andhra Pradesh, India. All five types of nuts (20 g each) were taken in separate paper plates and arranged in a circle in a steel container (30 cm diameter and 10 cm depth) having a lid. A mixed population of *C. hemipterus* adults (a total of 24) was released in the center so that each insect can move into the nuts according to its preference. There were six replications in a completely randomized design. The number of insects moved into each type of nuts was recorded five days after the release of insects (DAR). Subsequent progeny adult emergence from each nut species was recorded at 40 and 80 DAR and the total number of adults was worked out.

3. Results and discussion

During winter, the mean egg period of *C. hemipterus* was 5.25 days ranging from 4 to 6 days. The mean larval period was 19.3 days and the mean pupal period was 9.05 days. During summer, the mean period of the egg stage was 4.93 days and the mean larval period was 29.93 days, followed by the pupal stage that lasted for 8.7 days. The adults that emerged during the winter months survived for more than 120 days, whereas those that emerged during summer lived only for about one month. Similarly, an extension in larval duration for about 10 days during the dry period also indicated that this pest prefers high humidity. Pistachios and cashew nuts attracted significantly more numbers (9.33 and 8.67, respectively) of dried fruit beetle adults, followed by walnuts (4.50), whereas peanuts and almonds received the minimum numbers (0.50 and 0.67, respectively). Among the nuts offered to dried fruit beetle, pistachios and cashews were highly preferred producing a mean total progeny adult population of 125.0 and 114.83, respectively, followed by walnuts (24.67). Almonds were the least preferred (1.83 adults) as they were hard and with intact testa (Table 1). Thus, the order of preference of *C. hemipterus* to the processed nuts tested was pistachios > cashew nuts > walnuts > peanuts > almonds.

As *C. hemipterus* is a pest of quarantine importance, this information may be of great use in curtailing the pest through necessary preventive measures in storage and processing units.

Table 1 Preference and progeny development of *C. hemipterus* on different processed nuts

Tr.	Nuts	Insects moved into (No.)		Progeny adult emergence (No.)	
		At 5 DAR	**At 40 DAR**	**At 5 DAR**	**At 40 DAR**
T_1	Peanuts	0.67 (1.05)^{c}	1.50(1.28)^{d}	3.33(1.95)^{d}	4.83(2.31)^{c}
T_2	Cashewnuts	8.67(3.0)^{a}	17.83(4.27)^{b}	97.0(9.85)^{a}	114.83 (10.72)^{a}
T_3	Pistachios	9.33(3.12)^{a}	40.83(6.42)^{a}	84.17(9.19)^{b}	125.0(11.19)^{a}
T_4	Almonds	0.50(0.97)^{c}	0.83(1.12)^{d}	1.0(1.18)^{e}	1.83(1.42)^{d}
T_5	Walnuts	4.50(2.19)^{b}	5.0(2.32)^{c}	19.67(4.47)^{c}	24.67(5.01)^{b}
	SEm±	**0.21**	**0.15**	**0.32**	**0.28**
	CD (p = 0.05)	**0.43**	**0.33**	**0.65**	**0.58**

Note: The values in parentheses are square root transformed values; Tr, treatment; DAR, days after insect release. In each column, values with similar letters do not vary significantly at $p = 0.05$. The terms having different same alphabets as superscripts are statistically at par and with different alphabets are significantly different from each other.

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3.12 Study of Seed Quality of Rice Under Different Storage Environments

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Keywords: Germination; Rice; Seed quality; Seed vigor; Storage condition; Viability

1. Introduction

Good quality of seeds is one of the important means to increase productivity. The seed quality largely depends on the genotypes and storage conditions (Patil and Shekhargouda, 2007). Storage of seeds till the next sowing season is essential for crop production and is one of the most critical postharvest handling systems. Healthy seeds mean healthy seedlings that finally lead to better production. Seed vigor and germination ability directly affect yield and seed quality also affects seedling emergence. Proper storage conditions can bring about considerable improvement in the national economy by controlling the losses of the stored food grains. The knowledge of seed storability is essential to avoid huge financial losses and to carry over the seed stock for the use in next season. The research work was carried out to evaluate the impact of four seed storage container conditions on the seed quality of two rice varieties used by farmers in Bangladesh.

2. Materials and methods

An experiment was carried out to study the effect of a different storage container on the quality of rice seeds. Seeds of two *aman* rice varieties BR22 and BRRI dhan49 were collected from the farmers' field at the time of harvesting and were stored in gunny bag, plastic bag, airtight plastic drum, and semi airtight metal drum for six months and different seed quality attributes such as seed moisture%, 1000-seed weight, viability, germination%, seedling length, seedling dry weight, and seed germination index were evaluated. After proper drying, 20 kg seed of each variety was preserved in four types of storage containers following a completely randomized design (CRD) with four replications. All the sprouted or germinated seeds were counted for the viability test. Counting of the number of normal seedlings was done for the germination test. The vigor test of stored seeds was done by using indirect methods such as individual seedling length measurement, individual seedling dry weight measurement, and calculation of germination index (GI). All the data were analyzed for variance (ANOVA) by using computer operated statistical package MSTAT-C. The significance of differences between pairs of treatment means was evaluated by the least significance difference (LSD) test at a 5% level of probability.

3. Results and discussion

Seeds stored in plastic drum containers retained higher seed viability (92.87%) than in metal drums (89.75%), plastic bags (83.62%), and gunny bags (78.37%). The highest germination was obtained from the seeds stored in an airtight plastic drum (90.50%) and the lowest germination was obtained from seeds stored in a gunny bag (69.25%). The highest germination index (23.68) that represents the seed vigor was obtained from seeds stored in a plastic drum and the lowest vigor index was obtained from seeds stored in a gunny bag (18.55) at 6 months of storage. The seed quality of BRRI dhan49 was superior compared to the BR22 variety irrespective of storage conditions. Viability percentage, germination percentage, seedling length, seedling dry weight, and germination index significantly varied in BR22 and BRRI dhan49 seeds due to interaction with storage devices. The interaction effect of different storage containers and varieties showed statistically significant variation in terms of germination percentage of rice seeds at six months after storage. It may be concluded that airtight plastic drum storage container is superior to store a small amount of rice seeds for the next season's growing purpose in relation to the quality of rice seeds (Table 1). The deterioration of seed quality under different storage structures was observed due to storage conditions such as variation of seed moisture content, ambient relative humidity, and temperature of storage environment in different containers. The storage structure must protect the paddy from extreme temperature, seed moisture, and insect and microbial attacks. Moisture-proof containers are most suitable for seed storage (Chowdhury *et al*., 1990; Janmejai *et al*., 1999).

Table 1 Interaction effect of variety and storage conditions on seed viability, germination, seedling length, seedling dry weight, and germination index of rice

Treatments	Seed moisture (%)	1000-seed weight (g)	Viability (%)	Germination (%)	Seedling length (cm)	Seedling dry weight (mg)	Germination index
$C_1 \times V_1$	15.20b	23.82a	76.00g	66.66e	11.10g	9.30g	18.10g
$C_1 \times V_2$	15.47a	23.90a	79.66fg	70.66e	12.46g	10.06g	18.96fg
$C_2 \times V_1$	14.57d	23.22b	80.66f	72.76e	14.96ef	11.20ef	20.10ef
$C_2 \times V_2$	14.87c	23.75a	85.33c-e	74.33de	16.23e	12.06cd	20.90de
$C_3 \times V_1$	12.22e-g	20.07e	92.00a-c	89.66ab	21.40b	13.66ab	23.43ab
$C_3 \times V_2$	12.37ed	20.09e	94.33a	91.66a	23.93a	14.10a	24.10a
$C_4 \times V_1$	12.35ef	21.47cd	87.66a-d	81.33cd	18.11d	11.86c-e	21.96cd
$C_4 \times V_2$	12.47e	21.52c	92.33ab	87.66a-c	19.60c	12.83bc	22.40bc
CV (%)	9.0	8.9	3.8	4.8	3.8	4.0	2.7

Note: In a column, figures having a common letter(s) do not differ significantly as per DMRT. NS = not significant, 0.01 = significant at 1% level of probability, 0.05 = significant at 5% level of probability. **C_1** = gunny bag, **C_2** = plastic bag, **C_3** = plastic drum, and **C_4** = metallic drum; V_1 = BR22 and V_2 = BRRI dhan49.

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Moisture-proof containers are most suitable for seed storage. The present study suggests that rice seeds with appropriate initial moisture content should be stored in airtight plastic drum under ambient conditions which seems to be more promising for storage than other devices.

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3.13 Comparative Efficacy of Different Insecticides, Biopesticides, and Plant Extracts Against the Cutworms in Maize

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Keywords: Cutworms; Evaluation; Plant extracts

1. Introduction

Among the many species of insect pests that damage maize crops, cutworms (*Agrotis* spp.) (Lepidoptera: Noctuidae) are serious polyphagous and cosmopolitan pests of economic importance throughout the world. In Himachal Pradesh, cutworms are the most destructive insect pests of maize causing 23.92% damage to this crop. Here, maize is mainly grown in the *Kharif* season under rainfed conditions and is severely damaged by cutworms in the early stages of growth (up to four-leaf stage). The use of different insecticides and biopesticides for seed treatment, their application at the time of sowing, and spraying them immediately after the crop emergence effectively control the incidence of cutworms. This study was therefore undertaken to evaluate different insecticides and biopesticides against the cutworms.

2. Materials and methods

A field experiment was conducted at HAREC, Bajaura (1100 m amsl), Kullu, Himachal Pradesh during the *Kharif* season on maize crop (variety Girija) in a randomized block design with nine treatments each replicated thrice on June 4, 2018. Nine treatments including control were: T_1: Imidacloprid 600 FS @ 6 mL/kg of seed as seed treatment; T_2: Thiamethoxam 70 WS @ 5 g/kg of seed as seed treatment; T_3: Thiamethoxam 70 WS @ 7 g/kg of seed as seed treatment; T_4: Carbofuran 3G @ 30 kg/ha as a product in the soil at sowing in furrows; T_5: Quinalphos 25 EC @ 2.0 mL/L of water as a product at crop emergence; T_6: Imidacloprid 600 FS @ 6 mL/kg of seed as seed treatment followed by surface application of Chlorpyriphos 20 EC @ 2.0 mL/L of water as a product at crop emergence; T_7: Neem baan (azedarachtin 0.15% EC), which was applied at crop emergence as surface application @ 2.5 mL/L of water; and T_8: Sweet flag (*Acorus calamus*) 5% RE (root extract) @ 5 mL/L at crop emergence. The grain yield was recorded in each plot and analyzed by converting the values into q/ha. The average larval population/unit area (1×1 m^2) was also recorded at four-leaf stage of the crop. The data were analyzed statistically after appropriate transformations.

3. Results and discussion

Results revealed that pooled seedling mortality in different treatments varied from 0.00% to 9.91% as compared to control with 17.40% mortality (Table 1). Treatment consisting of seed treatment with imidacloprid 6 mL/kg followed by surface application of chlorpyriphos 2.0 ml/L (T_6) was the most effective treatment resulting in zero seedling mortality and thus recording a 100% reduction in the cutworm population over control. This was followed by a treatment consisting of seed treatment with thiomethoxam 70 WS (T_3) resulting in 1.89 seedling mortality and thus recording 89.13% reduction in the cutworm population over control. The data revealed that the highest grain yield of maize (57.26 q/ha) was recorded in the treatment T_6 consisting of seed treatment with imidacloprid (600 FS) followed by surface application of chlorpyriphos (20 EC), which was statistically at par with T_3 (55.05 q/ha), T_4, and T_5. The grain yield in different treatments varied between 43.53 and 57.26 q/ha. Treatment T_6 recorded the highest percent increase (54.04%) over the control with 35.09% avoidable losses, followed by T_3 which recorded a 48.10% increase over the control with 32.48% avoidable losses. The increased efficacy resulting in higher productivity in T_6, which consisted of two chemicals, namely, imidacloprid used as a seed treatment and chlorpyriphos as surface application, might be due to their combining and cumulative action against the cutworms which lasted for a prolonged period as compared to other treatments. The observations regarding the higher and better efficacy of the two chemicals by their combined use are in conformity with those of Zaki and Andrabi (1999). The data on the economics of different treatments used for the control of cutworms revealed that the benefit:cost ratio varied from 16.4 to 38.7. It was lowest in the case of seed treatment with imidacloprid followed by foliar application of chlorpyriphos (T_6) and highest in the case of seed treatment with imidacloprid (T_1) with the net monetary returns of Rs. 70,788/ha.

Table 1: Evaluation of different insecticides, biopesticides, and plant extracts against the cutworms in Kharif maize

Treatments	Seedling mortality (%)	Percent reduction over control	Yield (q/ha)	Percent increase over control	Avoidable losses
T_1	3.97 (2.24)	77.18	48.41	30.24	23.21
T_2	4.20 (2.28)	75.86	48.32	30.00	23.07
T_3	1.89 (1.70)	89.13	55.05	48.10	32.48
T_4	1.96 (1.72)	88.73	54.94	47.80	32.34
T_5	2.15 (1.78)	87.64	54.36	46.25	31.62
T_6	0.00 (1.00)	100.00	57.26	54.04	35.09
T_7	8.20 (3.03)	52.87	44.75	20.40	16.94
T_8	9.91 (3.30)	43.04	43.53	17.11	14.61
T_9 (Control)	17.40 (4.29)		37.17		
CD (p = 0.05)	0.18		4.17		

Note: The figures in parentheses are square root transformations.

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3.14 How We Successfully Managed the White Grub Menace in Himalayan Regions of Uttarakhand, India

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Keywords: Kharif, Pest management; Scarabaeid beetles

1. Introduction

The majorities of the beetles belonging to the family Scarabaeidae are pleurostict (phytophagous) and commonly known as scarabs, whereas their larvae are known as white grubs and are rhizophagous. Uttarakhand Himalayas, India constitutes the vast diversity of scarabaeid beetles with more than 100 species reported to infect agriculture fields, horticulture crops, and forest trees in the state (Chandra *et al*., 2012; Chatterjee, 2010). Among the different agro-ecological regions of India, the Northwestern (NW) Himalayan region comprising the states of Uttarakhand (UK), Himachal Pradesh (HP), and Jammu Kashmir (J&K) has been identified as a hot spot for white grub diversity. The damage caused by the grubs under rainfed conditions, which account for about 80% of the cultivated land in Uttarakhand and Himachal Pradesh and 59% in J&K, may vary on an average from 10% to 30% but sometimes complete crop failure is also observed. In NW Himalaya, cereals, millets, pulses, oilseeds, and vegetables are cultivated in an area of 1.32 million hectares with an estimated production of 3.44 million tons under rainfed conditions during the *Kharif* season. The damage caused by the white grubs under such a situation even at the rate of 10% amounts to the loss of 0.34 million tons, which consequently inflicts an estimated economic loss of Rs 1.8 billion annually (Sushil *et al*., 2008). Considering the huge economic losses caused by these white grubs, wide area pest management strategies for successful management of both white grubs and their adult beetles were designed and were proved to be culturally effective, economically feasible, and socially acceptable in Uttarakhand state of Indian Himalayas.

2. Materials and methods

A two-pronged strategy of pest management was designed for the management of both grubs and adults. The methodology included the use of a patented VL white grub beetle trap-1 (IN 290170) for attracting and trapping the adult beetles and a native virulent bacterial talc-based formulation of biocontrol agent *Bacillus cereus* WGPSB-2 for management of the first instar grubs through causing septicemia. Further, several other methods like monitoring the diet breadth or host range of 34 species of beetles were carried out to target and kill the adult stages before mating. The fourth and most successful strategy was to isolate a species-specific sex pheromone (1,2-, 1,3-, and 1,4-diethylbenzene) of a predominant negatively phototactic white grub species *Holotrichia seticollis.* All these methodologies were practiced on a community basis in six villages of Uttarakhand state and this wide area pest management strategy resulted in a rapid decline in pest population density over a period of 6 years.

3. Results and discussion

In the two-pronged strategy of white grub management, the installation of light traps in 15 locations of Uttarakhand (including low, mid, and high hills) resulted in a drastic population reduction over a period of 11 years (2011–2021), that is, 3782 beetles/trap/year in 2011, and by the year 2021 the number of beetles declined to 294 beetles/trap/year (Table 1). Moreover, the field application of *B. cereus* WGPSB-2 bio-fortified manure during the months of June and July for 11 consecutive years resulted in a drastic decline in the white grub population, wherein the average grub density in the year 2011 was 13.63/m^2 and this declined to 0.12/m^2 during 2021 (Figure 1). The diet breadth study of 34 scarab beetle species showed that most of the beetles preferred five major host plants (*Carya illinoinensis*, *Lagerstroemia indica*, *Ligustrum nepalensis*, *Rosa indica*, and *Zinnia elegans*) for feeding and mating. This information on diet breadth can be utilized for developing an eco-friendly pest management strategy against scarabaeid beetles in the Indian Himalayas. Additionally, to our surprise, we noticed that the predominant white grub species *H. seticollis* was negatively phototactic and it did not get attracted to light trap, and thus its management was very cumbersome. So, the reproductive behavior and mating cycle of *H. seticollis were studied and a* natural pheromone extracted through a handheld headspace sampling apparatus for *in situ* volatile collection (IN 373714) was identified as 1,2-, 1,3-, and 1,4-diethylbenzene through gas chromatography mass spectrometry (GC-MS). The commercially available synthetic analog methoxybenzene (anisole) was used for attracting and trapping the adult males of *H. seticollis. This resulted in a decline in the number of mating pairs on host trees (28.33 in the year 2019 to 24.33 in the year 2021) and an increase in the number of unmated females per unit area (26 in 2019 to 92 in 2021). Therefore, continuous use of* pheromone traps can lead to a significant increase in the number of unmated females and a decline in the number of mated females per unit area, which in turn reduces egg laying and thus leads to population reduction over the years.

Table 1 Population decline in white grub beetles over a period of 11 years in six locations of Uttarakhand, India

	Average number of beetles trapped per trap per year										
Altitudinal regime	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Low hills (<1200 m)	4427	4319	3978	3474	3247	3397	2415	1841	1120	759	421
Mid-hills (1200–1800 m)	3796	3894	3347	3234	3033	2974	1610	967	541	324	265
High hills (>1800 m)	2961	2918	1987	2411	2144	1967	1214	579	378	243	196
Average number of beetles/ trap/year	3728 ±424	3710± 414	3104± 587	3040± 321	2808± 337	2779± 424	1746± 353	1129± 373	680± 225	442± 160	294± 66

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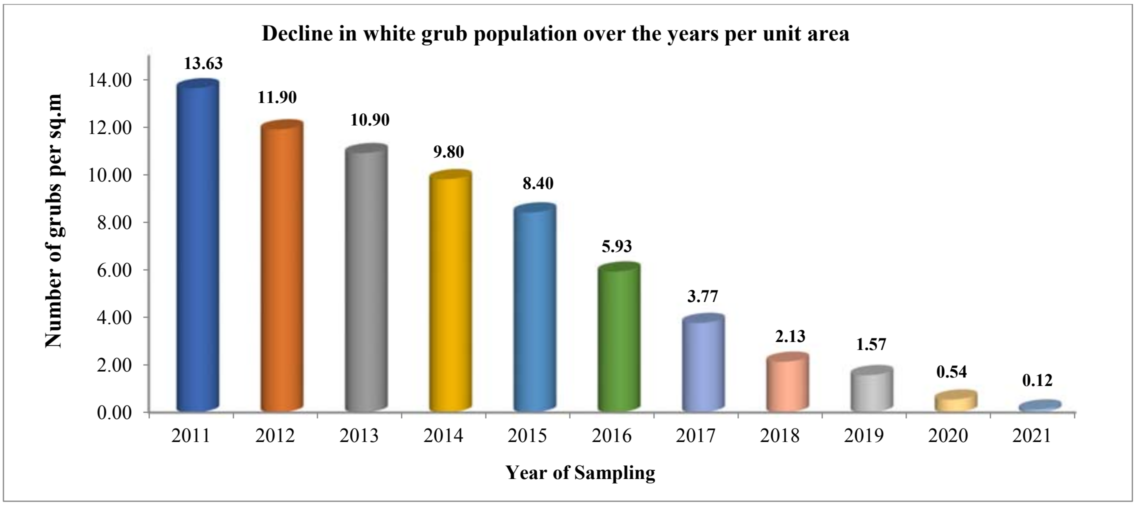

Figure 1 Decline in population of white grubs after field application of *B. cereus* WGPSB-2 bio-fortified manure.

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3.15 Integrated Management of *Callosobruchus maculatus* (Fab.) in Mungbean Stored as Seed

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Keywords: *C. maculatus*; Deltamethrin; Dharek kernel powder; Moong seeds; Neem oil; Storage

1. Introduction

Mungbean is an important pulse crop grown worldwide and it caters to the needs of the vegetarian population. The production of this crop has increased over the years, but due to postharvest losses, India relies on other countries for meeting its domestic need. In pulses, bruchids cause quantitative and qualitative losses to the tune of more than 85% during a storage duration of 6 months. Farmers generally rely on chemical measures for their management that leads to various problems, such as resistance development, pest resurgence, and residue problem along with environmental degradation. Thus, a move to search for an alternative using plant materials to control *C. maculatus* in stored mungbean was planned and executed.

2. Materials and methods

Laboratory studies were conducted in the Department of Processing and Food Engineering, Punjab Agricultural University (PAU), Ludhiana to store mungbean seeds by treating them with neem oil (0.50–1.50%) and dharek kernel powder (1.0–3.0%) and packing in jute bags treated with deltamethrin 2.8 EC (0.025–0.075%) in order to manage the attack of *C. maculatus*. Experiments were planned in the Box-Behnken design of response surface methodology. Mungbean seeds (5 kg) were mixed with selected treatment combinations for each bag and compared with a zerofly bag, existing Punjab Agricultural University (PAU) recommendation (cover the stored pulses in bulk with a 7 cm layer of sand) along with untreated control (jute bag). Twenty pairs of freshly emerged adults of *C. maculatus* were released into it. These bags were stored for 6 months to observe seed damage (%), weight loss (%), color change, moisture content (%), protein content (%), and germination (%) at an interval of 2, 4, and 6 months in disposable sets.

3. Results and discussion

Negligible seed damage (0.0–0.2%) and weight loss (0.0–0.13%) were observed in all the experimental combinations irrespective of the storage period, which corroborates with the study conducted by Sharma *et al*. (2019). Seed damage (0.4–1.6%) and weight loss (0.26–0.38%) were observed in zerofly bag stored seeds and no seed damage was found in PAU recommended practice during storage periods. Further, non-significant effect of different practices was observed on color change of mungbean seeds. Protein content ranged from 26.35% to 27.31% during different storage periods in various practices. Moisture content ranged from 10.10% to 10.80% irrespective of the experimental combinations used, 10.30–10.50% in zerofly, and 9.80–10.40% in PAU practice in 2-–6 months of seed storage, which is the safe limit. Seed germination varied from 73.33% to 89.67% irrespective of the experimental combinations in 2–6 months and conformed to the report by Kadam *et al*. (2013), where neem oil @ 5 mL/kg seed inhibits the seed germination up to 80.33% at 9 months of storage. Germination of mungbean seeds stored for 2, 4, and 6 months was found to be 91.0%, 86.0%, and 82.0% in zerofly bags, 95.0%, 94.0%, and 92.0% in PAU practice, and 78.50%, 63.0%, and 54.0% in control samples, respectively. All the treatments were superior to control. Numerical optimization showed that the mungbean seeds when treated with neem oil (0.55%) and dharek kernel powder (2.21%) and packed in jute bags treated with deltamethrin (0.055%) may be stored for 2.39 months and have the desirability of 0.975 with optimum color change (2.14), optimum moisture content (10.15%), maximum germination (89.67%), and maximum protein content (26.88%). Hence, it is concluded that with an optimized process mungbean seeds can be stored for approximately 2.5 months, while it can be stored in zerofly bags for 4 months and in PAU practice for 6 months with acceptable quality attributes.

Table 1 Optimum values of process parameters and responses for moong stored as seeds

Process parameters	Target	Experimental range		Optimum values	Desirability
		Minimum	Maximum		
Neem oil (%)	Range	0.5	1.5	0.55	0.975
Dharek kernel powder (%)	Range	1.0	3.0	2.21	
Deltamethrin (%)	Range	0.025	0.075	0.055	
Storage period (months)	Range	2	6	2.39	
Responses					
Color change	Minimize	2.14	3.89	2.14	
Moisture content (%)	Minimize	10.10	10.8	10.15	
Germination (%)	Maximize	73.33	89.67	89.67	
Protein content (%)	Range	21.11	26.88	26.88	

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3.16 Lethal Effects of Low Temperatures on *Tribolium castaneum* (Herbst) in Milled Products

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Keywords: Lethal effect; Milled products; Stored grain insect; Temperature

1. Introduction

Processed products are commonly used at the household level and attacked by secondary insects mainly *T. castaneum*. Owing to the hazardous effect of chemicals on human health, they are not advised to be used at the household level. There are various non-chemical options available such as irradiation techniques, microwave heating, controlled atmospheric, and low-temperature storage. These have no residue issues; hence, they are gaining more interest. Storage of the commodities at a low temperature can be effective, as it acts as an abiotic stressor for insects. Cold storage was one of the first methods used to control quarantine pests in traded commodities (Armstron, 1994). Among all these techniques, manipulation of temperature, that is, low-temperature storage, is gaining importance as it is cheaper and easily accessible than other methods like irradiation. Moreover, low temperature is a safe alternative as it will not affect the nutritional properties of the milled products.

2. Materials and methods

Laboratory studies were conducted in the Department of Processing and Food Engineering, Punjab Agricultural University (PAU), Ludhiana. The effect of low temperatures (5°C and 10°C) was tested against *T. castaneum* in sooji (semolina), besan (chickpea flour), makki atta (corn flour), and maida (white flour). A 100 g sample of each milled product was taken in plastic containers of 250 mL capacity. Ten mixed populations of test insects were released and replicated thrice. The data were analyzed by using a complete randomized design. Different sets of containers filled with samples of milled products containing a known population of test insects were later exposed to the above-mentioned temperature and compared with control (ambient temperature: 42±2°C and relative humidity: 50±5%). Observations on insect mortality were recorded after 7, 14, 21, 28, 35, and 42 days of interval.

3. Results and discussion

Complete mortality of *T. castaneum* in all milled samples was observed at 5°C exposed for 7, 14, 21, 28, 35, and 42 days. While these milled samples when kept at 10°C, there was 33.33–43.33% and 66.67–76.67% mortality of *T. castaneum* observed after 7 and 14 days of exposure, respectively. There was a significant difference in mortality of *T. castaneum* at 10°C when exposed for 7 and 14 days compared to other time intervals in all milled samples. The mortality of *T. castaneum* in all milled samples differed non-significantly at 10°C exposed for 21, 28, 35, and 42 days. The present study corroborates with the study of Nagel and Shepard (1934), where complete mortality of all stages of *T. confusum* at 7°C, if exposed for 25 days, was observed, but if the temperature was lowered –6°C, only 24 h of exposure was required. All the treated samples showed better results over control at different time intervals studied. Hence, low-temperature storage can be used as a substantial and easily accessible method for storing the milled products for a longer duration of time with the least effect on quality parameters.

Table 1 Lethal effect of low temperatures on *T. castaneum*

Exposure time	Mortality of *T. castaneum* (%)							
	5°C				10°C			
	Sooji	Besan	Makki atta	Maida	Sooji	Besan	Makki atta	Maida
7 days	100.00	100.00	100.00	100.00	33.33 (35.20)	40.00 (39.13)	40.00 (39.13)	43.33 (42.98)
14 days	100.00	100.00	100.00	100.00	66.67 (54.76)	73.33 (58.98)	73.33 (58.98)	76.67 (61.19)
21 days	100.00	100.00	100.00	100.00	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
28 days	100.00	100.00	100.00	100.00	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
35 days	100.00	100.00	100.00	100.00	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
42 days	100.00	100.00	100.00	100.00	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
C.D. (p = 0.05)	NS	NS	NS	NS	(3.68)	(5.16)	(5.16)	(7.15)

Note: Figures in parentheses are arc signed transformed values.

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3.17 Bioecology of Lepidopteran Pests and Natural Enemies in Rice Ecosystem of Balaghat District

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Keywords: Bioecology; Leaf folder; Seasonal activity; Species diversity; Stem borer

1. Introduction

Rice (*Oryza sativa*) is one of the most important cereal crops which provides food for nearly half the population at the global level (FAO, 2004). In India, about 100 insects have been reported as pests of rice, and 20 of these are accepted to be key pests causing more than 30% yield loss from germination to harvest of the crop (Atwal and Dhaliwal, 2005). More than 10 species of insect pests have been reported to cause severe damage to the rice crop in Madhya Pradesh, of which stem borers (*Scirpophaga incertulas,* Walker; *Chilo suppressalis,* Walker; and *Sesamia inferens*, Walker) and leaf folders (*Cnaphalocrocis medinalis*, Guenee and *Marasmia patnalis*, Bradley) are of economic importance. Together they damage rice plants at all the stages of crop growth and are the key factors responsible for poor rice yield. In the Chhattisgarh plain agro-climatic region of Madhya Pradesh, in particular Balaghat district, the stem borer is active from June to October and hibernates from November to March as a full-grown larva in the rice stubbles. In view of the above background, an attempt has been made to study bioecology of stem borer and leaf folder with natural enemies in rice ecosystem of Balaghat district.

2. Materials and methods

During the *Kharif* seasons of 2019 and 2020, the survey was conducted in two blocks of the Balaghat district, that is, Lalburra and Waraseoni. A total of five farmers' fields were selected from each village and a total of five villages were selected from each of the Lalburra and Waraseoni blocks. A total of 1250 samples were collected from selected blocks at 15 days intervals from nursery to harvest. A standard procedure was followed to record the observations on the percent incidence of stem borers and leaf folders of paddy as per Bentur (2012).

Species diversity: The total 50 adults of each of stem borers and leaf folders were collected from different locations. To determine the abundance of stem borer and leaf folder moths by sweep net and light traps sampling was done from different locations.

Natural enemies: The population counts of the natural enemies (NEs) were made simultaneously in the same locations in which the insect pest population was recorded. A total of 20 sweeps of collection net were made on five spots from each field. The observations were recorded at 30, 45, 60, 75, and 90 days after transplanting. The common predators such as wasps, spiders, mirids, dragonflies, and grasshoppers were counted on each spot.

3. Results and discussion

Based on the observations, it is concluded that the highest infestation of stem borer was observed in Mehandiwada village of Waraseoni and the lowest was recorded in Belgoan village of Lallburra (Table 1). The maximum percent damaged leaves were recorded in Bakoda village of Lallburra, and the minimum percent damaged leaves were recorded in Savngi village of Waraseoni block. The five natural enemies (Hymenoptera wasp, meadow grasshopper, dragonfly and damselfly, hemipteran bugs, and spider) were observed at different stages of crop growth. The maximum activities of natural enemies were recorded at the vegetative (60 DAT) and panicle stages (75 DAT) of the rice crop (Table 2). Based on adult trap catches, *S. incertulas* and *C. medinalis* were the predominant species of stem borers and leaf folders in the rice ecosystem of Balaghat district. The peak activities of stem borers and leaf folders were recorded at the tillering stage in the 4th week of August and the panicle stage during the 3rd week of September.

Table 1 Seasonal incidence of stem borer and leaf folder at Balaghat

Block	Village	Egg mass/hill*	DH (%)	WEH (%)	DL (%)
Lalburra	Ganeshpur	0.101	5.56	5.56	4.89
	Bakoda	0.062	5.17	4.97	5.46
	Belgaon	0.034	3.52	2.38	4.82
	Sihora	0.038	4.58	3.69	4.50
	Mohgaon	0.060	4.30	4.27	5.17
	Mean	**0.059**	4.63	4.17	4.97
Waraseoni	Kope	0.035	4.88	4.64	4.55
	Kayadi	0.037	4.43	4.07	4.82
	Mehndiwada	0.086	5.96	6.48	4.77
	Savngi	0.022	3.50	2.86	4.39
	Newargaon	0.078	5.42	5.73	5.15
	Mean	**0.052**	4.84	4.76	4.76
Overall mean		**0.055**	4.73	4.47	4.85

*Average of three observations (15 days after sowing and 50 and 70 days after transplanting. DH, dead heart; WEH, white earhead; DL, damaged leaves.

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Table 2 Abundance of natural enemies in rice ecosystem of Balaghat district

Natural enemy	Number of beneficial insects and spiders/20 complete sweeps						
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**Mean**
Hymenopteran wasps	3.61	7.00	10.54	14.55	11.20	6.72	**8.93**
Orthoptera grasshoppers	4.85	9.41	16.44	22.40	16.20	10.94	**13.37**
Odonata flies	8.97	11.60	16.42	13.25	6.83	2.49	**9.92**
Hemipteran bugs	1.91	5.19	9.17	12.10	8.03	4.07	**6.74**
Spiders	0.00	0.00	1.01	10.17	18.10	11.67	**6.82**
Mean	**3.87**	**6.64**	**10.71**	**13.91**	**12.65**	**7.18**	**9.16**

DAT, date of transplanting.

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3.18 Perception of the Litchi Growers Regarding Integrated Pest Management Practices in Punjab

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Keywords: Integrated Pest management; Litchi growers; Perception; Respondents; Socioeconomic

1. Introduction

Integrated pest management (IPM) is an effective and environment-friendly pest management system. The focus of IPM is to protect and encourage natural predators of pest insects (Naranjo *et al*., 2015). Integrated pest management, which is essentially a knowledge-based technology, involves the integration of different methods of disease and pest management. It is estimated that 50% of crop production in developing countries is lost due to insects (Christou and Capell, 2009). Insect pests have a negative impact on litchi farming, reducing not just production but also quality; for example, due to the infestation of the fruit borer *Argyroploce illepida*, the fruits emit a foul smell and reduce market price greatly. Insect pests have a negative impact on litchi farming, reducing not just production but also quality (Jha and Sarma, 2003).

2. Materials and methods

Perception was defined as the way in which the farmers understand or interpret various aspects of integrated pest management. The present study was conducted in the Gurdaspur and Pathankot districts of Punjab during the year 2021-22. Gurdaspur district has 11 blocks, namely, Batala, Dera Baba Nanak, Dhariwal, Dinanagar, Dorangla, Fatehgarh Churian, Gurdaspur, Kahnuwan, Kalanaur, Quadian, and Shri Hargobindpur, and Pathankot district is divided into six developmental blocks, namely, Pathankot, Sujanpur, Dharkalan, Gharota, Narot Jaimal Singh, and Bamial. Out of these blocks, two were selected from each district purposively having a maximum number of litchi growers and from each selected block, 25 respondents were selected randomly from the procured list of litchi growers from the horticulture department to make a sample size of 100 respondents. The interview schedule was prepared for the collection of the data. The perception of the farmers was measured on a three-point continuum, that is, Agree, Neutral, and Disagree, and 3 score was given to Agree, 2 to Neutral, and 1 to Disagree. Pearson's correlation coefficient was used to analyze the relationship between the dependent variable (i.e., income from litchi cultivation) and independent variables (i.e., socioeconomic variables).

3. Results and discussion

This study will contribute twofold: first, the study provides a comprehensive and integrated systematic analysis of socioeconomic factors of the litchi growers of Punjab. Second, the study adds to the relatively limited literature on litchi growers' perception of IPM technologies. After analyzing their perception, some lectures, camps, or training programmes for the litchi growers can be designed.

The data presented in Table 1 reveals that the majority of respondents (i.e., 65%) agreed that IPM is more effective than other practices of litchi growing. They believed that pesticides are more effective than any other practice. Only 24% of the respondents have no idea that IPM is better than synthetic pesticides. Respondents were unaware of the benefits of the IPM due to lack of proper knowledge and awareness and lack of training facilities and extension contacts. The results are in line with Blake *et al*. (2006).

With regard to the perception of the respondents towards plant protection measures, the results reveal that only 23% of the respondents agreed about IPM is a more effective management practice than other synthetic pesticides. The majority of the respondents (i.e., 55%) gave a neutral response about IPM practice and 22% had no idea about IPM practices for the control of insect- pests in litchi. Owing to the lack of proper knowledge and awareness, the respondents were unaware of the benefits of IPM.

Table 1 Perception of production practices of IPM and plant protection measures of the respondents

Parameter	Categories	Percent
Production practices of IPM	Low (11-12)	24.00
	Medium (12-13)	11.00
	High (13-14)	65.00
Plant protection measures	Low (16-17)	22.00
	Medium (18-19)	55.00
	High (20-21)	23.00

The relationship between the dependent variable income from litchi cultivation and independent socioeconomic variables is given in Table 2 which suggests that education and landholding have a significant and positive correlation at the 0.01 level.

Table 2 Relationship between socioeconomic variables and income from litchi cultivation

Socioeconomic variables	Correlation coefficient (*r* value)	*p* value
Age	0.061	0.545
Education	0.410**	0.000
Landholding	0.928**	0.000
Family size	0.067	0.511
Family type	0.069	0.492

**Correlation is significant at the 0.01 level (two-tailed).

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3.19 Evaluation of Different Cucumber Germplasm Against Cucumber Mosaic Virus in Jammu, India

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Keywords: Cucumber mosaic virus; Detection; DAS-ELISA; Management; Screening

1. Introduction

Cucumber (*Cucumis sativus* L.) is an important vegetable crop under the family Cucurbitaceae which is grown throughout the world, including India, for its edible fruits. Cucumber production is adversely affected by many biotic and abiotic factors. Among biotic factors, cucumber mosaic virus (CMV) belonging to the family Bromoviridae and genus *Cucumovirus* is one of the important plant viruses having a wide host range and causing up to 40–60% yield losses in susceptible varieties under favorable environmental conditions (Bananej and Vahdat, 2008). CMV is transmitted mainly by aphids (vector) and via sap/mechanical transmission. Identification of resistant germplasm is one of the important aspects of the management of viral diseases. Therefore, a good quality of research efforts has been directed toward screening accessible cucumber germplasm against CMV for the identification of resistant sources under field conditions in the Jammu region.

2. Materials and methods

The study was carried out at the experimental farm of the Division of Plant Pathology, SKUAST Jammu, main campus Chatha during the cropping season of 2019 and 2020. A total of 40 cucumber germplasm were collected from various sources and were evaluated against the cucumber mosaic virus in natural epiphytotic conditions. The trial was laid out in randomized block design (RBD) with three replications. Recommended cultural practices were followed except for insecticidal sprays to encourage the vector population for the natural spread of the disease. The data were recorded at 15 days interval on percent disease incidence and germplasm lines were divided into different categories (susceptible, moderately susceptible, moderately resistant, and resistant) according to the disease rating scale by Shah *et al*. (2011). The presence and absence of CMV were further confirmed serologically by using the DAS-ELISA (double antibody sandwich-enzyme-linked immunosorbent assay) method (Clark and Adams, 1977).

3. Results and discussion

During the course of the study, it was observed that cucumber mosaic disease is one of the major constraints in cucumber production. The data from both the cropping season of 2019 and 2020 revealed that out of 40 germplasm, two germplasm, namely, Dasher II and Poinsett, were resistant, whereas six germplasm, namely, CS-13, CS-16, CS-51, CS-54, Fumiko-10, and Don-1, were found moderately resistant. Twenty-one germplasm, namely, CS-1, CS-15, CS-20, CS-33, CS-22, CS-48, CS-52, CS-61, CS-73, CS-103, CS-115, CS-149, CS-88, RK-180, Pusa Sanyog, Khira Hybrid-1, Khira-75, Cucumber-DASH, Mahy Sylvia, Prabhat, and Kirloskar, were found moderately susceptible while 11 germplasm, namely, CS-67, CS-70, CS-34, Cucumber green long, Vardan, Garima super, Malini, Nandini-732, Cucumber summer green, RK-40, and Local, with highest percent disease incidence were found susceptible (Table 1). On the basis of symptomatology, except for resistant germplasm all the cucumber germplasm showed characteristic symptoms such as uneven yellow and green patches on the leaves, mottling, and distortion of the leaves in the field condition. Final confirmation of the virus infection was done serologically through DAS-ELISA and the results revealed that all the infected samples collected showed a positive reaction with the CMV-specific antibody except Dasher II and Poinsett, which showed a negative response. Thus, these resistant lines from our study can be further utilized in programs to explore resistant genes to develop CMV-resistant cucumber cultivars and are suggested to be used as one of the management strategies to control the disease.

Table 1 Disease reaction of cucumber germplasm against cucumber mosaic disease under field conditions during 2019 and 2020

Reaction group	Percent disease incidence	No. of entries	Germplasm
Resistant	0–10%	2	Dasher II, Poinsett
Moderately resistant	>10–30 %	6	CS-13, CS-16, CS-51, CS-54, Fumiko-10, Don-1
Moderately susceptible	>30–50%	21	CS-1, CS-15, CS-20, CS-33, CS-22, CS-48, CS-52, CS-61, CS-73, CS-103, CS-115, CS-149, CS-88, RK-180, Pusa Sanyog, Khira Hybrid-1 (KH-1), Khira-75, Cucumber-Dash, Mahy Sylvia, Prabhat, Kirloskar
Susceptible	>50%	11	CS-67, CS-70, CS-34, Cucumber Green Long, Vardan, Garima Super, Malini, Nandini-732, Cucumber Summer Green, RK-40, Local

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3.20 Allelopathic Effect of Aqueous Root Extract of *Anthemis cotula* L. on Some Important Crops of Chenab Valley, Jammu and Kashmir, India

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1. Introduction

A. cotula L. (may weed/dog fennel) is an annual, highly invasive weed belonging to the family Asteraceae with ruderal habitat. It is native to the Mediterranean region and invaded almost all the continents of the globe. In Kashmir valley, it is also reported as one of the exotic invasive weeds. The genus *Anthemis* is having about 130 species and is commonly found in cereal crops, farmyards, overgrazed pastures, waste areas, and roadsides. Although various medicinal benefits are attributed to *A. cotula*, as per Aberer (2008) this plant is no longer in use (as a medicine) in the present scenario due to its both irritative and allelopathic potential. As per reports, this plant has a long history as a successful invader which invades other plant populations in its vicinity and suppresses their growth by a phenomenon known as allelopathy. Before 300 BC, Democritus noted that weeds can be controlled by using naturally occurring plants. The agricultural system needs to overcome the problems such as shortage of food, fodder, fuel, fiber, and so on. For this purpose, a detailed study on allelopathy is needed to identify the possible invasive species which hampers the productivity of the crops. Besides this, other plants with the allelopathic potential to weeds need to be identified so that those plants would be used to restrict the growth of these weeds and in turn the crop yield would be enhanced. In the present study, an attempt was made to study the effect of the aqueous root extract of *A. cotula* L. on the growth performance of four different economically important crops (*Zea mays*, *Oryza sativa*, *Brassica caulorapa*, and *Raphanus raphanistrum*) growing in the Chenab Valley of Jammu and Kashmir (Shahnawaz *et al*., 2017).

2. Materials and methods

In all the zones (north, south, east, and west) of Kishtwar city, a total of four localities were identified during the field visits. At each locality, about 200 young flowering plants of *A. cotula* were collected randomly and submitted for identification at CSIR, IIIM-Jammu. After shade drying, the roots were chopped, and the aqueous root extract of the *A. cotula* was prepared by following the protocol of Qasem (2016), and different concentrations (4%, 10%, and 25%) were prepared in dH_2O for germination assay.

After that seeds of the *Z. mays* (corn), *O. sativa* (rice), *B. caulorapa* (Kashmiri purple-knol), and *R. raphanistrum* (radish) were purchased from the local market of Kishtwar city. Seeds were sterilized with 0.1% $HgCl_2$ solution for 5 s and washed 3 to 4 times with distilled water. Twenty seeds were aseptically planted in the sterilized petri-plates (Borosil) with germination paper. A total of four sets were made for each plant, that is, Set-I for control, Set-II for 4%, Set-III for 10%, and Set-IV for 25% aqueous root extract.

The allelopathic potential of aqueous root extract of the *A. cotula* was assessed using the three key parameters, namely, 1) percent seed germination, 2) seed germination index, and 3) percent elongation inhibition rate.

3. Results and discussion

Owing to the increasing concentration of aqueous root extract, percent seed germination (%G) of *O. sativa* was found to be inhibited at an increased rate. The highest rate of seed germination (76.67±7.64%) in *O. sativa* was reported in control. Maximum %G (70.00±26.46%) was recorded at 4% and least %G (55.00±5.00%) was recorded at 10% concentration. In the case of *Z. mays and B. caulorapa* seeds, maximum %G of 96.30±6.42% and 58.33±10.41% was recorded as compared to control 92.59±6.42% and 60.00±17.32% at 10% concentration, respectively, whereas least percent germination was reported at 4% concentration. Seed germination of *R. raphanistrum* at 10% was documented as 88.33±12.58 compared to control 95.00 ±0.00.

With the increasing concentration of aqueous root extract of *A. cotula*, the germination index (GI) decreases in all the plant seeds except *R. raphanistrum*. In the case of *R. raphanistrum*, maximum GI (95.95±19.62) was achieved at a 10% concentration of root extract.

Contrary to GI, percent elongation inhibition rates (%EI) of all the tested seeds were found to be directly proportional to the concentration of the aqueous root extract of *A. cotula*. Among all the four types of seeds, the highest EI was recorded in *B. caulorapa* (50.63±14.13%) at 25% concentration and the least EI was documented in *Z. mays* (13.40±3.90%) at 4% concentration.

In the past, many people have tested the allelopathic potential of different parts of the *A. cotula* and reported its allelopathic potential. It was reported that the tissue extracts of *A. cotula* (root, leaf, and stem) showed significant inhibition of the growth of the Alfalfa and Italian rye grass. The development of weed management by using allelopathic plants is receiving national and international attention. The weeds have superior allelopathic activity over the other crops in their competition. It plays a major role in agricultural management such as weed and pest control. As the concentration of allelochemicals increases reduction in plant, growth is seen at the maximum threshold level. Allelopathic substances may reduce the use of weedicides and the deterioration rate of crops. In the study carried out, it can be concluded that this plant can possess both positive and negative allelopathic potential. But the negative allelopathic phenomenon was the most dominant. We recorded significant level inhibition in terms of germination index and percent elongation inhibition rate of all the tested crops at different concentrations of the aqueous root extract.

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3.21 Isolation and Characterization of Endophytic Bacteria of Pearl Millet [*Pennisetum glaucum* (l.) R. Br.]

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Keywords: ACC utilization; Endophytic bacteria; HCN production; Siderophore production

1. Introduction

Pearl millet [*P. glaucum* (L.) R. Br.] is the oldest cultivated crop of Asian and African countries. India is considered to be the secondary center of pearl millet diversity. Pearl millet is the most widely grown drought-tolerant warm-season coarse grain cereal grown on 26 million ha in the world. Pearl millet is one of the common millets that serve as a poor man's food. Pearl millet crop is prone to a number of diseases, which is a major constraint in production causing low yield and economic losses. Among the leaf spots, blast disease caused by *Magnaporthe grisea* was considered a minor problem in the past but now has emerged as a serious problem affecting both forage and grain production of pearl millet in India. Plant-associated bacteria colonize the rhizosphere (rhizobacteria), phyllosphere (epiphytes), and inside plant tissues (endophytes). The use of indigenous bacterial endophytes with biocontrol activity as an environment-friendly and ecologically efficient approach has been reported within the framework of integrated plant disease management (IDM). Bacterial endophytes are considered to have a beneficial effect on host plants, improving their growth by different mechanisms.

2. Materials and methods

Plant samples were collected from pearl millet grown at the Plant Pathology experimental area of CCS Haryana Agricultural University, Hisar of the *Kharif* 2021. The plants were uprooted and separated into the leaves, roots, and shoot systems. Plant parts were washed with running tap water and then surface sterilized in 75% (v/v) ethanol for 2 min, 2.6% (w/v) sodium hypochlorite solution for 5 min, and 75% (v/v) ethanol for 1 min. One gram of plant tissues was fully ground to homogenate in 10 mL sterilized distilled water in a mortar. After natural precipitation for 20 min, the supernatant was diluted and placed on NA plates and incubated at 28±2°C for 3 days. Bacteria appearing on the plates were considered to be endophytes. Every single colony was maintained at 4°C for further studies. Isolated bacterial colonies were evaluated for biocontrol activity under *in vitro* conditions:

1. Siderophore production (Meyer and Abdallah, 1978)
2. ACC utilization (Penrose and Glick, 2003)
3. HCN production (Alstrom and Burns, 1989)

3. Results and discussion

A total of 38 pearl millet bacterial endophytes (PMRBE1–PMRBE38) were retrieved from roots, stems, and leaves of pearl millet streaked on nutrient agar plates. All endophytic bacterial isolates were retrieved in the *Kharif* 2021 crop. All endophytic bacterial isolates were assessed for biocontrol activities. Siderophore production ability of all the 38 bacterial isolates was assessed by spotting on chrome azurol S agar plates and development of orange halo zone on CAS medium amended with ferric chloride after 5 days of incubation at 28±2ºC. Among 38 pearl millet bacterial endophytes, 11 isolates were positive for siderophore production, 12 were found positive for HCN production, and 30% of the bacterial endophytes showed good growth on ACC supplemented plates.

Table 1 List showing siderophore production by pearl millet bacterial endophytes

Isolate	Siderophore production	Isolate	Siderophore production	Isolate	Siderophore production
PMRBE1	-	PMRBE14	–	PMRBE27	–
PMRBE2	+	PMRBE15	–	PMRBE28	–
PMRBE3	–	PMRBE16	–	PMRBE29	+
PMRBE4	+	PMRBE17	–	PMRBE30	–
PMRBE5	–	PMRBE18	–	PMRBE31	–
PMRBE6	+	PMRBE19	+	PMRBE32	+
PMRBE7	–	PMRBE20	–	PMRBE33	–
PMRBE8	–	PMRBE21	+	PMRBE34	+
PMRBE9	+	PMRBE22	–	PMRBE35	–
PMRBE10	+	PMRBE23	+	PMRBE36	–
PMRBE11	–	PMRBE24	–	PMRBE37	–
PMRBE12	–	PMRBE25	–	PMRBE38	–
PMRBE13	–	PMRBE26	–		

+: Zone formation; –: No zone formation.

Sharma and Johri (2003) reported that the production of siderophores by endophytes is advantageous for plants, as it is one of the mechanisms to outcompete phytopathogens by inhibiting their growth within the plants.

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3.22 Seasonal Incidence of *Thrips tabaci* Lindeman on Rabi Onion in Jammu

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Keywords: *Allium cepa*; Correlation; Seasonal incidence; *T. tabaci*; Weather parameters

1. Introduction

Onion (*Allium cepa* L.), a biennial herbaceous crop (family Alliaceae), is one of the most widely farmed vegetables and condiment crops in most countries. Thrips (*T. tabaci* L.) have been identified as a prevalent and significant onion pest wherein both nymphs and the adults feed by puncturing the fragile leaves and sucking plant sap and thus cause significant crop damage, with leaf damage ranging from 40–60% and yield losses of 10–20% each year (Waiganjo *et al*., 2008). The incidence of insect pests is greatly influenced by weather parameters, crop growth stages, and natural enemies of the pest. As a result, understanding seasonal pest recurrence in conjunction with weather parameters has a significant impact on crop infestation. These strategies have been previously studied on onion crop, but climatic conditions have changed, and their effects on pests must be reassessed in order to determine the seasonal predominance of *T. tabaci* on onion. Thus, keeping in mind the significance of this pest on onion, the present experiment was carried out to study the seasonal occurrence of *T. tabaci* on onion.

2. Materials and methods

A field experiment was carried out at Entomology Research Farm, SKUAST-J during rabi 2020-21. The seedlings of onion variety 'NHRDF-Red' were transplanted in raised plots (10×10 m^2) spaced at 15×10 cm. All cultivation practices were carried out as per the package of practices recommended by SKUAST-J. Twenty plants were randomly selected and tagged and data were collected from the leaves. The weekly mean population of thrips was recorded and correlated with different weather parameters. The regression equation and correlation coefficient (*r*) were computed between weather factors and an average number of nymph and adult thrips per plant. A population model was thus developed in which meteorological factors were used as predictor variables to explain the population fluctuation of nymphs and adults of *T. tabaci*. The required meteorological data was procured from Section of Agrometeorology, SKUAST–J for the study.

3. Results and discussion

The data recorded on seasonal incidence of onion thrips (nymphs and adults) in rabi 2021-22 are presented in Table 1. The data revealed that the thrips population ranged from 2.4 to 72.8 nymphs per plant and 0.44–24.60 adults per plant. The commencement of nymphs and adults of thrips was recorded in the 10th standard week (2.4 nymphs per plant; 0.4 adults per plant) from where the thrips population increased and the peak population was recorded in 20th SW (72.8 nymphs per plant; 24.6 adults per plant). Thereafter, the thrips population decreased and reached to a minimum (42 nymphs per plant; 20 adults per plant) in 22th SW. These results are supported by Mukhtar and Mir (2022) who recorded the first incidence of nymphs and adults of onion thrips from the 9th standard meteorological week. The correlation matrix between the seasonal incidence of thrips and meteorological parameters demonstrated that the mean maximum and minimum temperature had a positive and highly significant effect on the thrips (nymphs and adults) population. Mean relative humidity (morning and evening) had a highly significant but negative influence on nymphs (r = –0.775*; r = –0.523) and adults (–0.853* and –0.565*) of *T. tabaci*. However, rainfall was negatively correlated with nymphs (r = 0.407) and adults (r = 0.601*) of *T. tabaci*. Weather factors had a 93% and 98% contribution to the buildup of nymph and adult thrips populations in regression research on the effect of abiotic factors on the population of thrips. These results are in conformity with Zereabruk (2017) who found that maximum and minimum temperatures and rainfall favored the thrips population and relative humidity had a negative effect on the thrips population.

Table 1 Seasonal incidence of *T. tabaci* (nymphs and adults per plant) during rabi 2020-21

Standard meterological weeks	Mean nymphal population (no.)	Mean adult population (no.)	Maximum (°C) temperature	Minimum (°C) temperature	Morning relative humidity (%)	Evening relative humidity (%)	Sunshine hour	Rainfall (mm)	Rainy day
10	2.4	0.4	28.6	11.7	80.1	39.3	5.2	0.0	0
11	6.8	1.6	27.1	12.3	86.1	50.7	3.2	3.6	0
12	12.8	3.0	26.7	13.4	80.4	47.7	5.3	15.2	1
13	17.8	7.2	31.0	13.7	72.9	34.7	8.0	0.0	0
14	16.4	8.4	30.8	12.0	62.0	27.3	6.4	1.6	0
15	26.6	13.2	33.7	14.3	56.9	20.7	7.5	1.6	0
16	33.0	14.0	28.9	15.5	63.0	41.7	3.3	11.0	1
17	41.6	17.0	35.6	15.3	59.3	20.0	10.6	8.0	1
18	47.8	19.2	36.7	20.9	52.0	29.1	6.2	2.0	0
19	59.2	22.0	34.3	19.5	65.6	36.6	5.6	27.0	2
20	72.8	24.6	35.9	19.7	54.7	26.4	8.5	2.8	1
21	54.6	23.4	36.4	18.3	47.6	23.6	8.3	20.2	1
22	42.0	20.0	36.9	23.0	57.3	33.6	6.6	32.6	2

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3.23 Impact of Integrated Pest Management Farmer Field School Programme on Pesticides Use in North India

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Keywords: Application pesticides; Evaluation of IPMFFS programme and FEIQ;Pesticide use

1. Introduction

In India, research on integrated pest management (IPM) was started in 1974-75 on two crops, that is, rice and cotton, under Operational Research Projects (ORP). IPM is the use of a combination of pest management practices by farmers that are biologically, environmentally, economically, socially, and culturally acceptable (Kenmore *et al.*, 1985). IPM practices are based on the optimization andnot the maximization of chemical pesticides (Singh *et al.*, 2013).The farmer field school (FFS) was originally developed by the Food and Agriculture Organization (FAO) in the 1980s in response to the negative side effects of the Green Revolution onSoutheastAsian rice production (Gallagher *et al*., 2009; Kenmore *et al*., 1995). The FFS is a widely used method in rural development seeking to educate farmers to adapt their agricultural decisions to diverse and variable field conditions (Pontius *et al*., 2002; FAO, 2016).The current issues of climate change and sustainable agricultural development have diverted the attention of scientists all over the world towardsthe development of technologies that are environmentally friendly and cost-effectivefor the farmer. Emden and Peakall (1996) stated that chemicals are still needed in IPM strategy, however,'just as a stiletto instead of a scythe'. To review/rationalize pesticide use, many IPM programmes are implemented in India. To assess the long-term impact of IPM programmes in reducing the pesticide use in rice, we conductedan evaluation study.

2. Materials and methods

An e*xpost facto* (with/without) research design was employed to conduct an impact evaluation.The subtropics of Jammu and Kashmir (J&K) and Punjab were selected for drawing the sample of the villages. Under the IPM farmer field school (FFS), the Central Integrated Pest Management Centres (CIPMCs) ofJammuandPunjabhave covered 71 villages (Jammu 35 and Punjab 36) representing under rice IPM programme. Out of these, 12 villages were selected by applying a random sampling technique from Jammu and Punjab. Besides, fivevillages were selected where no IPM-FFS programme has ever been implemented from Jammu and Punjab. From each IPM village,10 rice growing farmersunder IPMFFS were selectedrandomly. From 10 non-IPM villages, 10 rice growers were selected randomly. Thus, the total sample size was 340 rice farmers, 240 IPMFFSfarmers,and 100 non-IPM farmers.The impact evaluation indicators were active ingredient (a.i.) kg/ha, pesticide applications, and field environmental impact quotient (FEIQ).

3. Results and discussion

In Jammu, the average pesticide use (a.i.) by weight in IPM villages was 1.247 kg/ha and in the non-IPM villages, it was 1.287 kg/ha and there was a difference of 0.040 kg/ha. The average pesticide application was slightly higher in non-IPM villages of Jammu as compared to the IPM villages and the difference was statistically significant (t=2.83, p=0.005). In Punjab, the average pesticide use (a.i.) by weight in IPM villages was 1.935 kg/ha and in the non-IPM villages it was 2.013 kg/ha and there was a difference of 0.078 kg/ha.The average pesticide application was higher in non-IPM villages of Punjab as compared to the IPM villages and the difference between the IPM and non-IPM farmers was not significant (Table 1).

The field environmental impact quotient (FEIQ) was the highest in non-IPM villages of Punjab at 57.06/ha, followed by IPM villages of Punjab at 54.36/ha, non-IPM villages of Jammu at 27.47/ha, and IPM villages of Jammu at 24.85/ha (Table 1). The insecticides contributed 49% each, fungicides contributed 20% and 23%, and herbicides contributed 31% and 27%to the total FEIQ in the IPM and non-IPM villages of Punjab, respectively.In Jammu,the FEIQ was higher in non-IPM villages at 27.47/haas compared to the IPM villages at24.85/ha. The insecticides contributed 14% and 17%, fungicides contributed 3%and 11%, and herbicides contributed 83% and 72% to the total FEIQ in the IPM and non-IPM villages of Jammu, respectively.The IPM-FFS programmes have resulted ina reduction in pesticide use.The study shows that the IPM-FFS programme reduces pesticide load in the rice crop andto strengthen there should be re-enforcement in the training of farmers under IPM.

Table 1 Pesticide use (a.i.) by weight (kg/ha), pesticide application number, and FEIQ in rice crop in Jammu and Punjab

Particular	Jammu				Punjab			
	IPM	Non-IPM	Diff.	*t*value	IPM	Non-IPM	Diff.	*t*value
Pesticide use (a.i.) by weight kg/ha	1.247± 0.043	1.286± 0.074	–0.039	0.472 (0.637)	1.935± 0.056	2.013± 0.084	– 0.078	0.764 (0.446)
Pesticides applications	2.300± 0.129	3.060± 0.279	–0.760*	2.833 (0.005)	8.092± 0.247	8.690± 0.259	– 0.598	1.433 (0.154)
FEIQ	24.85	27.47	–2.62	–	54.36	57.06	–2.70	–

± Std mean error;*Significant at p<0.05. Figures in the parenthesis are $p$values.

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2.24 Varietal Preference and Seasonal Incidence of Sucking Insect Pests on Bt Cotton under Subtropical Climate

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Keywords: Cotton cultivars; Sucking pests; Weather parameter

1. Introduction

Cotton is the second most important *Kharif* crop grown in southwestern districts (Bathinda, Mansa, Fazilka, Shri Muktsar Sahib, Faridkot, Barnala, and Sangrur) of Punjab. It harbors a number of insect pests that cause a major loss to cotton growers. The crop is attacked by two categories of insect pests, namely, bollworms (American bollworm, spotted bollworm, and pink bollworm) and sucking insect pests (leafhopper, whitefly, thrips, aphid, and mealybug). After the introduction of Bt cotton in 2005 in Punjab, the incidence of bollworms drastically reduced but sucking insect pests such as whitefly, leafhopper, and thrips have increased over a period of time. Sucking pests has assumed the status of serious pest on cotton in the recent past and it appeared in the epidemic form in 2007 on mealybug and in 2015 on whitefly under Punjab conditions. Environmental factors like temperature, humidity, and rainfall influence the population densities and result in seasonal fluctuations that can have positive or negative effects on the population of most insect pests (Prasad and Logiswaran, 1997). Keeping in view the importance of the cotton crop and losses caused by the insect pests, the experiment was planned to study the seasonal population dynamics of insect pests on cotton.

2. Materials and methods

The study was conducted at the Entomological Research Farm, Department of Entomology, PAU, Ludhiana during *Kharif* 2021. Various cotton cultivars (Ankur Jassi, F 2228, RCH 926, RCH 776, Sarpass 7172, MRC 7365, NCS 9024, US 71, Super 924, PAU Bt 1, PAU Bt 2, and PAU Bt 3) were grown under unprotected conditions and the incidence of sucking insect pests was recorded at a weekly interval from 10 plants in agreement with standard meteorological weeks and subjected to correlation analysis to estimate the effects of these abiotic factors on population counts of these insect pests. All agronomic practices recommended by Punjab Agriculture University were followed to raise the crop.

3. Results and discussion

Among the cotton germplasm, NCS 9024 of cotton hybrid recorded a maximum population of leafhopper (4.16 per three leaves) as compared to other cotton cultivars. Similarly, the highest population of whitefly and thrips was recorded in RCH 926 cotton cultivar (2.23 and 3.28 per three leaves) as compared to other selected cotton cultivars, respectively. A significant difference was recorded among the selected cotton cultivars. F 2228 non-Bt cotton cultivar recorded the lowest population of leafhopper (2.05 per three leaves) and on the other side Ankur Jassi showed a minimum population of whitefly (1.23 per three leaves). The peak population of *A. bigutulla bigutulla* and *B. tabaci* was recorded during 28 and 29 SMW, respectively. Weather parameters also play a role significant role in increasing and decreasing the population under natural conditions. *A. bigutulla bigutulla* showed a positive correlation with maximum and minimum temperatures (r = 0.383, 0.919) but a negative correlation with relative humidity (r = –0.392). *B. tabaci* recorded a positive correlation with minimum temperature (r = 0.367), relative humidity (r = 0.164), and rainfall (r = 0.712). Shera *et al*. (2013) also corroborate our finding and reported that *A. biguttula bigutulla* showed a significant positive correlation with minimum temperature, evening relative humidity, and rainfall. Similarly, whitefly showed a positive correlation with maximum and minimum temperatures and relative humidity.

Table 1 Sucking insect pests on different cotton cultivars during 2021

Cotton cultivars	Sucking insect pests per three leaves		
	Leafhopper	Whitefly	Thrips
Anukar Jassi	2.49 (1.85)	1.23 (1.47)	2.06 (1.56)
F 2228	2.05 (1.73)	1.78 (1.65)	2.96 (1.72)
RCH 926	2.59 (1.88)	2.23(1.77)	3.28 (1.81)
RCH 776	3.15 (2.02)	1.90 (1.69)	2.90 (1.71
SP 7172	2.17 (1.76)	1.44 (1.55)	2.87 (1.69)
MRC 7365	2.41 (1.81)	2.05 (1.71)	2.70 (1.67)
NCS 9024	4.16 (2.25)	1.99 (1.71)	2.81 (1.71)
US 71	2.50 (1.85)	1.85 (1.67)	2.40 (1.62)
Super 924	2.95 (1.97)	1.59 (1.59)	2.59 (1.65)
PAU Bt 1	3.08 (1.96)	1.72 (1.64)	1.26 (1.39)
PAU Bt 2	2.55 (1.84)	1.70 (1.63)	2.98 (1.72)
PAU Bt 3	2.10 (1.73)	1.47 (1.56)	2.54 (1.65)
CD (p = 0.05)	**(0.14)**	**(0.12)**	**(0.21)**

Note: Figures in the parentheses are square root transformed values.

Table 2 Correlation coefficient of sucking insect pests on cotton with weather parameters

Correlation coefficient (r)	Max. temp (°C)	Min. temp (°C)	RH (%)	Rainfall (mm)
Leafhopper	0.383	0.919	–0.392	0.07
Whitefly	–0.290	0.367	0.164	0.712
Thrips	0.076	0.544	-0.117	0.151

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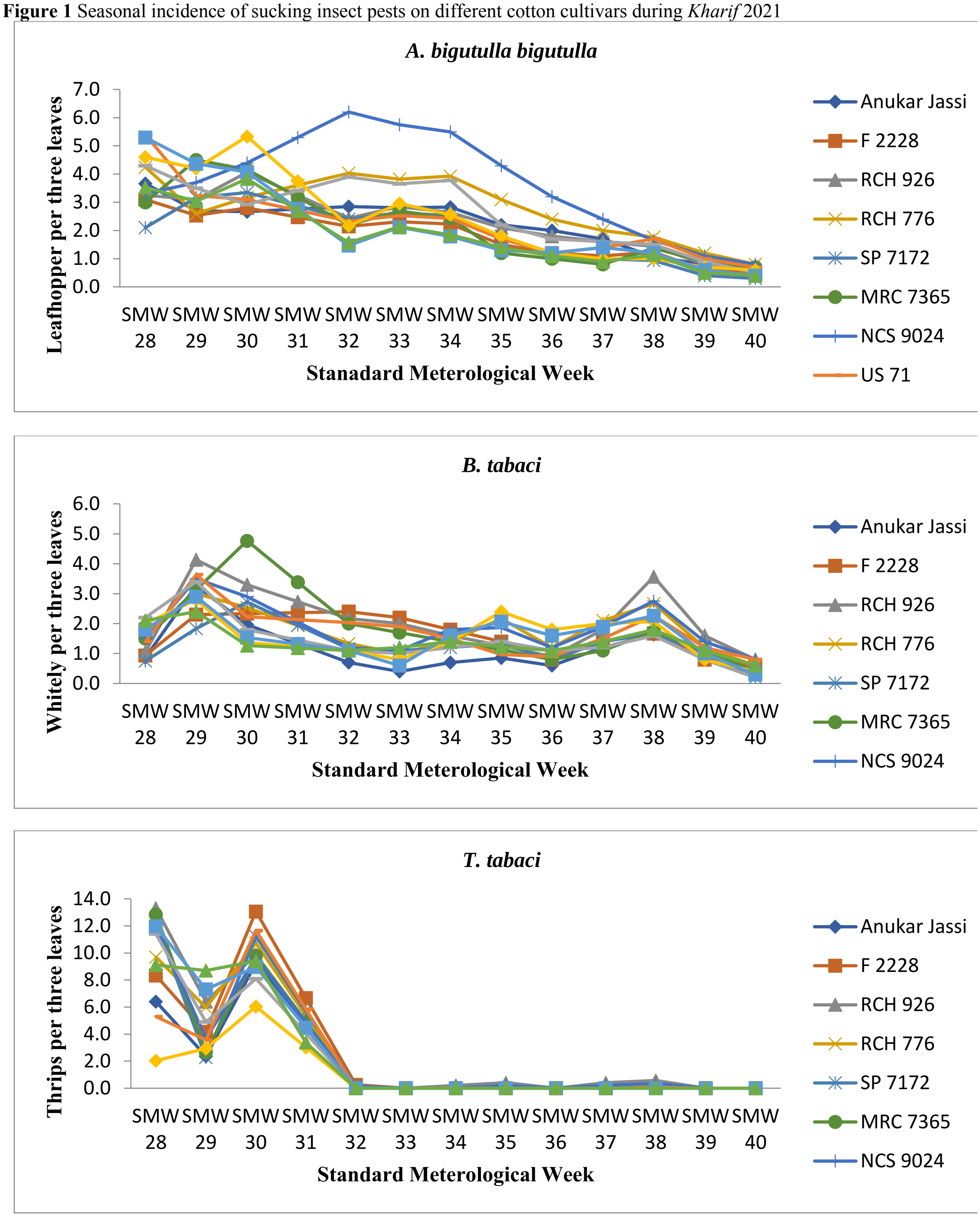
Figure 1 Seasonal incidence of sucking insect pests on different cotton cultivars during *Kharif* 2021



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2.25 Climatic Factors Affecting the Population Dynamics of Thrips, *Thrips simplex* on Gladiolus, *Gladiolus grandiflorus* L.

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Keywords: Correlation; Gladiolus; Incidence; Regression; *T. simplex*

1. Introduction

The gladiolus thrips *T. simplex* cause deformities and discoloration of gladiolus flowers, and corms (bulbs) become soft and are prone to decay. Gladiolus thrips are widespread and found almost in every place where gladiolus is grown, for example, Africa, southern Asia and Japan, Australia, several Pacific Islands, Europe, and North and South America. Although it cannot overwinter outdoors in northern Europe and northern North America, the annual spread of this thrips probably results from its infested corms being shipped to all parts of the country. Adults emerge milky-white, but soon turn brown and begin feeding. Internationally, thrips have become a limiting factor in hampering gladiolus production, vectoring tomato spotted wilt virus (TSWY) and causing damage to leaves, flowers, and buds, and in severe cases decreasing the regeneration ability of the corms in the next season (Zeier and Wright, 1995). Thrips are difficult to manage due to their secretive habit, comparatively short life cycle, and polyphagous nature. This pest poses an ever-increasing threat to commercial cut flower growers of gladiolus. Keeping in view the importance of this flower in commercial trade, the study was conducted to generate baseline data on the influence of weather parameters on the population of thrips on gladiolus in Kashmir valley.

2. Materials and methods

Meteorological data

For studying the effect of different abiotic factors on the population of thrips, gladiolus corms were planted in an open field condition at the Faculty of Agriculture, Wadura, SKUAST-K during *Kharif* 2020. Gladiolus corms were procured from the Division of Horticulture, FoA, Wadura, SKUAST-K. All the recommended agronomical practices were adopted for raising the crop. The meteorological data on different abiotic factors during the period of investigation were obtained from the Division of Agronomy, Wadura, SKUAST-K. The data generated on the population of thrips on gladiolus were correlated with maximum and minimum temperatures (°C), morning and evening relative humidity (%), and rainfall (mm). The estimate of the association between the population of pests and weather parameters was worked out using correlation analysis. Regression analysis of weather parameters with the population of thrips was computed. Data generated during the investigation of each experiment were analyzed using R software.

3. Results and discussion

Correlation analysis and regression analysis

The data on the correlation of weather parameters with the population of thrips on gladiolus from the 24th to 42nd standard week are presented in Table 1. The perusal of data revealed that the population of *T. simplex* had a significant positive correlation with the maximum temperature (r = 0.68), minimum temperature (r = 0.70), and evening relative humidity (r = 0.54). Morning relative humidity was non-significant and positively correlated (r = 0.24) with the population of *T. simplex*, while it was negative and non-significant with rainfall (– = –0.08). Naik *et al*. (2010) reported a significant positive correlation of temperature (r = 0.645) with the thrips population, which supports the present findings. The findings are further supported by Syed *et al*. (2015) who depicted a significant positive correlation of thrips with temperature (0.18) and relative humidity (0.77). The positive correlation of temperature and relative humidity with the thrips population as depicted by Kiran *et al*. (2017) also confirms the present findings. Vinuthan *et al*. (2018) observed a positive correlation of thrips with temperature and a negative correlation with rainfall, which are in congruence with the present findings. The coefficient of determination (R^2) ranged from 0.005 to 0.48. The maximum variability of 48% was shown by minimum temperature while the minimum variability of 0.57% was shown by rainfall. Maximum temperature, morning relative humidity, and evening relative humidity showed variability of 48%, 4.5%, and 27%, respectively. The models as depicted in Figure 1 are simple and could be used to predict the thrips population in gladiolus well in advance.

To sum up, the information generated from the present studies suggests that the weather parameters such as temperature, rainfall, and relative humidity have a significant influence on the emergence and development of thrips on gladiolus. The data also suggest that sowing dates can be adjusted in order to save this commercial cut flower from severe attacks of thrips reported in this study and predictions from forewarning models under changing climatic scenarios can help in managing the pest population efficiently.

Table 1 Correlation coefficient of population of thrips, *T. simplex*, with different abiotic factors

Weather parameters		Correlation coefficient (r)
Temperature (°C)	Maximum	0.689024365**
	Minimum	0.707606061**
Rainfall (mm)		–0.08
Relative humidity (%)	Morning	0.243424134
	Evening	0.542766108*

**Significant at 0.001 level, *Significant at 0.05 level

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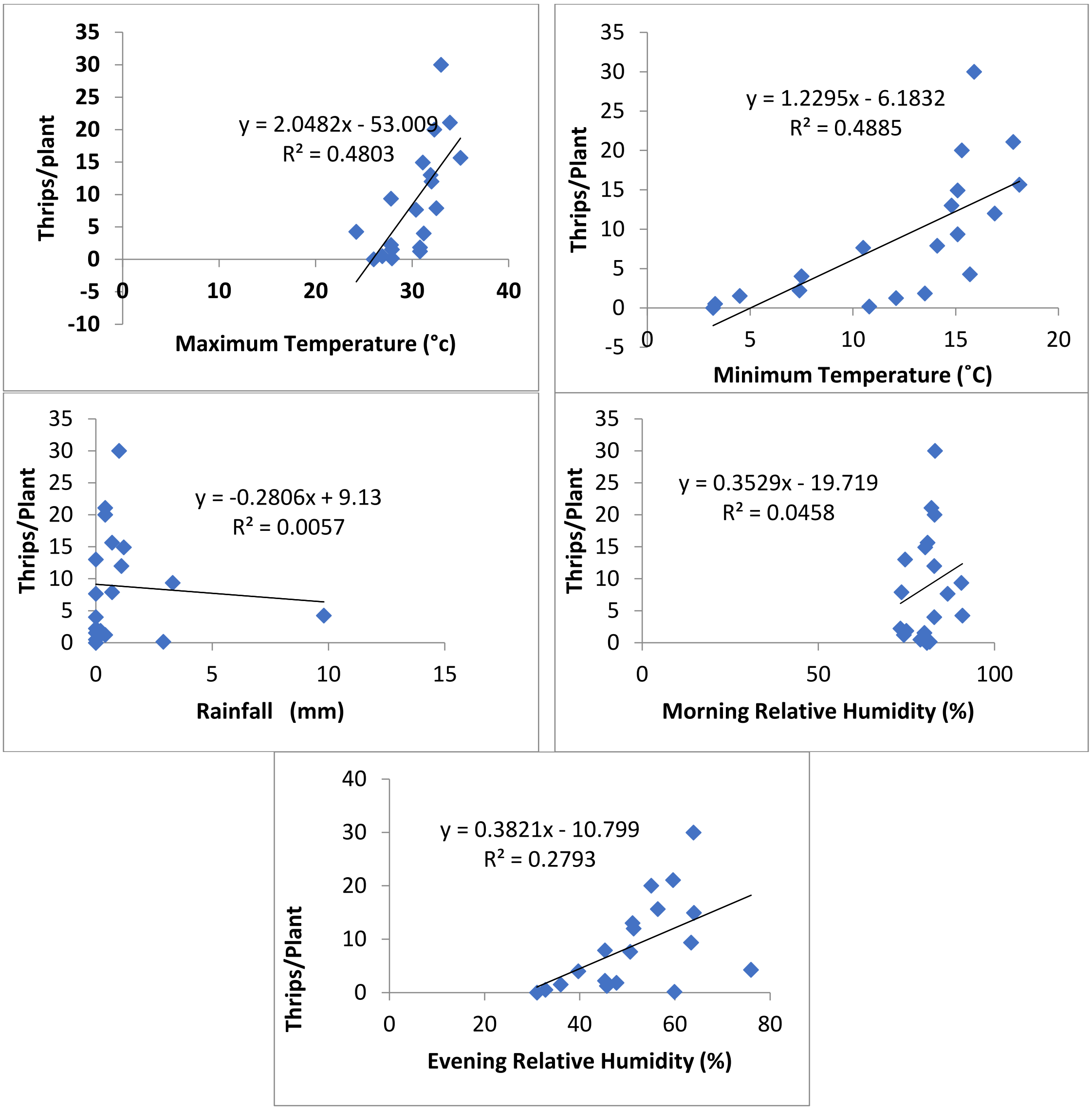

Figure 1 Linear regression equations fitted showing the influence of different weather parameters on the population of *T. simplex*

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3.26 Quantification of Grain Yield Losses in Relation to Sheath Rot in Different Rice Varieties

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Keywords: Crop loss model; Rice; Sheath rot; Yield loss

1. Introduction

Rice (*Oryza sativa* L.) is inflicted by a large number of diseases, among which sheath rot caused by *Sarocladium oryzae* is an emerging threat to rice production. The yield losses due to diseases vary from 9.6% to 85% depending on the cultivars and weather conditions prevailing during the panicle initiation stage. In Jammu and Kashmir, the disease is regularly occurring at a moderate level across rice-growing areas. The assessment of yield losses is a prerequisite for planning and executing disease management programs. The present investigations were undertaken to precisely explain the yield loss through a linear regression model between 1000-grain weight with disease severity in a 1:1 relationship.

2. Materials and methods

Forty-four rice cultivars were evaluated to assess crop losses due to sheath rot under artificial epiphytotic conditions during the *kharif* seasons of 2019 and 2020 at the Research Farm of Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu. The data on percent disease severity were recorded as per the standard evaluation system. Percent loss in 1000-grain weight was calculated as the difference between inoculated and uninoculated healthy plants. The correlation coefficient (r) was also determined between disease severity and 1000-kernel weight. Crop loss model of sheath rot of rice was developed using a simple linear regression equation $Y = a+bX$, where Y is the percent loss in 1000-grain weight (g), X is the disease severity, a is the intercept, and b is the slope of the regression.

3. Results and discussion

A significant positive correlation (r) was observed between disease severity and percent loss in 1000-grain weight among rice genotypes. The coefficient of determination (R^2) revealed that disease severity was responsible for 88%, 82%, and 85% variations for loss in 1000-grain weight in inoculated rice varieties during 2019, 2020, and for the pooled mean, respectively (Table 1). So, high goodness of fit for all the linear regression for percent loss in 1000-grain weight was observed during both the seasons (Table 1). The equation from the data during 2019 and 2020 and for pooled mean revealed that an increase in one unit of disease severity resulted in 0.90, 0.85, and 0.89 units increase in percent loss in 1000-grain weight (Table 1 and Figure 1). Similarly, Lore *et al*. (2021) observed that disease variables related to sheath blight were positively correlated with yield loss in rice.

Table 1 Crop loss models, correlation, and regression coefficients between disease severity of sheath rot and percent loss in 1000-grain weight of different rice varieties during 2019 and 2020

Year	Correlation coefficient (r)	Regression equation	Coefficient of determination (R^2)
2019	0.92^{**}	$Y = -5.569+0.9012x$	0.88
2020	0.91^{**}	$Y = -5.546+0.8595x$	0.82
Pooled	0.92^{**}	$Y = -5.581+0.8919x$	0.85

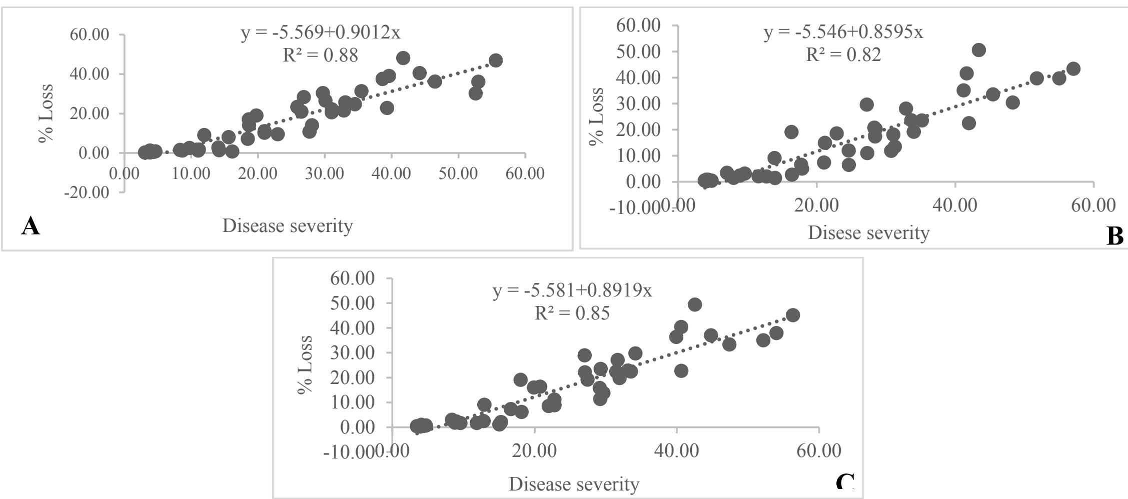

Figure 1 A strong positive relationship between sheath rot disease severity and percent loss (1000-grain weight) under artificial inoculation conditions during A) 2019, B) 2020, C) pooled, respectively.

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3.27 Diapause Induction and Post-diapause Development in Pink Stem Borer, *Sesamia inferens* Walker

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Keywords: Carryover; Diapause; *S. inferens*

1. Introduction

S. inferens Walker (Lepidoptera: Noctuidae) commonly known as the pink stem borer (PSB) is a polyphagous insect that feeds mostly on graminaceous crops such as rice, wheat, and maize. *S. inferens* was earlier a minor pest of rice crops in Punjab (Shahi *et al*., 1983). However, due to the continuous planting of crops like maize, wheat, rice, and sugarcane, the pest is now prevalent throughout the year with the exception of a brief period of diapause (halted growth) in January on wheat and May–June on rice due to extreme temperatures (Singh and Kular, 2015). This period of suspended growth is referred to as diapause and understanding the conditions that cause PSB diapause during these months of the year is critical for studying the pest's survival and carryover in northern India's rice-wheat cropping system. Keeping the aforementioned points in mind, the study was carried out under controlled conditions to evaluate diapause induction and post-diapause development in *S. inferens* Walker.

2. Materials and methods

The investigations were conducted on the F_2 population (4th instar stage) of PSB larvae which were exposed to pre-decided temperature combinations of 10±1°C and 14±1°C under a constant photoperiod of 10:14 h (L:D) and 30±1°C and 34±1°C with a photoperiod of 13:11 h (L:D) in the BOD incubators and observed for the induction of diapause. A separate set of egg clusters of *S. inferens* was also monitored simultaneously at normal temperature/photoperiod of 25±1°C, 65±5% RH, and 12:12 h (L:D) photoperiod to compare the differences between diapausing and non-diapausing larvae. The larvae that failed to pupate at 10±1°C and 14±1°C were considered as undergone hibernation, whereas the larvae that did not undergo aestivation at 30±1°C and 34±1°C and completed their life cycle normally were considered as non-diapausing larvae. The diapausing larvae were allowed to remain in diapause for about 6–8 weeks (depending on mortality) at their respective temperatures and afterward larvae were exposed to 27±1°C and 65±5% RH and 12:12 h (L:D) for termination of diapause.

3. Results and discussion

The early 4th instar larvae of *S. inferens* exposed to constant temperatures of 10±1°C and 14±1°C, along with a photoperiod of 10:14 h (L:D), failed to pupate earlier than their control counterparts exposed to 25±1°C with a photoperiod of 12:12 h. (L:D). The total larval development at 10±1°C and 14±1°C (LD 10:14 h) was completed in the significantly longer time period of 61.74 and 52.41 days, respectively, as compared to 25±1°C (LD 12:12 h) (30.11 days). The larvae that did not pupate at the above temperatures by the 45th day were considered to enter into hibernation. Similarly, the larvae that were subjected to higher temperatures of 30±1°C and 34±1°C to determine the incidence of aestivation completed their larval development in a significantly much shorter period of 24.87 and 23.89 days, respectively, and were therefore assumed to have avoided entering diapause. The population of larvae exposed to 10±1°C and 14±1°C recorded non-significant differences in larval survival of 64.01% and 65.45%, though significantly lower in comparison to other temperature and photoperiod treatments, and at 30±1°C and 34±1°C it reduces significantly to 81.32% and 71.86%, respectively. The percent larval survival (pupation) was significantly higher (86.36%) at the temperature exposure of 25±1°C (control) (Table 1). Pupal period of larvae at 10±1°C and 14±1°C (LD 10:14 h) was prolonged significantly to 12.64; 14.12 and 10.52; 12.04 days in males and females, respectively, followed by non-diapausing control treatment (25±1°C). However, a significantly shorter pupal period of 6.11; 7.64, and 5.85; 7.24 days was observed in the male and female larval populations at 30±1°C and 34±1°C, respectively. Similarly, the adult emergence was also recorded to be significantly lower in a population exposed to hibernating temperatures. The highest adult emergence (93.70%) was recorded at a treatment combination of 25±1°C (12:12 h LD), followed by the populations exposed at 30±1 (78.45%) and 34±1°C (69.69%), respectively. The total development period was significantly different at the different temperature treatments. The longest duration of 81.20 and 82.68 days followed by 69.75 and 71.27 days in the males and females was recorded in the hibernating populations at 10±1°C and 14±1°C (10:14 h L:D), respectively. The total development period of males and females was 44.04, 46.18; 38.19, 39.72 and 36.56, 37.89 days, respectively, at the above three treatments (Table 1).

Table 1 Effect of temperature and photoperiod on duration and survival of *S. inferens* during 2019-20

Temperature (°C); photoperiod (L:D) h	Pre-diapause larval period (days)*	During diapause/non-diapause larval period (days)	Post-diapause larval period (days)	Total larval period (days)	Percent pupation (%)	Pupal period (days)		Adult emergence (%)	Total development period (days)	
						Male	Female		Male	Female
10±1; 10:14	12.35±0.04	43.10 ±0.09	6.29±0.11	61.74±0.21	64.01±0.97	12.64±0.04	14.12±0.05	50.62±0.66	81.20±2.05	82.68±2.42
14±1; 10:14	12.35±0.04	37.49±0.03	2.57±0.08	52.41±0.18	65.45±1.08	10.52±0.02	12.04±0.01	52.58±0.69	69.75±0.65	71.27±1.79
25±1; 12:12	12.35±0.04	17.76±0.28	_	30.11±0.41	86.36±1.30	8.09±0.11	10.23±0.26	93.70±0.73	44.04±1.80	46.18±2.19
30±1; 13:11	12.35±0.04	12.52±0.07	_	24.87±0.02	81.32±0.87	6.11±0.02	7.64±0.08	78.45±0.72	38.19±1.52	39.72±0.84
34±1; 13:11	12.35±0.04	11.54±0.01	_	23.89±0.10	71.86±1.11	5.85±0.04	7.24±0.02	69.69±0.82	36.56±1.67	37.89±1.23
CD (*p*=0.05)	NS	0.43		0.72	3.17	0.42	0.56	2.14	4.22	6.33

Values are the mean±SE; each figure is the mean of five replications (50 individuals per replication for a total of *n* = 250).

*Time taken by the larvae reared at 27±1°C up to 3rd instar stage was considered as the pre-diapause larval period; total development period includes incubation period, larval period, and pupal period.

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The results of the present study clearly reveal that *S. inferens* exhibits a facultative diapause at a lower temperature (10±1°C; 14±1°C) and shorter day length photoperiod (10:14 h; L:D) and it can be established that *S. inferens* population during the period of December–January undergoes hibernation which results in increased duration of the total larval period and reduction in the percentage pupation and adult emergence in the spring season under north Indian conditions though the surviving populations are sufficient for its carryover to next season crops.

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3.28 Knowledge Level of Kinnow Growers on the Management of Pests and Disorders of Kinnow Crop in Punjab

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Keywords: Disorders; Kinnow; Knowledge level; Management; Pests

1. Introduction

The genus *Citrus*, among the most widely known groups of fruit crops globally, belongs to the Rutaceae family, which includes 140 genera and 1300 species spread around the globe. Kinnow cultivation currently covers 53.05 thousand hectares with a production of 1246.82 thousand metric tonnes. Punjab's Fazilka, Hoshiarpur, Sri Muktsar Sahib, Bathinda, Ferozpur, and Faridkot districts account for nearly half of the kinnow-growing area (Anonymous, 2019). Citrus foot rot/gummosis (*Phytophthoranicotianae* var. *parasitica*) is the most common pathological problem causing mild to severe damage tokinnow mandarin plants in nurseries and orchards (Thind *et al*., 2004). Citrus is affected by a variety of insect pests, diseases, and physiological disorders just like other fruit crops. Foot rot/gummosis disease is a significant threat to the future of citriculture in Punjab and surrounding areas, with over 67.5% of trees in orchards declining (Thind*et al*., 1999). Thus, it is very important to study the knowledge level of kinnow growers about management practices of insect pests, diseases, and disorders for making appropriate decisions based on kinnow grower's knowledge level for improving the management of insect pests, diseases, and disorders which will help in improving the overall growth, quality, and yield of the kinnow crop in Punjab.

2. Material and methods

Four districts, namely,Fazilka, Hoshiarpur, Shri Muktsar Sahib, and Bathinda, were purposively selected because the number of kinnow growers and the area under kinnow cultivation were maximum in these districts. A combined list of kinnow growers consisting of 1745 farmers from four districts was obtained from the concerned horticulture development officers of the Horticulture Department. Two-hundred kinnow growers were selected from the four districts with probability proportional to the size sampling method and 92, 74, 18, and 16 kinnow growers were selected from Fazilka, Hoshiarpur, Shri Muktsar Sahib, and Bathinda, respectively.

Construction of knowledge test

A knowledgetest was prepared to test the knowledge of respondents. Two rules were followed for the selection of items for the knowledge test; these items should promote thinking rather than memorization and another was that too difficult and too easy answerable items were to be removed from the knowledge test. At last, 59 items were shortlisted in the knowledge test.It was done to find out the index of item difficulty and item discrimination.

I. Item difficulty index

$$Pi = \frac{ni}{Ni} \times 100$$

Here,
Pi = Difficulty index percentage
ni = Number of growers responding correctly
Ni = Total number of respondents administrated

II. Item discrimination index

$$E^{1/3} = \frac{(S_1+S_2) - (S_4+S_5)}{N/3}$$

Here,
$E^{1/3}$ = phi-coefficient
S_1, S_2, S_4, S_5 = Frequencies of correct answers in groups
N= Total number of respondents

In this study, the item difficulty index ranging 30–85 and item discrimination index ranging0.30–0.55 were taken for the final selection of items in the knowledge test, and based on item analysis, 39 items were finalized for the final knowledge test.

3. Results and discussion

Data given in Table 1 show that more than 55.5% of the respondents had a medium level of knowledge falling in the score group of 18–26 out of the total 39 score followed by 25.5% of the respondents who had a high level of knowledge and falling in the score group of 27–35 out of the total 39 score, and 19% of the respondents had a low level of knowledge falling in the score group of 9–17 out of the total 39 score.

Table 1 Distribution of the respondents according to knowledge level regarding management practices of kinnow crop

***n*=200**

S. No.	Categories	Scores	*f*	%
1.	Low	9–17	38	19
2.	Medium	18–26	111	55.5
3.	High	27–35	51	25.5

Focus variables of respondents such as education, the experience of kinnow cultivation, extension contacts, and mass media exposure were positively and significantly correlated with the knowledge level of respondents at a 0.05 level of significance. The other variables such as age, the number of family members, and operational landholding were non-significantly associated with knowledge level at a 0.05 level of significance. On the basis of data, it can be said that more than half of the respondents had a medium level of knowledge, so the extension activities should be enhanced for further improving the current knowledge levelof kinnow growers regarding management practices of kinnow crop.

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3.29 Comparative Biology of Solitary Endoparasitoids *Glyptapanteles agamemnonis* and *Meteorus pulchricornis* on Virus Infected *Spilarctia obliqua* Larvae

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Keywords: Glyptapanteles agamemnonis; *M. pulchricornis*; Nucleopolyhedrovirus; *S. obliqua*

1. Introduction

In nature, insect parasitoids and baculoviruses coexist for the natural control of insects and are considered major components of biological control against most lepidopteran pests (Brodeur and Boivin, 2004). To effectively integrate baculoviruses and parasitoids in biological control programs, it is particularly important to understand the interaction between these two types of natural enemies. Such interactions have been reviewed in detail, mainly focusing on their safety and efficacy in biological control programs. When a host is simultaneously infected by a virus and parasitized by insect parasitoids, an important aspect in the development of baculoviruses as biopesticides is the evaluation of their possible impact on predators and parasitoids. Although these parasitoids are not susceptible to viral infection, their developmental biology often depends on the quality or survival of the virus-infected host. Hence, the impact of baculoviruses on parasitoids should be considered. The Bihar hairy caterpillar, *Spilosoma*(=*Spilarctia) obliqua* (Walker) (Arctiidae: Lepidoptera), is a serious pest in India. At present, parasitoids along with other natural enemies such as nucleopolyhedrovirus (NPV) are being evaluated to manage early instars. Synergetic interactions between pathogens and insect natural enemies can enhance control efficacy, whereas antagonistic interactions can reduce total control efficacy. Such interactions are crucial for devising the management strategy against this pest. Understanding this interaction is important for assessing the potential use of baculovirus and parasitoid to control pest populations and may be proven as a crucial element in constructing a sustainable and healthy food system by minimizing environmental strain. As a tailored, non-chemical input, it can provide a comprehensive and balanced solution for sustainable agriculture. Therefore, the present study was planned to investigate the comparative biology of larval endoparasitoids, namely, *G. agamemnonis* (Wilkinson) and *M. pulchricornis*, and nucleopolyhedrovirus.

2. Materials and methods

Rearing of bihar hairy caterpillar *Spilosoma (Spilarctia) obliqua* (walker): The nucleus culture of *S. obliqua*was established in the Biocontrol Laboratory of Division of Entomology, SKUAST-J, FOA-Chathaby collecting the adults in a light trap. The culture was reared in the laboratory at a temperature of 26±2°C and 70±10% RH and L:D (16:8) photoperiod.

Virus extraction and standardization: The multiple nucleopolyhedrovirus used in this study was propagated in third instar *S. obliqua* larvae maintained on a semi-synthetic diet based on chickpea flour. Viral occlusion bodies (OBs) were extracted by homogenizing virus-killed larvae in 0.1% sodium dodecyl sulfate(SDS), followed by filtration through muslin cloth and subsequent pelleting through continuous sucrose gradient centrifugation for 1 h at 50,000g. The virus was quantified using a hemocytometer and phase contrast microscope at ×1000 magnification.

Effects of SoMNPV infection on the fitness of parasitoids: A batch of 50 newly molted third instar larvae were parasitized by *G. Agamemnonis* followed by feeding of virus-treated castor leaves @ 32×10^7 OBs/mL for 24 h, 96 h post parasitization. The biological attributes of these parasitoids were studied. A similar procedure was followed with *M. pulchricornis*.

Susceptibility of parasitized host larvae: *S. obliqua* larvae were parasitized with *G. agamemnonis* for 1 day and then exposed to SoMNPV concentration representing double the LC90 (3.32×10^7 OBs/mL) 4 days post parasitization. Larvae that consumed contaminated food were maintained and fed with tender castor leaves without virus.*M. pulchricornis* underwent a similar process.

3. Results and discussion

Effects of SoMNPV infection on the fitness of parasitoids is that the viral contamination had no effect on the egg-larval period of the parasitoids *G. Agamemnonis* (F=0.91, df=1, 38, *P*>0.05) and *M. Pulchricornis* (F=0.61, df=1, 38, *P*>0.05) emerged from SoNPV-treated and untreated larvae (Table 1). The pupal period of the parasitoids *G. Agamemnonis* (F = 0.43, df=1, 38, *P*>0.05) and *M. Pulchricornis* (F=1.41, df=1, 38, *P*>0.05) was notsignificantly different when emerged from SoNPV-treated and untreated larva (Table 1).Cocoon weight of parasitoids *G. Agamemnonis* (F=0.806, df=1, 18, *P*>0.05) and *M. Pulchricornis* (F=0.962, df=1, 18, *P*> 0.05) that emerged from SoNPV-treated and untreated larvae was not significantly different (Table 1). However, no significant difference was observed in the body weight of the parasitoids *G. Agamemnonis* (F=1.07, df=1, 18, *P*>0.05) and *M. Pulchricornis* (F=0.94, df=1, 18, *P*>0.05)that emerged from SoNPV-treated and untreated larvae (Table 1).

Table 1 Effects of SoMNPV infection on fitness parameters of parasitoids

Parameters	Parasitoids	Treatments	
		Control	Treated
Egg-larval period	*G.agamemnonis*	19.40±0.28a	18.90±0.25a
	M.pulchricornis	10.15±0.24a	9.80±0.22a
Pupal period	*G. agamemnonis*	6.30±0.25a	6.60±0.23a
	M. pulchricornis	7.50±0.27a	7.90±0.22a
Cocoon weight	*G. agamemnonis*	0.79±0.06a	0.72±0.05a
	M. pulchricornis	2.70±0.11a	2.54±0.10a
Body weight	*G. agamemnonis*	0.57±0.42a	0.51±0.45a
	M. pulchricornis	2.10±0.11a	1.96±0.97a
Adult emergence from cocoons	*G. agamemnonis*	83.04±1.35a	80.35±1.23a
	M. pulchricornis	82.16±1.40a	78.95±1.28a
Longevity	*G. agamemnonis*	4.60±0.63b	2.50±0.26a
	M. pulchricornis	4.90±0.31b	3.10±0.45a

Values are means±SE. Means within a column followed by different letters are significantly different, *P*<0.05.

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Although virus infection had no effect on the percent emergence and weight of parasitoids, infection with SoMNPV significantly affected the longevity of parasitoids. The parasitoids that emerged from untreated larvae survived for a longer period as compared to parasitoids emerged from SoNPV-treated larvae in *G. agamemnonis* (F = 9.25, df =1, 18, *P*< 0.05) and *M. pulchricornis* (F = 10.48, df =1, 18, *P*< 0.05) (Table 1).In our study, when larvae were treated with parasitoid and virus, no significant differences were observed in the percentage emergence of parasitoids, the weight of the emerged parasitoid cocoons, and the weight of the adults emerged from cocoons from healthy and virus inoculated larvae. There is also no significant difference in the developmental period (egg to pupae) of parasitoids that emerged from SoNPV-treated and untreated larva. These results find support from earlier findings of Guo *et al.*(2013) who reported that the development time of the *M. pulchricornis* that emerged from SeMNPV-infected *S. exigua* was not affected by the virus.

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3.30 Eco-friendly Pest Management Strategies for Controlling Cabbage Butterfly (*Pieris brassicae* Linnaeus)

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Keywords: Bt; Cabbage butterfly; Eco-friendly management; IPM

1. Introduction

IPM is a critical component of the sustainability of many agroecological systems. In the current scenario, the optimized use of pesticides is important to reduce environmental contamination while increasing their effectiveness against the target pest. The cabbage butterfly (*P.brassicae* Linnaeus) inflicts heavy damage on the cabbage crop in the cold arid zone (Kargil, UT of Ladakh) and causes significant yield losses. Controlling cabbage butterfly is not an easy practice although synthetic chemicals are available for use. But continuous use of chemicals promotes the development of pesticide resistance in the target pest, causes pest resurgence, affects non-target pest species, and affects the environment and health (Mayanglambam *et al*., 2021). Therefore, the use of an alternative strategy was essential to grow a healthy crop of cabbage. This has led to the consideration of the rational use of pesticides and the physiological and ecological selectivity of pesticides. An experiment was conducted to determine the efficacy of different eco-friendly management strategies for controlling the cabbage butterfly (*P.brassicae* Linnaeus)*"* in the cold arid zone of SKUAST-Kashmir.

2. Materials and methods

The experiment was conducted in the experimental vegetable field of MARES, Kargil, during Rabi 2017-18 and 2018-19. The experiment was conducted to determine the efficacy of five different eco-friendly management strategies against the cabbage butterfly (*P.brassicae*Linnaeus) and alsoto assess the best management practice in terms of production. The trial was laid out in a randomized block design having a plot size of 1.8 m×1.35 m and spacing of 60 cm×45 cm with cabbage cv. Golden Acre, replicated thrice. IPM module was adopted for the said experiment and five treatments (control, cultural, mechanical, biological, and chemical) were carried out against untreated control.All the treatments were conducted at their specific time to control the specific stage of the pest. However,treatment-wise application of Bt (Dipel 8L)and Fenvelrate20 ECwas given at 15 days interval after 22–25 DAT, when pest level crossed the economic threshold level,that is, two or three larvae per plant with required concentration, and the efficacy was worked out by Abbot's formula:

$$\text{Efficacy (mortality \%)} = 1 - \frac{\text{n in T after treatment}}{\text{n in Co after treatment}} \times 100$$

Here, n = insect population, T = treated, and Co = control.

Treatment Details

T1	Control	
T2	Cultural control	Early transplantation
T3	Mechanical control	Hand picking of larvae
T4	Biological control	(Spraying of Dipel 8L sumitomo @ 0.2% at 15 days interval after 22–25 DAT
T5	Chemical control	Spraying with Fenvele rate @ 0.1% at 15 days interval after 22–25 DAT

3. Results and discussion

The results of the experiment conducted during 2017–2019 revealed that the adoption of the integrated pest management strategy capsule for control of the cabbage butterfly at a specific time and stage brought about satisfactory control of pests. All the treatments yielded significantly superior results over control. However, spraying with biopesticide (Bt, Dipel 8L Sumitomo @ 0.2%) was found significantly superior (best) over other treatments in terms of yield (52.3kg/plot) as well as depicted least percent infestation (1.67%) and maximum efficacy (85.15%). Jaquet *et al*. (1986) reported that the larvae of *P. brassicae* were highly susceptible to purified crystals of strains of *Bacillus thuringiensis* (Bt). The biological control was followed by mechanical control (yield:40.33kg, percent infestation:4.99%, efficacy: 68.34%) and chemical control Fenvelrate 20 Ec @0.1% (yield: 39.11 kg, percent infestation:7.22%, efficacy: 66.31%). The use of synthetic pyrethroid (Fenvel rate 20 Ec) depicted effective control of *P.brassica e*as also documented by Sharma *et al* (2017).The cultural control recorded yield of 23.07 kg, mean percent infestation of 25.00%, and efficacy of 34% and was least effective in reducing the cabbage butterfly population. However, all the IPM strategies could be collectively used to overcome the population of *P.brassicae* at a specific time and stage as the practices designed under the module have minimal environmental disturbance (Archer *et al*., 2017).

Table 1 Yield, percent mean plant infestation, and efficacy of different management strategies against cabbage butterfly (2017–2019)

Treatments	Yield (kg/plot)	Percent mean plant infestation (%)	Efficacy (%) (percent population reduction)
T1	7.87	68.34	3.95
T2	23.07	25.00	38.07
T3	40.33	4.99	68.34
T4	52.30	1.67	85.15
T5	39.11	7.22	66.31
CD			6.05

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3.31 Targeted Delivery of Soil-Insecticide Mixture in Maize Whorls to Manage Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith)

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Keywords: Maize; Neem seed kernel powder; Soil-insecticide mixture; *S.frugiperda*; Whorl application

1. Introduction

Fall armyworm (FAW), *S. Frugiperda* (J.E. Smith), is an invasive pest causing massive destruction to maize crop, which invaded India in Karnataka state during *Kharif*2018 (Sharanabasappa *et al*., 2018). Although different control measures such as host plant resistance and biological and cultural methods are recommended for its management, the major focus is on the use of chemical insecticide (Sisay *et al*., 2019). The incidence of fall armyworm in maize occurred from early whorl to later stages of crop growth and the pest prefers to feed in maize whorls. The larvae hide in plant whorl during daytime at farmer's field, and pest is difficult to control due to the wrong selection of insecticide and the faulty method of spray application. For rainfed ecological areas, where resources are limited and farmers do not have efficient spray equipment, the management of FAW is more challenging. Moreover, at the grand vegetation stage, the maize plants grow tall and wide with small gaps between planted rows, making uniform and safe spraying with a knapsack sprayer extremely difficult. Consequently, for the management of FAW, a user-friendly, precise, and cost-effective technology, that is, whorl application with the soil-insecticide mixture, was evaluated.

2. Materials and methods

The trials were conducted at the Department of Plant Breeding and Genetics, PAU, Ludhiana during *Kharif* (rainy) season of 2020. The whorl application of spinetoram 11.7 SC @ 5 mL/kg soil, bait application, soil, soil-lime mixture, sand, neem seed kernel powder (NSKP), a spray of spinetoram @ 0.5 mL/L of water along with untreated control were evaluated in grain maize crop for the management of FAW. To prepare a soil-insecticide mixture for one acre, 15 kg of soil was mixed with 75 mL of test insecticide diluted in 150 mL of water. A pinch of (approximately 0.5g) soil-insecticide mixture per maize whorl was applied. The percent plant infestation by FAW was recorded in whorls before application and7 and 14 days after application. Further, this method was also used to compare the efficacy of Dipel 8 L (*Bacillus thuringiensis* var kursutaki strain HD-1) in maize crop (spray vs. mixture with soil) during the *Kharif*2021 season. The grain yield (q/ha)was recorded in each treatment.

3. Results and discussion

In the present investigation, the application of soil+ spinetoram 11.7 SC was on par with its spray application and rice bran-based bait at the recommended dose (Table 1). However, rice bran may not be readily available and its preparation is comparatively laborious than soil-insecticide mixture feasible at farmer's field. The treatments such as soil or its mixture with lime or neem seed kernel powder and sand did not prove significantly effective in reducing FAW incidence. The whorl application of other label claim insecticides, that is, chlorantraniliprole 18.5 SC or emamect in benzoate 5 SG@ 5 mL/kg soil, was as effective as spinetoram 11.7 SC @ 5 mL/kg soil in reducing the damage by FAW(data not shown). The grain yield was significantly more in soil+insecticide mixture, bait, and spray-treated plots in comparison to untreated control.

The incidence of FAW in soil-Dipel 8 L mixture whorl application was low (19.60% and 9.83%) in comparison to its spray with the incidence of 29.03% and 26.42% after two weeks of the first and second treatment, respectively (Table 2). Thus, the efficacy of the Dipel 8 Lwas substantially improved when directly applied in leaf whorl and this methodology can be an important component of IPM strategies for the management of FAW in maize involving biopesticides.

Table 1 Evaluation of indigenous technology knowledge (ITK) practices for the management of fall armyworm, *S. frugiperda*, in *Kharif* maize at Ludhiana during *Kharif* 2020

Sr. No.	Insecticide	Dose	Plant infestation (%) by fall armyworm					Grain yield (q/ha)
			14 DAG* (Pre-treatment)	21 DAG (7 DAT)	28* DAG (14 DAT)	35 DAG (7 DAT)	42 DAG (14 DAT)	
T1	Soil	15 kg/acre	45.65	30.34	33.96	29.71	23.85	54.28
T2	Soil+insecticide (spinetoram 11.7 SC) (15 kg soil used/acre)	5 mL/kg soil	42.66	2.14	1.20	1.20	1.18	68.22
T3	Soil+lime	9:1	44.55	12.83	14.54	17.24	21.34	59.44
T4	Soil+NSKP	8:2	40.42	32.83	37.79	30.12	24.27	53.81
T5	Neem seed kernel powder	10 kg/acre	38.68	34.84	35.61	32.14	24.93	54.58
T6	Sand	15 kg/acre	38.57	23.31	24.21	19.79	19.75	57.67
T7	Bait (rice bran+gur+spinetoram 11.7 SC) (16 kg bait/acre)	5 mL/kg	39.33	1.98	2.23	2.12	1.58	67.75
T8	Spinetoram 11.7 SC	0.5 mL/L	42.20	2.44	2.82	2.85	1.98	67.11
T9	Untreated control	–	42.23	37.82	41.89	35.41	30.42	53.19
CD (p=0.05)			NS	6.13	3.50	4.81	1.76	3.93

DAG =Days after germination; DAT =Days after treatment.
*Treatment was done at 14 and 28 DAG; hybrid: PMH 1; D.O.S.: 18.7.2020; plot size: 4.0 m×5 rows.

Table 2 Evaluation of biopesticide for the management of fall armyworm, *S.frugiperda*, in *Kharif* maize at PAU, Ludhiana during *Kharif*2021

Treatment	Dose mL/kg seed	Before treatment	1 WAT_1	2 WAT_1	1 WAT_2	2 WAT_2	Grain yield (q/ha)
Soil+ Bt (Dipel 8L)	25g Dipel 8 L/kg soil	34.44	16.98	19.60	13.19	9.83	57.32
Bt spray	2 g/L	4.67	21.04	29.03	27.85	26.42	53.89
Chlorantraniliprole 18.5 SC	0.4 mL/L	8.92	3.05	13.08	2.13	3.19	66.76
Control	–	5.77	31.87	45.77	49.75	44.22	48.89
CD (*p*=0.05)		4.68	9.63	7.10	9.13	9.68	8.40

WAT_1: weeks after 1st application; WAT_2: weeks after 2nd application.

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3.32 Seasonal Abundance of Major Insect Pests Infesting Kinnow and Their Relationship with Weather Parameters

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Keywords: Insect pests; Kinnow; Seasonal abundance; Weather parameters

1. Introduction

Citrus is the largest group of fruits in the world, which includes wet orange, limes, lemons, kinnow, and grapefruit. The kinnow, a mandarin hybrid, is successfully grown in Punjab, Haryana, Himachal Pradesh, and Uttar Pradesh. In Haryana, the major citrus growing districts are Sirsa, Fatehabad, Hisar, and Bhiwani. Sirsa leads in the highest area and production of kinnow, which is about 65% of the total production of kinnow in Haryana. Citrus is grown in an area of approximately 88 thousand hectares in India and 25 thousand hectares in Haryana (Anonymous, 2021). The area under citrus crop is increasing especially under kinnow, which is the most popular fruit crop due to its precocious bearing and fruit quality (Devi and Sharma, 2014). The kinnow in Haryana is attacked by a number of insect pests, namely, citrus psylla, citrus leaf miner, citrus whitefly, lemon butterfly, and fruit sucking moths. These insect pests inflict heavy economic loss on citrus plants, both in the nursery and orchards. So, the seasonal incidence and their fluctuation with abiotic factors may play a major role to manage this pest further.

2. Materials and methods

The present investigation on the seasonal abundance of major insect pests infesting kinnow was carried out at the horticulture research farm, CCSHAU-Hisar from September 2020 to May 2021. Observations on the seasonal abundance of the five major insect pests infesting kinnow were recorded. The observations for citrus psyllid, *Diaphorina citri* Kuwayama, were recorded from 10 cm terminal portion (shoots) of the five selected branches/tree. The incidence of the whitefly, *Dialeurodes citri* (Ashmead), was recorded based on the total number of adults on five leaves of the randomly selected five branches per tree. The total number of lemon caterpillar, *Papilio demoleus* Linn, larvae were recorded from randomly selected five branches per tree. The population of leaf miner, *Phyllocnistis citrella* Stainton, was recorded based on the number of infested leaves from five branches per plant and the percent infestation was worked out. The incidence of fruit sucking moths *Othreis fullonica* Linn. and *O. materna* Linn. was also recorded by counting the number of damaged fruits from five branches per tree and the percent of damage was calculated. The weather data was collected from the Department of Agro-meteorology, CCS HAU, Hisar.

3. Results and discussion

The results of the present investigation show that the weather parameters not only affect the growth and development of kinnow, but also provide congenial conditions for the incidence of pests. The population of citrus psylla ranged 0.33–18.06/shoot during the study period. The maximum population (18.06 adults/shoot) of psyllids was recorded in the 19th SMW, that is, 1st week of May. Later from November onward the pest begins to disappear and occurs only in small numbers up to February 1st week and again starts to increase thereafter. Whitefly population ranged 0.60–14.66 adults/leaf with a peak of 14.66 adults/leaf during 41st SMW, that is, the second week of October. No population of whitefly was recorded during winter, that is, 49th to 8th SMW and again it appears thereafter in February end with the rise in temperature. The population of citrus caterpillars ranged from 2.20 to 14.80/plant from 36th to 48th SMW from September to November. The maximum larval population (14.80 larva/plant) was recorded during the first week of October (40th SMW) and afterward the population density declined gradually till the end of November. The highest population during the second flush (8.34 larva/plant) was recorded during the 18th SMW (April). The infestation of leaf miner fluctuated from 5.67% to 46.32% during the period of study. Its incidence starts to increase from February onward, that is, 8th SMW onward, and coincides with new vegetative flush leaves. Maximum leaf infestation damage by leaf miner (46.32%) was observed during 39th SMW (September) and declined trend was observed thereafter in winter and again it tends to increase from March. Fruit sucking moth damage started to appear from 3rd week of October at the fruit ripening stage and continued till harvest. The fruit damage was increased as the fruit turned toward ripening and the maximum damage (13.40%) was recorded in the last week of November. The population of citrus psylla showed a significant positive correlation with maximum temperature (0.682), minimum temperature (0.674), morning relative humidity (0.718), and evening relative humidity (0.753). Likewise, the population of whitefly, lemon caterpillar, and leaf miner infestation also showed a significant positive correlation with the temperature (maximum and minimum) and relative humidity (morning and evening). The fruit damage by fruit sucking moth showed a significant negative correlation with maximum temperature (–0.795) and a significant positive correlation with relative humidity (morning and evening), while it was found non-significantly correlated with minimum temperature (0.574) (Table 1).

Table 1 Correlation of weather parameters with population/infestation of major insect pests in kinnow

Weather parameters	Citrus psylla/shoot	Whitefly/leaves	Lemon caterpillar/plant	Leaf miner incidence	Fruit damage (%)
Maximum temperature	0.682^{**}	0.793^{**}	0.950^{**}	0.910^{**}	-0.795^{**}
Minimum temperature	0.674^{**}	0.585^{**}	0.944^{**}	0.944^{**}	0.574^{NS}
Relative humidity (morning)	0.718^{**}	0.763^{**}	0.778^{**}	0.778^{**}	0.871^{**}
Relative humidity (evening)	0.753^{**}	0.524^{**}	0.704^{**}	0.747^{**}	0.789^{**}

**Significant at 1%.

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3.33 Current Status and Management Options against Fall Armyworm *Spodoptera frugiperda* (J.E. Smith) in Fodder Crops in Punjab

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Keywords: Bajra; Biopesticides; Fodder; Maize; Mixed cropping; Sorghum; *S. Frugiperda*

1. Introduction

Fall armyworm (FAW), *S. frugiperda* (J. E. Smith), is a polyphagous pest known to feed on over 350 plant species belonging to 76 plant families (Montezano *et al*., 2018). Owing to its broad host range and strong dispersal ability, the FAW is considered a global threat to food and fodder security across the tropical and subtropical regions of the world. It was been observed feeding on seven fodder crops in the country with incidence ranging from 2.2% to 84.62% (Keerthi *et al*., 2021). Management of fall armyworm is a major challenge to fodder crops especially maize and needs the use of multiple options at the same time for successful cultivation. Host plant resistance, agronomic interventions, biological control, and use of chemicals are the commonly used practices in an IPM programme. This work highlights the status of fall armyworm in fodder crops especially maize in Punjab and the management options to tackle this invasive pest.

2. Materials and methods

Surveys were conducted from 2019 to 2021 to monitor the incidence of fall armyworm in farmers' fields on fodder crops. The trials on the efficacy of biopesticides were conducted at the Department of Plant Breeding and Genetics, PAU, Ludhiana during *Kharif* season of 2020 and 2021. A spray of *Bacillus thuringiensis* (Bt), *Beauveria bassiana*, and *Metarhizium anisopliae* and spray of spinetoram @ 0.5 mL/L along with untreated control were evaluated in fodder maize for the management of FAW. The percent plant infestation by FAW was recorded in whorls before, 5, and 10 days after spray. Green fodder yield was also recorded. Furthermore, in another trial, mixed cropping of maize with other fodder crops was evaluated to study the influence of mixed cultivation on the infestation levels of this pest during *Kharif* 2020.

3. Results and discussion

The pest appeared in Punjab on grain and fodder maize in late August of 2019. Of the 92 spots surveyed across the state for fodder maize during 2019, 58 spots had the presence of fall armyworm with incidence ranging from 1% to 30%. Within a few years, it has become a major pest of the maize crop. However, the incidence on sorghum, pearl millet, and small millet in the state has been very low (less than 10%) as compared to South India. In biopesticide trials, the plant infestation in different treatments varied from 13.66% to 14.33% and 52.66% to 64.66% before spray in 2020 and 2021, respectively (Tables 1 and 2). The differences were non-significant. All treatments were significantly better than the untreated control 5 and 10 days after spray. The infestation of FAW on maize in chemical control was lowest (7.66% and 5.66%) 5 and 10 days after spray as compared to other treatments in 2020. It was 28.00% and 8.66% after 5 and 10 days of spray, respectively, in 2021. Among the biopesticides evaluated, *Bacillus thuringiensis* (Bt) based biopesticide (Dipel 8 L) was comparatively better than other treatments in reducing the damage by fall armyworm on 5 and 10 days after spray; plant infestation levels were 9.66% and 23.33% in 10 days after spray during 2020 and 2021, respectively. Insecticide-treated plots yielded the highest green fodder followed by Bt spray. The incidence of fall armyworm was highest when fodder maize was sown alone (33.5%). When mixed with bajra and sorghum, the incidence was 22% in line sowing and 18% in the broadcast. Bajra is least preferred among these, and mixed cropping of maize with bajra as broadcast or line sowing resulted in only 20–21.5% infestation levels. Maize–cowpea mixture is the recommended sowing practice and it also reduced the infestation to some extent (26%) (Table 3). Overall, *B. thuringiensis* (*Bt*) based biopesticide (Dipel 8 L) was comparatively better than other treatments in reducing the damage by fall armyworm However, chemical control was the best treatment, and significantly higher plant damage was recorded in the untreated control. Mixed cropping may be preferred over the sole cultivation of maize. Biopesticides, insecticides, and mixed cropping can be integrated for the effective management of this pest.

Table 1 Field evaluation of biopesticides against fall armyworm on fodder maize during *Kharif* 2020

Treatments	Dose/acre	*Plant infestation (%)			Yield (q/ha)
		Before spray	5 DAS	10 DAS	
Dipel 8 L (*B. thuringiensis kurstaki*)	400	14.33	11.33 (19.66)	9.66 (18.04)	251.75
Daman 1.0 WP (*B. bassiana*)	1000	14.33	13.33 (21.35)	11.00 (19.35)	235.75
Kalichakra 1.0 WP (*M. anisopliae*)	1000	14.00	12.33 (20.53)	10.66 (19.05)	241.75
Delegate 11.7 SC	0.4 mL/L	14.00	7.66 (16.04)	5.66 (13.72)	285.00
Untreated control	–	13.66	16.00 (23.55)	19.00 (25.79)	211.75
CD (p = 0.05)		NS	(2.45)	(1.90)	8.6

*Figures in parentheses are arc sine transformed values; DAS-days after spray, Reps=3.

The spray was done at 30 days after germination. D.O.S: 18.7.2020, Variety: J 1006; Plot size: 4 m×6 rows.

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Table 2 Field evaluation of biopesticides against fall armyworm on maize fodder maize during *Kharif* 2021

Treatments	Dose/acre	*% Plant infestation			Yield (q/ha)
		Before spray	5 DAS	10 DAS	
Delfin WG (*B. thuringiensis kurstaki*)	400	55.33	38.66 (38.43)	18.66 (25.58)	250.67
Dipel 8 L (*B. thuringiensis kurstaki*)	400	64.66	46.66 (43.04)	23.33 (28.84)	247.50
Mahastra 0.5 WP (*B. thuringiensis kurstaki*)	400	52.66	42.00 (40.37)	22.66 (28.42)	243.00
Daman 1.0 WP (*B. bassiana*)	1000	58.00	52.00 (46.13)	30.00 (33.18)	228.83
Kalichakra 1.0 WP (*M. anisopliae*)	1000	53.33	45.33 (42.30)	26.00 (30.63)	236.50
Delegate 11.7 SC	0.4 mL/L	60.00	28.00 (31.90)	8.66 (17.01)	281.50
Untreated control		62.00	58.66 (49.98)	42.00 (40.37)	206.50
CD (p = 0.05)		NS	(4.90)	(3.30)	7.23

*Figures in parentheses are arc sine transformed values; DAS – days after spray, Reps = 3.
The spray was done at 25 days after germination. D.O.S: 26.7.2021, Variety: J 1006; Plot size: 4 m×6 rows.

Table 3 Effect of mixed cropping on the incidence of fall armyworm in fodder maize (*Kharif* 2020)

Treatment	Percent plant infestation
Maize sole crop	33.50
Maize+bajra+sorghum (line sowing)	22.00
Maize+bajra+sorghum (broadcast)	18.00
Maize+bajra (broadcast)	15.00
Maize+bajra (line sowing)	20.0
Maize+cowpea	26.00
Maize+bajra (line sowing)	21.50
Maize+sorghum (line sowing)	25.00
Maize+bajra (border rows)	–

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3.34 Management of *Galleria mellonella* Linn. in *Apis mellifera* Linn. Colonies Using Biorationals

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Keywords: Acceptance; Bacillus thuringiensis; Brood survival; Greater wax moth; Honey bees; Neem products

1. Introduction

Honey bees are economically beneficial insects as they provide honey and other highly valuable products such as beeswax, royal jelly, propolis, pollen, and bee venom apart from rendering the most useful pollination services. Owing to this, beekeeping has emerged as a promising subsidiary occupation and attracting the attention of farmers in the current scenario of stagnation in farm income. Incidences of pests and diseases are major constraints in *A. mellifera* colonies. *G. mellonella* is considered as one of the most notorious and devastating insect pests of honey bees. *G. mellonella* larvae feed on combs, pollen, larval exuviae, and other proteinaceous matter both under stored and in live honey bee colonies. Various chemicals are being used for its management, but various problems are associated with the excessive use of chemical pesticides. In the present study, biorationals such as Neem oil, Neem Seed Kernel Extract (NSKE), Dhrek Seed Kernel Extract (DSKE), *B. thuringiensis* subsp. *kurstaki*, Azadirachtin 3000 ppm, and Azadirachtin 10,000 ppm were used in various concentrations for the management of *G. mellonella* by impregnating foundation wax sheet by the sandwich method.

2. Materials and methods

For preparing double-layered comb foundation sheets, a rectangular glass sheet of size 35.5×19.5 cm was first dipped into water containing surfactant (Lissapol) (5 mL in 1 L). Further, it was dipped into molten wax for one time. Then it was taken out and dipped into the water so that the two wax sheets, one on each side of the glass plank, could be easily separated. Different treatments were applied on one surface of the sheets using a smooth brush and then shade dried. Thereafter, two such sheets were joined in such a way that the treated surfaces come in contact with each other. Further, these twin sheets were passed through embossing rollers of a comb foundation mill to prepare a comb foundation with a double layer. These comb foundations were then inserted into frames. Finally, each frame was provided to a pre-equalized 8 bee-frame *A. mellifera* colony. After the combs were drawn by the bees, they were left in the hives, and observations were made on the amount of egg laying and survival of larval and pupal brood. After completing one life cycle of honey bees on combs, the developing brood, if any, was removed. These combs were stored in chambers by releasing two 2nd instar larvae of greater wax moth per treated comb in the month of June. It was followed by recording observations on percent of comb area damaged by released *G. mellonella* larvae.

3. Results and discussion

Among the various treatments, *Bt kurstaki* @ 7% was the most effective. Initially raising of comb foundation sheets by honey bees was slow due to the repellent effect of neem products but after 72 h of providing the double-layered wax comb foundation sheets, all the sheets were fully raised (means raised comb area being 1599.60 cm^2). Larval (97.74%) and pupal (99.09%) survival of *A. mellifera* was found to be significantly highest in sheets treated with *Bt kurstaki* @ 7%. The percent comb area infested by *G. mellonella* larvae was found to be least in sheet treated with *Bt kurstaki* @ 7% (126.43 cm^2) as compared to other treatments. Elbambi (1992) studied the effect of bacterial biopesticide *B. thuringiensis* on the honey bee and larvae of the greater wax moth. He found that there was no evidence that the bacteria affected the honeybee activity or age, but it was more effective in reducing activity and increasing the mortality ratio of the greater wax moth larvae. Thus it can be concluded that *Bt* was found to be more persistent than all other biorationals. Also, *Bt* did not show any adverse effect on honey bees. So, *Bt* can be used for the management of greater wax moth.

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3.35 Characterization of CAPAr gene from *Bemisia tabaci* Asia II 1

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Keywords: *CAPA receptor; Isoforms; Whitefly*

1. Introduction

B. tabaci (Gennadius) is a species complex having economic importance with worldwide distribution. Using modern biotechnological tools, functions of various genes have been characterized in whitefly and other insects. Insect G-protein coupled receptors (GPCR), also known as seven transmembrane receptors, play an important role in the regulation of insects' physiological processes. Hence, they prove to be ideal candidates for the development of next-generation new chemistry insecticides. In whitefly, diuresis is a key physiological process that helps in excreting out the waste substances. *CAPA* peptide and its G-protein coupled receptor (GPCR) interaction is a key factor responsible for the diuresis process in insects. The present investigations aimed to characterize the *CAPA* receptor (*CAPAr*) gene in whitefly.

2. Materials and methods

The predicted sequence of the *B. tabaci BtabCAPAr* gene was identified through BLAST analysis in National Centre for Biotechnology Information (NCBI) and whitefly genome database using the available receptor gene sequence of other insects. Total RNA was isolated and cDNA was synthesized. The full-length *BtabCAPAr* gene was amplified from synthesized cDNA and cloned into pGEM®-T Easy. The sequence was BLAST analyzed in NCBI and nucleotide sequences were aligned in the CLC sequence viewer. The complete nucleotide sequences of the *BtabCAPAr* gene and predicted sequence were translated into protein and aligned together to see the variation in the amino acids (aa). The amino acid sequence of the *BtabCAPA*r gene was analyzed to decode the transmembrane topology using TMHMM Server v.2. The putative homologs of *CAPAr* genes from other insects were retrieved from the online NCBI database and the phylogenetic tree was constructed using MEGA version 10.2.6.

3. Results and discussion

Two isoforms of *CAPAr* gene, that is, *BtabCAPAr*-1 (1263 bp, 421aa) and *BtabCAPAr*-2 (1065 bp, 355aa), were identified (Figure 1). BLAST analysis of *BtabCAPAr*-1 and *BtabCAPAr*-2 isoform sequences showed 98.26% and 98.56%, respectively, identity with the predicted gene in NCBI. The isoform differs by missing of 198 nucleotides and 66 aa residues in the *BtabCAPAr*-2 as compared to *BtabCAPAr*-1. The nucleotide sequence alignment of *BtabCAPAr*-1 and *BtabCAPAr*-2 isoforms with the reference gene (XM_019044129.1) revealed the nucleotide substitutions at 22 and 16 positions, respectively. In both the isoforms, a single amino acid difference was observed where 'Alanine' in the reference gene sequence (XM_019044129.1) was replaced by 'Glutamine' in the *CAPAr* gene isoforms. The *CAPAr* gene variants have also been reported for *R. prolixus*, namely, *capa-r1* and *capa-r2* (Paluzzi *et al*., 2010). The *BtabCAPAr*-1 and *BtabCAPAr*-2 have seven and five transmembrane domain polypeptides, respectively. The phylogenetic relationship revealed that the *BtabCAPAr*-1 and *BtabCAPAr*-2 isoforms formed a single clade with predicted reference *CAPA* receptor gene isoforms. However, the *CAPAr* gene in other insect orders, namely, Hemiptera, Hymenoptera, Coleoptera, Diptera, and Lepidoptera, also showed close association with *BtabCAPAr* gene isoforms. The characterization of CAPAr in whitefly will be useful to further study its function in whitefly through RNAi and test the activity of CAPA peptides on the CAPAr gene.

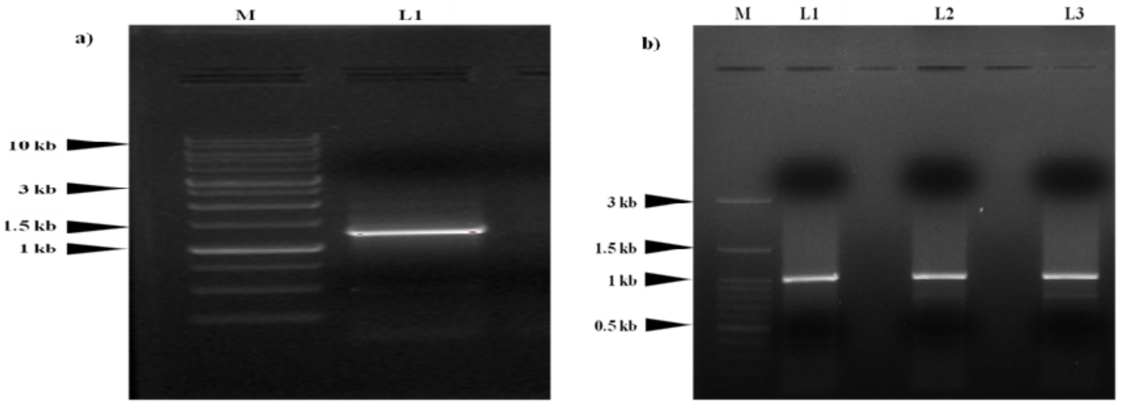

Figure 1 PCR amplification of (a) *Btab CAPAr-1* and (b) *BtabCAPAr-2* isoforms from whitefly *Bemisia tabaci*

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3.36 Impact of Adoption of IPM Technology Against Whitefly on Bt Cotton in Punjab

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Keywords: Adoption; Cotton; IPM; Socioeconomic status; Whitefly

1. Introduction

Bt cotton provides protection against bollworms, but it does not provide resistance against sucking insect pests. Among these, whitefly, leafhopper, thrips, and so on cause economic damage to cotton, and severe concerns were identified with whiteflies because of their high biotic potential, wider adaptability, and ability to transmit viral infections (Shera *et al*., 2020). Whitefly, *Bemisia tabaci* (Gennadius), appeared in the epidemic form in Punjab during *Kharif* 2015. Consequently, the cotton productivity in the Punjab state fell substantially from 574 kg lint/ha in 2014-15 to only 197 kg lint/ha in 2015-16 (Kumar *et al*., 2020). The excessive and injudicious use of insecticide tank mixtures with synthetic pyrethroids as one of the components has aggravated the problems of whitefly. Therefore, special attention is required to promote the IPM technologies on Bt cotton. The focus of an IPM program was on the use of non-chemical and to promote the judicious use of insecticides on the basis of economic threshold level (ETL) for reducing insecticide load in the environment. In this context, the impact of the adoption of IPM on the socioeconomic status of farmers was studied.

2. Materials and methods

Under the IPM project, Bathinda, Mansa, Sri Muktsar Sahib, and Fazilka districts, covering 80% of cotton growing areas, were selected for dissemination of IPM technology during 2018-19. In all eight adopted villages, the IPM technology was disseminated to farmers. The area under cotton in the IPM adopted farmers was 1625 acres. The numbers of farmers involved were 160.

In each village of the adopted districts, the literature pertaining to cotton production and protection technology was distributed to the farmers at their doorstep. Farmers' training program were organized at regular intervals in each village. The IPM strategy included regular surveillance of whitefly on alternate hosts, clean cultivation, timely sowing, use of non-chemical approaches such as yellow sticky traps, neem-based insecticides, use of insect growth regulators based on ETL, and proper spray methodology. IPM farmers were compared with non-IPM farmers and the impact of the adoption of IPM on the socioeconomic status of farmers was studied.

3. Results and discussion

In Punjab, the average number of insecticide sprays for IPM adopted farmers was 5.67. However, it was 6.75 in non-IPM adopted farmers. There was an 18.37% reduction in the number of sprays over non-IPM adopted farmers. The mean cost of sprays was more in non-IPM adopted farmers (Rs 3468.50) as compared to the adopted IPM farmers (Rs 3224.50). However, the percent reduction in the cost of sprays was 7.03% over non-IPM. In the IPM project area, the maximum number of sprays was for the control of whitefly and jassid. The cost of cultivation was slightly less for the adopted IPM farmers (Rs 14,655/acre) as compared to non-IPM adopted farmers (Rs 15,863/acre). Seed cotton yield was higher (9.91 q/acre) in adopted IPM farmers as compared to non-IPM adopted farmers (8.94 q/acre). So the average net profit was more (Rs 47,251.25) for the adopted IPM farmers as compared to non-IPM adopted farmers (Rs 37,777). The impact of dissemination of IPM technology led to successful management of whitefly in adopted villages with a reduction of insecticides cost and number of sprays. The additional profit of the adopted IPM farmers over non-IPM adopted farmers was Rs 9474.25 per acre (Table 1).

Table 1 Impact of cotton IPM technology on the economics and net returns of farmers in Punjab

Village	Area under cotton	Number of insecticide sprays	Cost/ acre (Rs)	Yield (q/acre)	Cost of input (Rs/acre)	Cost of farm operation (Rs/acre)	Cost of cultivation (Rs/acre)	Gross return (Rs)	Net return (Rs)
IPM adopted farmers									
Mansa	452	5.68	3150	10.52	6525	8250	14775	65750	50975
Muktsar	344	5.33	2960	9.56	6615	7250	13865	59750	45885
Bathinda	383	5.51	3295	9.82	6480	7150	13630	61375	47745
Fazilka	446	6.15	3493	9.72	6730	9620	16350	60750	44400
Mean/Total	**1625**	**5.67**	**3224.50**	**9.91**	**6587.50**	**8067.50**	**14655.00**	**61906.25**	**47251.25**
Non-IPM adopted farmers									
Mansa	197	7.11	3365	9.20	6822	8850	15672	55200	39528
Muktsar	144	6.60	3415	9.12	7550	7560	15110	54720	39610
Bathinda	283	6.15	3450	8.54	7520	7490	15010	51240	36230
Fazilka	132	7.15	3644	8.90	7450	10210	17660	53400	35740
Mean/Total	**756**	**6.75**	**3468.50**	**8.94**	**7335.50**	**8527.50**	**15863.00**	**53640.00**	**37777.00**

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3.37 Occurrence of Corm Rot of Saffron in District Kishtwar of Jammu and Kashmir

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Keywords: Corm rot; *Fusarium oxysporum*; Kishtwar; Saffron

1. Introduction

Globally saffron (*Crocus sativus* L.) is cultivated in India, Afghanistan, China, Iran, Spain, Greece, Italy, Iraq, Turkey, France, Switzerland, Israel, Azerbaijan, Egypt, UAE, Japan, Morocco, and Australia. India contributes 3.0% and 5.8% in the total area and production of saffron, respectively. The declining saffron production is associated with corm rot complex, caused by *Bacillus croci*, *Penicillium corymbiferum*, *Macrophomina phaseolina*, *F. solani*, *F. oxysporum f. sp. gladioli*, *Sclerotium rolfsii*, *Aspergillus niger*, *Rhizoctonia crocorum*, *Burkholderia gladioli*, *F. oxysporum*, and *Penicillium solidum*. These pathogens can survive in soil and directly penetrate the corms or gain entry through roots or wounds (Palmero *et al*., 2014). Precise knowledge regarding the occurrence of disease and population dynamics of pathogens is prerequisite for devising sustainable disease management strategies. Hence, the present investigation was undertaken with an aim to study the occurrence of corm rot of saffron and to determine the prevalence of major pathogens associated with it.

2. Materials and methods

Ten prominent saffron-growing villages, namely, Lower Poochal, Upper Poochal, Nagin, Hatta, Laynyal, Tund, Matta, Cherrhar, Bhera-bhata, and Hullar, in the district Kishtwar (Union Territory of Jammu & Kashmir) were surveyed to ascertain the status of corm rot disease. In each field, a plot of 1 m^2 was marked and all the corms were carefully dug out with a shovel during the harvesting season of daughter corms (July). These were examined for the characteristic symptoms of corm rot infection. The disease was assessed as percent incidence and severity at each location. These were calculated as given below (Gupta and Vakhlu, 2015)

$$\text{Disease incidence (\%)} = \frac{\text{Percent of corms infected in a particular field}}{\text{Total number of corms collected in selected field}} \times 100$$

$$\text{Disease severity (\%)} = \frac{0(Hn) + 1(Xn) + 2(Yn) + 3(Zn)}{\text{Total number of corms collectd in selected field}} \times 100$$

Here,

Hn = No. of healthy corms

Xn = No. of corms having lesions covering less than half of the corm

Yn = No. of corms having lesions covering half of the corm

Zn = No. of corms having lesion covering more than half the corm

Thirty samples of infected corms were collected from each location, bagged, and labelled separately and brought to the laboratory for isolation of pathogen(s). Morphological examinations and the cultural characters of the isolated fungi were recorded and the observations compared with the standards (Cooke, 2006) for confirmation.

3. Results and discussion

During surveys, corm rot was observed to be prevalent in all the selected villages of Kishtwar district (Table 1). Overall disease incidence and severity were in the range of 42.67–59.33 and 17.80–37.78 per cent, respectively. Maximum corm rot (59.33%) incidence and severity (37.78%) were recorded from Lower Pochhal, followed by 57.33% and 35.00%, respectively, from Upper Pochhal. The minimum disease incidence (42.67%) and severity (17.80%) were recorded from village Hullar. The variations recorded in the incidence and severity of corm rot, across the selected locations, might be due to the variability in the built up of primary inoculum, predisposing factors, such as infection by nematodes, and poor agronomic practices. As the saffron crop in Kishtwar is cultivated under rainfed conditions, frequently occurring droughts and lack of precipitation during the phonologically critical months of September and October tend to increase the incidence of corm rot. Out of various myco-pathogens, *F. oxysporum* was the dominant pathogen recorded in all collected samples. Maximum prevalence of *F. oxysporum* was recorded in Hatta (40.00%) followed by Upper Poochal, Matta, Hullar, and Laynal (36.67% each), whereas 33.33% each was recorded from Lower Poochal, Cherrhar, and Nagin. *F. solani* was the second most dominant pathogen having the maximum prevalence of 26.67% each in Upper Poochal and Cherrhar, followed by 23.33% in Bhera-bhata and 20.0% each from Lower Poochal, Matta, and Tund (Figure 1). On the basis of the occurrence of pathogens isolated from the infected corms, it could be concluded that *F. oxysporum* plays an important role in the corm rot complex disease of saffron in Kishtwar district.

Table 1 Percent disease incidence and severity of corm rot of saffron recorded in Kishtwar district

Location	Corm rot of saffron	
	Disease incidence (%)	Disease severity (%)
Lower Poochal	59.33	37.78
Upper Poochal	57.33	35.00
Matta	48.67	23.89
Hatta	56.00	26.11
Bhera-bhata	45.00	20.56
Cherrhar	46.67	23.33
Hullar	42.67	17.80
Tund	50.33	23.89
Laynal	54.67	25.00
Nagin	56.67	27.22

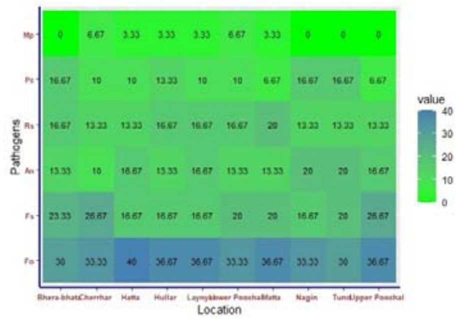

Figure 1 Prevalence of the myco-pathogens associated with the corm rot of saffron Fo=*F. oxysporum*; Fs=*F. solani*; Rs=*Rhizoctonia solani*; An=*Aspergillus niger*; Pc=*Penicillium corymbiferum*; Mp=*Macrophomina phaseolina*

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3.38 Evaluation of Different IPM Modules for the Management of Major Insect Pests of Linseed (*Linum usitattisimum* L.)

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Keywords: Evaluation; IPM; Modules; Linseed; Linseed bud fly; *Helicoverpa armigera*

1. Introduction

Nowadays, linseed which is also known as flaxseed has emerged as an important functional food ingredient to mitigate the risk of many disorders and diseases and also holds a significant share in food industries. The seed of linseed contains 37–43% oil which is highly valued for its nutraceutical properties and fiber content. It is the most abundant source of α-linolenic acid (ALA) which is the precursor of docosahexaenoic acid, structural material for nervous tissue, including the brain. Linseed crop is attacked by a large magnitude of insect pests in the different growth stages of the crop. Among these, linseed bud fly, *Dasineura lini* Barnes, and *Helicoverpa armigera* Hubner are the key pests of linseed and cause 88% grain yield losses (Mukherji *et al*., 1999). Bud fly alone causes economic loss in seed yield ranging from 24.47% to 56.22%, while Minz (2007) reported that the yield loss caused by bud fly and capsule borer simultaneously remained up to 61.75% on linseed crop. Minz (2007) reported that imidacloprid (0.02%) was found to be most effective in terms of insecticidal efficacy in regulating the linseed bud fly, whereas the incidence of capsule borer was reduced maximum by lambda cyhalothrin (0.005%) followed by cypermethrin (0.005%) and oxydemeton methyl (0.025%). Among the botanical insecticides, NSKE (4%), Vanguard (0.100%), and Karanj oil (2%) were proved to be moderately effective against the incidence of bud fly and capsule borer and remained superior over the untreated check. The rationale of the study was to manage major insect pests of linseed by evaluating different IPM modules for the management of major insect pests of linseed (*L. usitattisimum* L.).

2. Materials and methods

The experimental trial on the management of major insect pests of linseed (*L. usitattisimum* L.) was conducted at the Entomology field, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu during *Rabi* season 2019-20. Cultural operations were done according to the package of practices of SKUAST-Jammu 2016. The experiment was laid out in randomized block design (RBD) with three replications. The crop variety of Neelum was selected for sowing in the line sowing method in November 2019. The plot size was 5×3 m and plant geometry was 30×10 cm. Data for linseed bud fly and *Helicoverpa* were recorded from different fields. There were five different modules for efficiently managing the major insect pests of linseed which have been validated under the field condition and depicted in Table 1.

Table 1 Different IPM modules for managing the major insect pests of linseed

Modules	Treatments
Module-I (Bio-intensive IPM modules)	1. Cultural practices like 2 weeding and hoeing 2. Soil application of Neem cakes @ 500 kg/ha 3. Installation of Delta Traps 4. Spraying of Neem oil 5% at the time of bud damage stage (dough stage) 5. Installation of Pheromone traps 6. Installation of Bird perches 7. Spraying of HaNPV @ 250 LE/ha 8. Spraying of Bt formulation @ 500 g/ha (ETL 5 moths trap catches/week or 1 larva/m^2).
Module II (IPM modules)	1. Cultural practices like 2 weeding and hoeing 2. Soil application of cartap hydrochloride 4G @ 20 kg/ha 3. Installation of Delta Traps 4. Poison Baiting with malathion+Gur 5. Installation of Pheromone traps 6. Installation of Bird perches 7. Spray the crop with Novaluron 10EC @ 1 mL/L of water 8. Spraying of Spinosad @ 0.2 mL/L of water (ETL 5 moths trap catches/week or 1 larva/m^2)
Module III (Chemical modules)	1. Cultural practices like 2 weeding and hoeing 2. Soil application of carbofuran 3G @ 30 kg/ha 3. Installation of Delta Traps 4. Spot spraying of Poison bait with malathion+Gur 5. Installation of Pheromone traps 6. Installation of Bird perches 7. Spraying the crop with dimethoate 30 EC @ 1.5 mL/lit 8. Spraying of with Coragen @0.3 g/L (ETL 5 moths trap catches/week or 1 larva /m^2)
Module IV (Farmer's Practice)	–
Module V (Control)	Sole crop (Water spray)

3. Results and discussion

Among the five modules tested against bud fly damage, Module II was found to be superior in reducing the damage percentage of linseed bud fly (1.33%) at the vegetative stage. Module I and Module III were found at par in reducing the damage percentage of linseed bud fly (4.67% and 7.00%) than Module IV (12.00%) and Module V (13.00%). At the 50% flowering stage, Module II (8.00%) was found to be

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significantly superior in reducing the damage percentage of linseed bud fly on flowers over the rest of the modules. At the 50% capsule setting stage, the mean damage percentage of bud fly was observed wherein Module II (17.67%) again registered the least infestation followed by Module I (23.33%), which stood superior over the other modules. Regarding infestations of the larval population of *H. armigera* at the vegetative stage, Module III (1.00 larvae/m row length of plants) was found to be superior followed by Module II (2.33), Module I (4.33), Module IV (6.67), and Module V (8.00). However, a significantly higher larval infestation of plants was recorded on Module IV (6.67) and Module V or untreated check (8.00 larvae/m row length). At the 50% flowering stage, Module III (4.67 larvae/m row length) was found to be significantly superior in reducing the larval population of *H. armigera* on flowers. Overall, the impact of Module III was found to be the best and superior treatment combination than Module II, Module I, Module IV, and Module V in suppressing the borer larval population. In the case of yield attributes against *H. armigera,* all the modules showed significantly different results, that is, Module III (9.64 q/ha) accounted for maximum linseed yield than Module II (8.17 q/ha), I (6.53 q/ha), IV (4.97 q/ha), and V (4.32 q/ha) after harvest.

Table 2 Evaluation of different modules for the management of major insect pests of linseed on the basis of yield

Different types of IPM modules	**Yield from first picking (q/ha)* in the case of linseed bud fly *Dasyneura lini***	**Yield from first picking (q/ha)* in case of *Helicoverpa armigera***
Module I	7.5333^{c}	6.5333^{c}
Module II	9.8533^{d}	8.1733^{d}
Module III	6.3033^{b}	9.6367^{e}
Module IV	4.6967^{a}	4.9700^{b}
Module V	4.4433^{a}	4.3200^{a}

Note: Treatments with the same letter are not significantly different ($p < 0.05$) (ANOVA, Tukey HSD).

*Mean value of yield of three replications.

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3.39 Opinion of Vegetable Growers Regarding Pesticide use in Punjab

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Keywords: Opinion; Pesticide use; Vegetable; Vegetable growers

1. Introduction

The post-green revolution age has seen a phenomenal shift in cropping patterns in Punjab state, with primary concentration on wheat-paddy crop rotation and a reduction in the area under pulses, maize, oilseeds, fruits, vegetables, and so on. This has led to the exploitation of natural resources. Vegetable cultivation has emerged as an important enterprise for the farming community and many farmers have adopted it as a main source of the family income. During the year 2017-18, the area under vegetable crops in Punjab was 24.3 thousand hectares with a production of 4.91 million tons (Anonymous, 2018). Chemical pesticides are without a doubt the most efficient, short-term control tool for a number of agricultural pests and pathogens, but their negative impacts on human, animal and environmental health have also been extensively documented (Tyagi *et al*., 2015) and their indiscriminate use over the years is a cause of concern. In certain circumstances, improper pesticide uses results in air pollution and the deterioration of different systems, such as agro-ecosystems, marine life and alluvial groundwater aquifers (Foster *et al*., 1991). Though no part of the human population is fully immune to pesticide exposure, occupationally exposed groups, such as those engaging in agricultural operations and pesticide manufacture, face a substantially higher risk. Farmer's exposure to pesticides is unavoidable; therefore, knowing the repercussions of pesticide misuse and the possible risk connected with it is essential. This study intends to learn about the opinion of the vegetable growers regarding pesticide use in the Punjab state.

2. Materials and methods

The study was conducted in Punjab state (Jalandhar, Sangrur and Amritsar districts). Two clusters of five villages each having a maximum number of vegetable growers were selected from each district. Thirty-five vegetable growers (of pea, tomato, potato, brinjal, chilli, and okra) were randomly selected from each cluster, and hence 70 vegetable growers were selected from each district. Thus, a total of 210 vegetable growers were the respondents of the study.

3. Results and discussion

Table 1 depicts the opinion of respondents regarding pesticide use in vegetable crops. The majority of the respondents opined that pesticides help in decreasing losses made by pests while half of the respondents disagreed with the opinion that a prolonged period of exposure to pesticides leads to serious health risks. About 60.96% of the respondents were of the opinion that farm laborers should be made aware of the risks involved in applying pesticides without proper safety measures and precautions while 64.76% of the respondents thought that pesticides have no residual effects. 60.48% of the respondents opined that pesticides can pollute air, soil and water while 46.67% of the respondents disagreed that indiscriminate use of pesticides contributes to many negative effects on the environment and health of humans/animals.

Table 1 Distribution of respondents according to opinion regarding pesticide use

Items	AG	DG	N	Mean score	Rank	SD	Correlation coefficient			
		f (%)					Age	Education	Operational landholding	Farming experience
Pesticides help in decreasing losses made by pests	174 (82.86)	9 (4.29)	27 (12.85)	2.78	1	0.508	0.066	–0.061	0.012	0.063
Prolonged period of exposure to pesticides may lead to serious health risks	72 (34.28)	106 (50.48)	32 (15.24)	1.83	8	0.908	–0.111	0.246**	0.170*	–0.199**
Farm laborers should be made aware of the risks involved in applying pesticides without proper safety measures and precautions	128 (60.96)	53 (25.23)	29 (13.81)	2.35	6	0.859	0.145*	0.233**	0.131	0.158*
Pesticides have residual effects	43 (20.47)	136 (64.76)	31 (14.76)	1.55	11	0.812	–0.136*	0.252**	0.173*	–0.212**
Pesticides can pollute the air, soil and water	127 (60.48)	17 (8.10)	66 (31.42)	2.52	5	0.643	–0.213**	0.278**	0.075	–0.211**
Indiscriminate use of pesticides contributes to many negative effects on the environment and the health of humans/animals	66 (31.43)	98 (46.67)	46 (21.90)	1.84	7	0.872	–0.123	0.206**	0.128	–0.177*
Excessive use of pesticides can kill natural predators of pests/friendly insects/parasitoids/pollinators	27 (12.86)	134 (63.81)	49 (23.33)	1.49	12	0.714	–0.099	0.311**	0.175*	–0.187**
Pesticides cause not only acute but also chronic pesticide poisoning in humans	41 (19.53)	117 (55.71)	52 (24.76)	1.63	10	0.790	–0.101	0.266**	0.111	–0.185**

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Non-chemical methods are inefficient as compared to chemical methods of pest control	153 (72.85)	23 (10.96)	34 (16.19)	2.61	3	0.676	–0.062	0.179**	–0.026	–0.063
Using pesticides in more than recommended doses and frequencies will kill the pests more effectively	159 (75.71)	32 (15.24)	19 (9.05)	2.60	4	0.739	–0.034	0.056	0.020	–0.092
The use of pesticides is one of the important ways of increasing farm income	76 (36.20)	114 (54.28)	20 (9.52)	1.81	9	0.936	–0.151*	0.293**	0.178**	–0.209**
Technical information regarding pesticides is beyond the comprehension of any ordinary farmer	166 (79.05)	23 (10.95)	21 (10.00)	2.68	2	0.662	0.017	–0.053	0.046	0.009

*Significant at 0.05 level **Significant at 0.01 level AG, DG, N stands for Agree, Disagree, No opinion

Punjab is an agrarian state, so farmers and farm laborers should be made aware of the potential risks involved in prolonged exposure to pesticides. Village level campaigns regarding the ill effects of overuse of pesticides on the environment and human health should be promoted. Alternative approaches to chemical use such as Integrated Pest Management (IPM), which has the potential to reduce the quantity of pesticide use and exposure to chemicals, should be promoted for vegetable cultivation.

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3.40 Weather/Crop Ecology – What Influences *Spodoptera litura* Population?

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Keywords: Pheromone trap; *S. litura*

1. Introduction

India is one of the largest producers of oilseeds and pulses in the world. Groundnut is an important oilseed crop grown on 26.4 million ha worldwide with a total production of 37.1 million metric tons and average productivity of 1.4 metric t/ha. A polyphagous insect pest, *S. litura* Fabricius (Lepidoptera: Noctuidae) has been causing immense damage to various crops including groundnut across India (Niranjan Kumar and Regupathy, 2001). Kulkarni (1989) found that a severe infestation of this pest caused a yield loss of 66.6% in groundnut at Dharwad. The pheromone traps offer one of the best sampling tools for flying adult insects and have been used commonly for pest surveillance (Prasannakumar *et al*., 2012). The interaction between pheromone trap collections and prevailing weather during the period in any area for a fairly long period can be used for the development of models to predict seasonal pest incidence (Agarwal and Mehata, 2007).

2. Materials and methods

The *S. litura* male moth catches in the sex pheromone trap from 2012 to 2021 (10 years) during the *Kharif* season was used for the study. A weekly total was obtained from daily average catches of male moths in three pheromone traps located exclusively in groundnut fields within a distance of 100 m between traps located at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The lures were changed once every 15 days throughout the season. The sleeve traps with commercially available *S. litura* pheromone (Z,E)-9,11-tetradecadieny-lacetate and (Z,E)-9,12-tetradecadienyl (at the ratio of 10:1) and the quantity of the chemical present was 0.84 mg per lure (PCI made). Male moths trapped from 26 to 42 standard meteorological week (SMW) was considered for analysis. The average weekly total number of moths trapped and the average weather parameters of the corresponding SMW were considered for analysis. The weather variables such as maximum and minimum temperature, morning and evening relative humidity, and total weekly rainfall were considered independent variables.

3. Results and discussion

The pheromone trap catches of *S. litura* were studied from 2012 to 2021 at MARS, Dharwad. The pheromone trap collection from 26th (first week of July) to 44th SMW (last week of October to the first week of November) was considered for analysis. The peak trap catches of *Spodoptera* male moth during this decade (2012–2021) varied between 31st and 37th SMW in the majority of years. The level of *Spodoptera* incidence was low in 2012, 2015, and 21 and was almost nil in 2019 and 2016 (Table 1). The pest incidence level and peaks may vary from place to place depending upon the prevailing weather and crop ecology. The number of male moths trapped was correlated with corresponding weather parameters such as maximum and minimum temperature, morning and evening relative humidity, and rainfall. The average total trap catches from 2012 to 2016 were not significant with any of the weather parameters. However, trap catch between 2017 and 2021 exhibited significant negative and positive relations, respectively, with maximum temperature (-0.762^{**}) and evening RH (0.786^{**}) at a 0.01% level. Similarly, it was positive and significant with morning RH (0.490^{*}) at a 0.05% level. The average total trap catches from 2012 to 2021 exhibited a significant negative correlation with maximum temperature (-0.476^{*}), whereas it was positive with morning (0.497^{*}) and evening RH (0.539^{*}) at a 0.05% level (Table 2). The increased temperature probably reduces the *Spodoptera* population. Conversely, higher humidity positively supports the *Spodoptera* population growth and multiplication. The relative humidity ranging from 89% to 92% supported the higher population and growth of *S. litura*. Further, a negative relation with temperature was also reported in the past by Selvaraj *et al*. (2010).

The correlation studies indicated that increasing temperature and decreasing relative humidity reduce the *Spodoptera* population. However, the *Spodoptera* population was almost nil during the years 2016 and 2019 at Dharwad despite very favorable relative humidity (more than 90% almost throughout the *Kharif* cropping season) and moderate temperature. This indicates that there may also be a few other factors such as environmental resistance and the changing cropping pattern in the region may also play a vital role in deciding the *Spodoptera* population.

Table 1 Pheromone trap catches of *S. litura* male moth (2012–2021)

SMW	Year										Mean
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
26	28	0	0	0	33	9	0	3	36	13	12.20
27	45	0	0	0	42	13	7	4	70	17	19.80
28	62	0	6	3	24	28	17	4	83	21	25
29	93	0	9	16	25	32	26	4	162	100	47
30	138	5	11	27	20	48	39	0	196	112	60
31	139	37	30	41	17	113	97	1	223	144	84
32	220	78	61	56	21	171	158	0	217	195	118
33	374	45	89	79	5	89	71	0	164	214	113
34	648	56	105	645	4	69	60	0	130	256	197
35	624	85	126	424	0	54	46	1	82	293	174
36	382	39	181	314	0	45	45	0	49	335	140
37	297	18	263	206	0	33	28	1	36	246	113

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SMW	Year										Mean
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
38	240	30	218	138	0	21	19	1	27	185	88
39	151	146	174	91	0	12	5	0	19	75	67
40	153	188	77	59	0	7	0	0	6	40	53
41	79	9	23	21	0	3	0	0	4	2	14
42	28	0	6	7	0	0	0	0	0	2	4
43	13	0	6	0	0	0	0	0	0	1	2
44	2	0	6	0	0	0	0	0	0	0	1

Table 2 Relation between trap collections and weather parameter

	Temperature		Relative humidity		Rainfall
	Max	Min	Morning	Evening	
Moth catch (2012–2016)	–0.244	0.167	0.359	0.318	–0.105
Moth catch (2017–2021)	–0.762**	0.389	0.490*	0.786**	0.382
Moth catch (2012–2021)	–0.476*	0.291	0.497*	0.539*	0.015

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3.41 Management of Rice Blast Disease Caused by *Pyricularia oryzae* through Application of Biocontrol Agents and Fungicides Alone and in Possible Combination

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Keywords: Biocontrol agents; Fungicides; Integrated disease management; *P. oryzae*; Rice blast disease

1. Introduction

Among the cereals, rice (*Oryza sativa*) is an important food crop. The rice crop is reported to be attacked by many microorganisms such as fungi, bacteria, viruses, and phytoplasma causing many diseases. The rice blast is caused by *Magnaporthe oryzae* (Couch and Kohn, 2002), which is considered a major disease in all rice-growing areas. The fungus *P. oryzae* has many races which are easily adapted to the environmental conditions. The new races formed usually are more virulent than the old ones. Repeated use of fungicides is causing severe concern to the resistance in the pathogen, health, and environment. In view of these, the development of eco-friendly IDM-based control measures for rice blast was proposed in this study.

2. Materials and methods

In vitro evaluation of different biocontrol agents

Three biocontrol agents, namely, *Trichoderma viride*, *T. harzianum*, and *Pseudomonas fluorescens*, were tested *in vitro* for their antagonistic effect against *P. oryzae* by the dual culture technique. The experiment was conducted in a completely randomized design with four replications.

In vitro evaluation of different fungicides

The bio-efficacy of contact fungicides Mancozeb, Captan, Copper Oxychloride, Chlorothalonil (@100, 250, and 500 ppm), systemic fungicides Hexaconazole, Carbendazim, Tricyclazole, Azoxystrobin, Propiconazole (@25, 50, and 100 ppm), and one combination fungicide Tebuconazole 50%+Trifloxystrobin 25% (@25, 50, and 100 ppm) was evaluated under laboratory conditions using the poisoned food technique against *P. oryzae* to record the inhibition of radial growth.

Integrated disease management under field conditions

The integrated management of rice blast was evaluated under field conditions to find out the efficacy of effective biocontrol agents, namely, *T. harzianum* and *T. viride*, and fungicides, namely, Tricyclazole and Tebuconazole 50%+Trifloxystrobin 25%, against *P. oryzae*, which showed the best efficacy against *P. oryzae* under *in vitro* conditions.

Disease assessment

The percent disease index (PDI) was calculated by using the following formula:

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of individual disease ratings}}{\text{Total no. of plants observed}\times\text{Maximum grade}} \times 100$$

3. Results and discussion

In vitro evaluation

The minimum mycelial growth of the *P. oryzae* was observed in the case of *T. harzianum* followed by *T. viride*. Among fungicides, tricyclazole showed the minimum mycelial growth of *P. oryzae* followed by the combination fungicide Tebuconazole (50%)+Trifloxystrobin (25%). Our results are in agreement with Naik and Jamadar (2014) who evaluated *in vitro* the bioassay of systemic fungicides against *P. grisea* where tricyclazole showed maximum mycelial inhibition.

Integrated disease management under field conditions

Effect on the severity of disease

Pooled analysis of data for 2 years (2018 and 2019) showed that the rice blast severity ranged from 7.85% to 39.57 % (Table 1). The combination of seed treatment with Tricyclazole @ 2 g/kg of seed along with two foliar sprays of combination fungicide (Tebuconazole 50%+Trifloxystrobin 25%) @ 0.01% recorded the lowest disease severity followed by a combination of seed treatment with Tricyclazole @ 2 g/kg and two foliar sprays of Tricyclazole @ 0.01%.

Effect on grain yield

Table 1 also revealed that the maximum grain yield (29.60 q/ha) was recorded with seed treatment of Tricyclazole @ 2 g/kg of seed along with two sprays of Tebuconazole 50%+Trifloxistrobin 25% @ 0.1% which is statistically at par with seed treatment of Tricyclazole @ 2 g/kg of seed along with two sprays of Tricyclazole @ 0.1% (28.78 q/ha) followed by seed treatment of *T. harzianum* @ 8 g/kg of seed+two sprays of Tebuconazole 50%+Trifloxistrobin 25% @ 0.1%. The results are in agreement with Rao and Kumar (2018) who conducted a field experiment on integrated management of blast by using fungicides, plant extracts, and biocontrol agents.

It can be concluded that the treatments with the use of biocontrol agents were observed as the second best treatment. Therefore, for lowering the pesticidal load on produce and the input cost of the farmer, these treatments may be recommended.

Table 1 Pooled data analysis for integrated disease management of rice leaf blast under field conditions during 2018 and 2019

Treatment	Disease severity (%)	Percent control	Yield (q/ha)	Percent increase in yield
Seed treatment of *Trichoderma harzianum* @ 8 g/kg of seed	38.06	3.96	23.4	1.96
Seed treatment of tricyclazole @ 2 g/kg of seed	37.07	7.41	23.58	2.71
Two sprays of tricyclazole @ 0.1%	21.59	45.52	25.93	11.56
Two sprays of tebuconazole 50%+trifloxistrobin 25% @ 0.1%	20.98	47.00	26.62	13.77
Two sprays of *T. harzianum* @ 2%	34.35	13.27	24.40	5.85

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Treatment	Disease severity (%)	Percent control	Yield (q/ha)	Percent increase in yield
Two sprays of *T. viride* @ 2%	36.54	7.79	23.75	3.37
Seed treatment of *T. harzianum* @ 8 g/kg of seed+two sprays of tricyclazole @ 0.1%	17.42	56.08	27.45	16.39
Seed treatment of *T. viride* @ 8 g/kg of seed+two sprays of tricyclazole @ 0.1%	20.02	49.88	26.93	14.70
Seed treatment of tricyclazole @ 2 g/kg of seed+two sprays of tricyclazole @ 0.1%	10.33	73.85	28.78	20.26
Seed treatment of *T. harzianum* @ 8 g/kg of seed+two sprays of tebuconazole 50%+trifloxistrobin 25% @ 0.1%	13.00	67.11	28.33	18.99
Seed treatment of *T. viride* @ 8 g/kg of seed+two sprays of tebuconazole 50%+trifloxistrobin 25% @ 0.1%	15.53	60.64	27.77	17.34
Seed treatment of tricyclazole @ 2 g/kg of seed+two sprays of tebuconazole 50%+trifloxistrobin 25% @ 0.1%	7.85	80.23	29.60	22.40
Seed treatment of *T. harzianum* @ 8 g/kg of seed+two sprays of *T. harzianum* @ 2%	29.65	25.94	25.23	9.02
Seed treatment of *T. viride* @ 8 g/kg of seed+two sprays of *T. viride* @ 2%	31.16	21.34	24.62	6.76
Control	39.57	–	22.97	–
CD (p = 0.05)	1.70		1.27	

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3.42 Morpho-cultural Variability in *Rhizoctonia solani* Associated with Black Scurf of Potato in Jammu

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Keywords: Jammu; Morpho-cultural variability; Potato; *R. solani*

1. Introduction

Black scurf of potato caused by *R. solani* Kuhn affects the potato crop globally as well as in India and the losses may range between 10% and 25%. The disease causes significant damage in cool and wet soil. The pathogen is posing a possible threat to rapidly expanding seed potato cultivation in North Indian states. Pathogen exhibits symptoms on both above- and belowground plant parts of potatoes. The brown to black sclerotia on potato tubers, often known as 'black scurf of potato', is the most conspicuous and distinct sign. *R. solani* exhibits diversity in the cultural and physical traits that may have an impact on how the disease is to be managed (Guleria *et al*. 2007). Therefore, research on variability in *R. solan*i isolates is important for breeding programmes as well as the development of cost-efficient and efficient disease control strategies.

2. Materials and methods

Thirty-two isolates collected from different villages and seed-tuber multiplication farms of the Jammu district were designated as JRS-1 to JRS32. The sclerotia of collected isolates were individually placed in an aseptic manner on PDA petri plates. Isolates were further sub-cultured on PDA. Cultural and morphological variability was determined by taking observations of colony color, growth, texture, and hyphal diameter. Sclerotial characteristics such as color, texture, intensity, size, honeydew secretion, arrangement pattern, and location of sclerotia were also recorded. Based on colony and sclerotial characteristics, isolates were categorized under different groups.

3. Results and discussion

R. solani isolates were categorized into different groups on the basis of morphological parameters (Table 1). Based on the colony growth rate, the isolates were grouped as slow, medium, fast, and faster. Isolates that had colony growth rate of more than 0.90 mm/h were categorized as faster, whereas the isolates that had a growth rate of 0.71–0.90 mm/h were categorized as fast. The medium growth rate isolates showed a 0.51–0.70 mm/h growth rate and slow category isolates showed a growth rate of 0.30–0.50 mm/h. A colony growth study revealed that out of 32 isolates, 8 isolates (i.e., 25.0%) exhibited a slow growth rate, 7 isolates (i.e., 21.87%) exhibited a medium growth rate, and 11 isolates (i.e., 34.37%) showed a fast growth rate. However, the faster gowth rate was observed in six isolates (i.e., 18.75%).

On the basis of colony texture, isolates were categorized into three groups, that is, appressed, raised, and fluffy. Twenty isolates (i.e., 62.5%) had appreseed colony texture and four isolates (12.5%) had fluffy colony texture, whereas eight isolates (25%) had raised colony texture. The isolates varied in colour appearance and showed four types of colony color. Nine isolates (28.12%) showed light yellowish-brown colour, three (10.25%) were pale brown, and 18 (56.25%) showed pale yellow colour, whereas one was brown in color. Hyphal diameter of 32 isolated ranged between 8 and 10 µm in size. (Table 1). Visible differences in sclerotial characters were observed after 12 days of incubation. The characters, namely, sclerotial arrangement, sclerotial intensity, sclerotial size (mm), sclerotial colour, honeydew secretion, and sclerotial location, were recorded and categorized into different groups. Based on the pattern of sclerotial arrangement, 12 isolates (37.5%) showed sclerotia that aggregated at the center. Nine isolates (28.1%) isolates produced sclerotia in multiple rings, whereas four isolates (12.5%) exhibited the formation of sclerotia in aggregation at the center with peripheral sclerotial ring. The isolates were also different in the number of sclerotia produced per culture plate with significant differences observed in sclerotial size that ranged from 0.1 to 3.0 mm. Sclerotia were either produced on the surface of plate or aerially depending upon the mycelia growth. Sclerotial color of isolates varied from yellowish brown to dark brown. Seventeen isolates (53.1%) showed yellowish brown color, and 18.7% and 15.6% isolates showed brown and dark greyish brown color, respectively. Honeydew secretion was observed in 13 isolates. Conclusively, the study undertaken showed the presence of immense diversity in *R. solani* isolates in the Jammu region.

Table 1 Grouping of *R. solani* isolates on the basis of colony characters

Group description			Isolates name	No. of isolates in each group	Frequency (%)
Growth rate (mm/h)	Slow	0.30–0.50	JRS-1, JRS-2, JRS-8, JRS-13, JRS-25, JRS-26, JRS-28, JRS-32	8	25.0
	Medium	0.51–0.70	JRS-5, JRS-6, JRS-9, JRS-16, JRS-22, JRS-24, JRS-29	7	21.87
	Fast	0.71–0.90	JRS-3, JRS-4, JRS-7, JRS-14, JRS-15, JRS-18, JRS-19, JRS-23, JRS-27, JRS-30, JRS-31	11	34.37
	Faster	≥ 0.90	JRS-10, JRS-11, JRS-12, JRS-17, JRS-20, JRS-21	6	18.75
Colony texture	Appressed		JRS-1, JRS-2, JRS-4, JRS-5, JRS-6, JRS-8, JRS-9, JRS-10, JRS-12, JRS-13, JRS-14, JRS-15, JRS16, JRS-17, JRS-18, JRS-20, JRS-24, JRS-27, JRS-28, JRS-30	20	62.5
	Raised		JRS-3, JRS-7, JRS-21, J RS-22, JRS-23, JRS-25, JRS-26, JRS-29	8	25
	Fluffy		JRS-11, JRS-19, JRS-31, JRS-32	4	12.5
Colony color	Pale yellow		JRS-1, JRS-2, JRS-6, JRS-7, JRS-8, JRS-9, J RS-10, JRS-11, JRS-12, JRS-13, JRS-19, JRS-20, JRS-22, JRS-23, JRS-27, JRS-28, J RS-30, JRS-32	18	56.25
	Light yellowish brown		JRS-3, JRS-4, JRS-14, JRS-15, JRS-16, JRS-18, JRS-21, JRS-26, JRS-29	9	28.12
	Pale brown		JRS-5, JRS-24, JRS-31	3	10.25
	Brown		JRS-25	1	3.12
	Light brown grey		JRS-17	1	3.12

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3.43 Screening for Resistance Against Rust in Pea Genotypes Under Plains of Jammu Region

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Keywords: Pea; Rust; Vicia Lathyrus; Wild species

1. Introduction

The garden pea (*Pisum sativum* L.) belongs to the family Fabaceace. It is grown as a cool season vegetable crop in plains and low/mid hill regions in North India. The genus *Pisum* consists of about six species (i.e., *P. sativum*, *P. fulvum*, *P. abyssinicum*, *P. humile*, *P. elatius*, *P. jomardii*) mostly found in the Mediterranean area and West Asia. Pea is highly nutritive containing a high percentage of digestible protein along with carbohydrates, vitamins, and minerals. Pea improves soil health due to its biological nitrogen fixation ability, thereby reducing dependence on chemical fertilizers that are becoming more expensive and cause harm to the environment. Most cultivated pea varieties are susceptible to fungal diseases like pea rust, powdery mildew, wilt, and insect pests. Pea rust (*Uromyces pisi*) significantly reduces the yield and quality of pea across the country. The sources of resistance in wild species have earlier been reported through screening in Himachal Pradesh (Gupta, 1989). *Uromyces* is an autoecious rust fungus inflicting disease in many legume hosts and is widely distributed in many parts of the world. Pea rust is a major problem in those areas that are characterized by warm humid conditions. Thus, the current approach was used with the objective to assess the screening program against rust resistance sources of pea genotypes.

2. Materials and methods

The present study was conducted under subtropical conditions of Jammu at the vegetable experimental farm, Division of vegetable Science and Floriculture, FOA, SKUAST-J, Main Campus, Chatha, Jammu (J&K) during 2016-17 and 2017-18. A total 25 promising genotypes of pea (*P. sativum* L.) and one wild species (*P. fulvum* L.) and related genera were collected from different parts of the country and field evaluated against rust for two years 2016-17 and 2017-18 when diseased appeared early and caused severe yield losses.

3. Results and discussion

Pea rust appeared early in the season (January and February) when the pea crop was in the flowering or early pod formation stage during warmer and humid weather conditions that favored growth, reproduction, and spread of the rust pathogen. The field screening of 26 pea genotypes (promising lines, wild species) and 3 related genera during disease epidemic conditions for two successive years indicated a variable host plant reaction against pea rust (Table 1). Among the screening of 26 diverse genotypes, one wild genotype of pea bearing red flowers was found to be highly resistant to rust. The four cultivated pea genotypes, namely, Arka Priya, Arka Karthik, Arka Ajit, and Arka Apoorva, were tolerant to rust. But 18 cultivated pea genotypes were found to be highly susceptible and severe yield losses occurred. The other legumes *Vicia faba* (two accessions), *Lathyrus odoratus*, and *Lathyrus aphaca* showed an immune response. In one of the earlier studies, Gupta (1989) also reported variable type of host plant resistance response against rust in diverse pea genotypes and wild species (*P. humile* and *P. jomardii*) but immune type of reaction in related genera (*V. faba* and *L. aphaca*) under Palampur conditions. Vijayalakshmi *et al*. (2005) reported continuous distribution and considerable variation for the number of pustules per leaf in BC1F2 population suggestive of the polygenic nature of inheritance. Rai *et al*. (2011) also suggested rust resistance in the pea cross 'HUVP FC 1' to be a quantitative trait.

Table 1 Maturity group and rust reaction of pea genotypes, wild species, and related genera against rust

Genotype	Maturity group	Rust reaction (0–9 scale)	
		2016-17	2017-18
Palam Triloki	Early	9	9
Palam Priya	Late	9	9
Arka Karthik	Late	3	3
ArkaAjit	Medium	3	3
Arka Apoorva	Late	3	3
Arka Priya	Late	3	3
Azad Pea-3	Early	9	9
Arkel	Early	9	9
Vivek Matar-10	Medium	9	9
Vivek Matar-11	Medium	9	9
Matar Ageta-7	Medium	9	9
Mithi Phali	Late	9	9
P-89	Medium	9	9
Azad Pea-1	Late	7	7
VL Ageti Matar-7	Early	9	9
Matar Ageta-6	Early	9	9
PN-13	Medium	9	9
PSO-53	Medium	9	9
W-1-2	Medium	9	9
BT-2	Medium	9	9
PSO-54	Medium	9	9
BT-30	Medium	9	9
BT-29	Medium	9	9
Rachana	Medium	7	7
Wild Pea	Late	7	7
Leh Local	Late	0	0
Vicia faba	Late	0	0
Lathyrus odoratus	Late	0	0
Lathyrus sativus	Late	0	0

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3.44 Biological Control of Aonla Cottony Cushion Scale, *Icerya purchasi*, using Entomopathogens

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Keywords: Aonla; Biopesticides; Cottony cushion scale; *L. purchasi*

1. Introduction

Aonla (*Phyllanthus embellica*) is an important crop in subtropical regions of the country. Scales are an important pest of aonla causing heavy damage to the tree. These scales are managed using a variety of chemical pesticides. Managing this pest is tedious because of the natural waxy coating that covers its body. Hence, a higher concentration of pesticides has to be used that poses serious issues like residue, the resurgence of minor pests, pollution, and so on. The use of entomopathogenic fungi and botanicals may prove a better option for their management. In view of this, the experiment on seasonal incidence of cottony cushion scale and efficacy of entomopathogens and botanicals for the management of cottony cushion scale was designed.

2. Materials and methods

Field experiments were conducted during 2019-20, 2020-21, and 2021-22 with the objective to record the seasonal incidence of aonla scale and to assess the efficacy of various entomopathogens against it under field conditions at the Research Farm of Advanced Centre for Rainfed Agriculture, Dhiansar, SKUAST-Jammu. The experiment was laid in a randomized block design with five treatments and four replications each. Two trees made one replication, and thus treatments were imposed on eight randomized trees per treatment. Nucleus cultures of *Lecanicillium lecanii*, *Beauveria bassiana*, and *Metarhizium anisopliae* were obtained from NBAIR, which was further multiplied and assessed against scales, for three consecutive years. Entomopathogenic fungi *B. bassiana*, *M. anisopliae*, and *L. lecanii* formulations along with Azadirachtin 10,000 ppm were assessed against the Aonla scale. The first spray of entomopathogen biorational insecticide Azadirachtin was done in March and the second spray was done in April.

Pre-spray counts of the scale population, counting both adults and nymphs, were recorded immediately before the application of treatments. Post-spray counts after the first spray were recorded on the 3rd and 7th days after the application of entomopathogens. The second spray was carried out at 15 days interval. Percent reduction was calculated as per the formula suggested by Henderson and Tilton (1955). The data presented in Table 1 are the pooled data for 3 years and the data on post-spray count are after the second spray.

3. Results and discussion

The scale, *I. purchasi*, incidence in Aonla orchard was recorded standard week-wise. The population started increasing when the climatic conditions were congenial for their multiplication during March–April every year. By May 18th Std. week scale, infestations went up to 7.67 per 10 cm branch of the tree in Aonla. A significantly higher percent reduction in scale population was recorded in Azadirachtin spray (46.01% reduction) followed by *B. bassiana* spray (34.43% reduction) at 7 DAS during the first year of experimentation. At 3 DAS scale, the population was significantly lower in Azadirachtin spray (4.93 scales/10 cm twig). A significantly higher scale population was recorded in the untreated control (8.93 scales/10 cm twig).

During the second year of experimentation, a significantly higher percent reduction in scales population was recorded in *M. anisopliae* and Azadirachtin spray (36.62% and 36.53% reduction, respectively) followed by *B. bassiana* spray (35.29% reduction) at 7 DAS. At 3 DAS scale, the population was significantly lowest in Azadirachtin spray (5.53 scales/10 cm twig). A significantly higher cottony cushion scale population was recorded in the untreated control (8.53 scales/10 cm twig). Likewise, a significantly higher percent reduction in the cottony cushion scale population was recorded in *M. anisopliae* and Azadirachtin spray (35.06% and 35.71% reduction, respectively) followed by *B. bassiana* spray (34.67% reduction) at 7 DAS. At 3 DAS scale, the population was significantly lowest in Azadirachtin spray (5.20 scales/10 cm twig). Significantly highest cottony cushion scale population was recorded in the untreated control (8.14 scales/10 cm twig). Managing aonla scale, *L. purchasi*, and mealybug, *Planococcus citri*, menace under rainfed conditions of Jammu subtropics was done utilizing several biorational means – heavy training, pruning, application of neem cake in the tree basin and swabbing of a tree trunk with cow dung, and cow urine mixture, which gave complete check over the scale incidence for complete 1 year. Simply spraying these entomopathogens, namely, *M. anisopliae*, *B. bassiana*, or Azadirachtin 10,000 ppm @ 1 ml/L, can also provide a 35–45% reduction in the scale population and so can be combined with other management techniques.

Table 1 Percent reduction in scale nymphs and adults and fruit yield as affected by the application of various entomopathogens after the second spray (3 years of pooled data)

Treatments	Pre-spray count	Post-spray count (mean no. per 10 cm twig)		Percent reduction at 7 DAS	Fruit yield (kg/tree)
		3 DAS	7 DAS		
T_1 – *B. bassiana* (NBAIR-Bb-5a) @ 5 g/L	7.54	6.61	4.92	39.40 (38.88)	64.15
T_2 – *M. anisopliae* (NBAIR-Ma-4) @ 5 g/L	7.52	7.14	5.20	35.79 (36.74)	67.97
T_3 – *L. lecanii* (NBAIR-VI-22) @ 5 g/L	7.64	7.17	5.48	33.40 (35.30)	56.40
T_4 – Azadirachtin 10,000 ppm @ 1 ml/L	7.54	5.22	4.56	43.85 (41.47)	64.76
T_5 – Untreated control	7.92	8.28	8.53	–	29.30
CD at 5%	N.S.	1.91	1.06	(2.09)	2.18

Figures in parenthesis are arc-sine transformed values DAS = Days after spray

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3.45 Effect of Differential Dates of Transplanting on Population Dynamics of Whitefly (*Bemisia tabaci* Gennadius) and Chilli Thrips (*Scirtothrips dorsalis* Hood) in Chilli Ecosystem in West Bengal

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Keywords: Chilli; Dates of transplanting; Thrips; Whitefly

1. Introduction

Chilli is a widely used universal spice, also named as a wonder spice. It is one of the commercial spice crops with different varieties cultivated for various uses like vegetables, pickles, spices, and condiments. Botanically it is known as *Capsicum annuum* L. (2n = 24), also called red pepper, and belongs to the family Solanaceae. India is the largest producer, consumer, and exporter of chilli, which contributes to about 40% of total world production, followed by China and Pakistan(Agropedia, 2013), with a production of 14.92 lakh tons from an area of 7.75 lakh hectares (Jayasree *et al*. 2018; Sowjanya and Vijaya, 2015). The excellent export potential of Chilli is constantly threatened by multiple limiting factors, out of which the biotic stress such as insect pests and diseases occupies prime importance (Hanumanthappa *et al*., 2018). Chilli has a broad spectrum comprising more than 293 insects and mite species debilitating the crop in the field as well as in storage (Anonymous, 2004). Ahmed *et al*. (1987) reported that among the major sap sucking insects, thrips and whitefly are responsible for the low productivity of chilli and reduce up to 50% yield. The studies on population dynamics of insect pests affecting the production of a particular crop define the prediction of incidence of the pests in a particular region, which further proves to be a tool for effective pest management. Therefore, a temporal and spatial study of population dynamics of sucking pests infesting chilli was conducted, which would give an idea about the peak period of insect activity and help to develop a forecasting system and to implement timely plant protection measures.

2. Materials and methods

The present study was carried out at Kalyani "C" Block Farm under the research field of All India Coordinated Research Project (AICRP) on Vegetable Crops, Kalyani, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal (situated at 23.5° N latitude and 80.9° E longitude with an altitude of 9.75 m above the mean sea level) during rabi season. The experiment was conducted for two consecutive years 2015-16 and 2016-17, with staggered transplanting of the crop on six different dates at an interval of 30 days starting from October 30 up to March 30 in two seasons. Twenty-five-day-old seedlings of local variety Bullet were transplanted with spacing of 60 cm (R-R) and 45 cm (P-P) with recommended agro-techniques. Observations for population fluctuations of chilli pests were recorded throughout the crop growth initiating from first week after transplanting (WAT) at weekly intervals. The mean population of different dates of transplanting was subjected to Duncan's Multiple Range Test to infer the significance.

3. Results and discussion

The observation taken for 2 years on mean population of whiteflies revealed that there was a significant effect of dates of transplanting on the incidence and mean population of whiteflies as well as thrips. In the first season, the highest mean population of whiteflies was recorded in chilli crop transplanted on December 30, that is, 12.66/3 leaves, followed by January 30 (11.50/3 leaves), November 30, February 28, October 30, and March 30 (10.75/3 leaves, 8.19/3 leaves, 7.48/3 leaves, and 7.25/3 leaves, respectively). In the second season, the inference recorded was that the highest mean population was recorded on transplanting carried out on November 30 (10.26/3 leaves) and the least population was recorded on transplanting carried out on March 30 (7.95/3 leaves). The mean populations of whitefly recorded on all the different dates of transplanting were found to be significantly at par. The highest mean population of thrips in the first season was recorded on transplanting carried out on January 30, that is, 14.32/3 leaves, and the lowest mean population to be recorded was on crop transplanted on October 30 (5.72/3 leaves). In the second season, the inference derived was that the highest mean population of thrips was recorded on transplanting carried out on February 28 (18.38/3 leaves) and the lowest mean population was observed on transplanting carried out on October 30 (7.47/3 leaves) (Table 1).

Table 1: Population fluctuation of insect pests over differential dates of transplanting

First season (2015-16)			**Second season (2016-17)**		
	No. of sucking pests/3 leaves			**No. of sucking pests/3 leaves**	
Dates and months of transplanting	**Whitefly**	**Thrips**	**Dates and months of transplanting**	**Whitefly**	**Thrips**
October 30, 2015	7.48^{b}	5.72^{a}	October 30, 2016	8.44^{b}	7.47^{a}
November 30, 2015	10.75^{d}	8.86^{b}	November 30, 2016	10.26^{f}	9.07^{b}
December 30, 2015	12.66^{f}	12.91^{c}	December 30, 2016	10.15^{e}	13.97^{c}
January 30, 2016	11.50^{e}	14.32^{e}	January 30, 2017	9.88^{d}	14.37^{d}
February 28, 2016	8.19^{c}	13.28^{f}	February 28, 2017	9.07^{c}	18.38^{e}
March 30, 2016	7.25^{a}	13.11^{d}	March 30, 2017	7.95^{a}	13.77^{c}

Note: Figures marked by a common letter are not significantly different according to Duncan's Multiple Range Test at $p \leq 0.05$.

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3.46 Behavioural Response of Rice Leaf Folder, *Cnaphalocrocis medinalis* (Guenee), to Variable Abiotic Factors

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Keywords: Abiotic factors; Behavioural physiology; *C. medinalis*; Leaf folding

1. Introduction

Rice (*Oryza sativa* L.) is the world's leading staple food that nourishes more than 65% of the world's population. In India, insect pests pose a major threat to rice production causing average losses of about 25–30% to rice production (Dhaliwal and Arora, 2010). Rice leaf folder, *C. medinalis* (Guenee), which was considered a pest of minor importance has attained the status of a major pest in many parts of India causing losses to the crop in the larval stage. Larvae defoliate or eradicate the chlorophyll content of the leaves leading to significant yield losses. The characteristic behaviour of leaf folder larva is to make leaf roll longitudinally by stitching up opposite rims of a rice leaf and feed inside by scraping mesophyll. Insects, being poikilothermic, are greatly influenced by environmental factors which include a change in temperature, carbon dioxide (CO_2) concentrations and relative humidity in the atmosphere. The global mean surface temperature is predicted to escalate by 1.4–5.8°C from 1990 to 2100 (IPCC, 2007). It can alter the distribution of an insect species directly by influencing its physiology and behaviour or indirectly through its effects on the insect's host plants, besides effects on their population dynamics, abundance, intensity, and feeding behaviour. The leaf folding habit of rice leaf folder larva provides benefits for insects themselves, such as sunshine shielding, enhancement in microclimate, and protection from natural enemies (Bodlah *et al*., 2016). If the capacity of larva to make leaf fold was impacted by heat stress, the rice leaf folder would be subjected to more harm than the direct injury of heat. It is presumed that the high temperature would impact the behavioural physiology of leaf folder larvae to choose a host plant and make the folds. Therefore, the main objective was to evaluate the effects of elevated temperature, CO_2, and RH on larval leaf folding behaviour. The results will help in better understanding of the role of climate change in the behavioural physiology of rice leaf folders and aid the monitoring, forecasting, and management of this important rice insect pest.

2. Materials and methods

Rice leaf folder, *C. medinalis* (Guenee) (Lepidoptera: Pyralidae), was used as a test insect reared on test variety PR 121 under the following set of maximum/minimum temperature maintained for 14:10 hours, RH, and carbon dioxide concentration levels (Table 1). The experiment was conducted on two 30 days old plants of the test rice variety at the test combinations. There were four replications for each test combination. Ten neonate larvae were collected and released on plants of the test rice variety PR121 to record the leaf folding behaviour of the test insect. Observations on the number of folded leaves, time taken to fold the leaf, and the leaf folding pattern of larval instars of test insects were assessed during the period of their confinement on test plants.

Table 1 Test combinations of temperature, CO_2, and RH

Treatment	Temperature (°C)		CO_2 concentration (ppm)	RH (%)
	Minimum	Maximum		
T1	22	32	400	75
T2	22	32	450	75
T3	22	35	400	75
T4	22	35	450	75
T5	24	32	400	75
T6	24	32	450	75
T7	24	35	400	75
T8	24	35	450	75
T9	26	32	400	75
T10	26	32	450	75
T11	26	35	400	75
T12	26	35	450	75

3. Results and discussion

The results of the study revealed that more leaves were folded by *C. medinalis* with an increase in temperature, CO_2, and RH to avoid heat stress. The change in leaf folding pattern at elevated temperature and CO_2 was also noticed (Table 2). Larvae usually built single-leaf longitudinal shelters at the optimal temperature, but it was observed that larvae had built more multi-leaf overlapping shelters during heat stress due to elevated temperature and CO_2. The larvae folded six leaves for shelter to avoid heat stress at T_{12} whereas folded only two leaves at T_1. Time taken for leaf folding was also increased with an increase in temperature, CO_2, and RH and recorded maximum at T_{12} as compared to other treatments (Table 2). It was found that changes in abiotic factors influenced the leaf folding behaviour of this pest. The studies by Bodlah et al. (2019) also supported our present findings that larvae spent more time selecting a site and building a shelter during and after heat shock than at the optimal temperature. More than 70% of larvae folded two or three leaves to build a shelter during and after heat stress. These abiotic factors directly or indirectly influenced the behavioural physiology of this *C. medinalis*.

Table 2 Influence of variable abiotic factors on leaf folding behaviour of *C. medinalis*

Treatments	No. of folded leaves (Mean±S.E)	Time taken to fold leaf (days) (Mean±S.E)	Leaf folding pattern
T_1	2.00±0.57	1.25±0.50	Single
T_2	2.50±0.96	1.50±0.96	Single
T_3	3.00±0.50	1.75±0.48	Single
T_4	3.25±0.81	2.00±0.54	Single
T_5	4.00±0.50	2.25±0.73	Single
T_6	4.25±0.58	2.50±0.25	Single
T_7	4.75±0.31	2.50±0.43	Double
T_8	5.00±0.96	2.75±0.76	Double
T_9	5.25±0.37	3.00±0.58	Double
T_{10}	5.75±0.34	3.25±0.96	Double
T_{11}	6.00±0.48	3.50±0.50	Multiple
T_{12}	6.00±0.75	3.50±0.50	Multiple

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3.47 Status and Prospects of Traditional Beekeeping (*Apis cerana* F.) in Jammu Region

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Keywords: *Apis cerana*; Constrains; Predators; Traditional beekeeping; Wax moth

1. Introduction

Beekeeping has been practiced throughout Asia for many centuries and plays an important, though under-recognized, role in contributing to the livelihoods and cultural heritage of many indigenous communities (Schouten *et al*., 2019). Beekeeping with *A. cerana* is an indigenous industry and forms an integral part of the social and cultural heritage of the rural communities in India (Singh, 2014). Traditional hives are made from locally available materials, and thus they are economically cheaper and thicker in width than modern hives and are not susceptible to external temperature fluctuation (Tiwari *et al*., 2013). Traditional beekeeping is practiced with indigenous bee *A. cerana* in log hives and wall hives of various designs, sizes, shapes, and dimensions in various regions of Jammu and Kashmir. A survey was conducted in order to find out the various constraints faced by the beekeeper in the Jammu region, assess the socioeconomic background of beekeepers, honey production quantity, honey processing method, honey harvest method, predators, and enemies of the honeybee. Beekeeping with *A. cerana* does not require a lot of management like sugar feeding, disease control, and migration; therefore, it is easy for the isolated farming community to practice beekeeping with this type of bee species based on their indigenous knowledge. Beekeeping has improved the economic and nutritional requirements of the people (Reda *et al*., 2018). Beekeeping acted as a source of additional income for the farmers, as it does not involve high investment and is not labor intensive (Gupta *et al*., 2015).

2. Materials and methods

Location of study: The study was conducted in Doda, Ramban, and Khistwar districts because of the abundance of traditional beekeeping practiced in the region.

Sampling plan: Two blocks were selected from each district.

Sampling technique: Multi-stage sampling technique was employed for the study of traditional beekeepers using log hives for *A. cerana*. At first, the total numbers of blocks were six from the selected districts. Twenty beekeepers using log hives and wall hives were selected by a convenient sampling method. Thus, data were collected from a total of 120 beekeepers in the study area.

Tools of data collection: A personal interview method was employed to collect the data by using the questionnaire method.

3. Results and discussion

The majority of beekeepers who were engaged in traditional beekeeping also practice farming with an average landholding size of 0.42 ha. The study revealed that traditional beekeeping was dominated by males, as there was no association of females in beekeeping. Beekeepers have received no formal training in beekeeping and neither they watch nor listen to any television and radio programs related to beekeeping. Most of them have gained indigenous knowledge from their ancestors to practice beekeeping. The source of bees was catching the migratory bees.

The average number of log hives and wall hives per household was 5.45 and 1.20, respectively, whereas the average honey production per hive per season in log hives and wall hives was 8.17 and 3.29 kg, respectively. Traditional hives are locally named *hadd*, *crund*, *ganat*, *gunfaat*, *pahar*, *karanja*, *kothar*, and *khuud*. Honey was harvested manually without the use of equipment and only 13% of the beekeepers practiced honey processing for the removal of impurities from honey. Bee enemies and predators recorded were wax moth, wasps, pseudoscorpion, birds, ants, and bear. On the major findings it was revealed that wax moth was 65.83% more frequent than other predators and thus ranked 1st; other predators and enemies are listed in Table 1 as per their rank. Except honey other bee products were not gathered by the beekeepers and honey was directly sold to consumers without intermediaries. The traditional hives require minimum investment from the beekeepers as they are made from locally available material, but the major problem that arises in these hives is that their ends are fixed or plastered with wood and clay, so routine inspection of the colony is not possible. Major constraints faced by beekeepers were the attack of predators, absconding, theft of hives, lack of consultation with professional and scientific experts in order to adopt modern beekeeping practices, and unavailability of medicine in case of a disease outbreak; these constraints are listed in Table 2 as per their rank and response percentage.

Table 1 Rank index for major predators and enemies of the honeybee in the Jammu region

Name of the predators and enemies	Percentage (%)	Rank
Wax moth	65.83	1
Bee eater bird	40.00	4
Wasp	56.66	2
Ants	47.50	3
Bear	7.50	6
Pseudoscorpion	17.50	5

Table 2 Response proportion of constraints faced by beekeepers in the Jammu region

Constraints faced by beekeepers	Percentage (%)	Rank
Attack of predators	71.60	1
Absconding	59.10	3
Lack of consultation and medicine in case of disease outbreak	70.00	2
Theft of hives	5.00	4

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3.48 Effects of Bee Venom Collection on Survival of *Apis mellifera* Linnaeus Brood During Monsoon Season in Punjab

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Keywords: *A. mellifera;* Bee venom; Larval brood; Monsoon; Survival

1. Introduction

Honey bees not only provide pollination services but also provide economically important hive products such as honey, royal jelly, beeswax, propolis, pollen, and bee venom and thereby help beekeepers earn their livelihood. Among these valuable hive products, bee venom has a wide range of commercial uses in the medical and cosmetics sectors (Aparna, 2020). Honey bee venom has great potential to raising the beekeepers economically but the collection technique is not comprehensively standardized in India so far. Although the venom collection techniques have been standardized in other countries, no comprehensive work has been conducted in India. A package of practices for bee venom collection will not be complete without studying the effect of bee venom collection from *A. mellifera* colonies on the survival of bee brood, and hence the present study was carried out.

2. Materials and methods

A. mellifera colonies of 16 and 8 bee-frame strength were exposed to DPS-BVC-01 and Bee Whisper 5.0 bee venom collectors, respectively, for 30 and 60 minutes to determine the effect on bee brood survival. For calculation of brood survival in the colony, larval brood areas of 4 $inch^2$ (25.8 cm^2) were marked at three different locations in each colony with the help of pearl headed pins. The number of empty cells, at the time of marking of brood areas of freshly hatched out larvae, was counted and subtracted from 93 to get the initial number of larvae present in the marked brood area of 4 $inch^2$ (25.8 cm^2). The observations on the marked area were again recorded after 6 days when all the larvae were supposed to have been capped. The number of brood cells found capped on the observation day was counted toward larval survival and the percentage of such survival was then worked out on the basis of the initial reading at the time of larval marking. Four such observations were continually recorded at fortnightly intervals during each of the seasons.

$$\text{Larval brood survival} = \frac{\text{No. of brood cells capped after six days of marking}}{93 - \text{Empty cells at the time of marking}} \times 100$$

3. Results and discussion

Data recorded during the monsoon season revealed that a significantly higher mean percentage of brood survival was recorded in colonies exposed to Bee Whisper 5.0 bee venom collector (77.77%) than in colonies exposed to DPS-BVC-01 bee venom collector (71.18%). In relation to the strength of colonies, a significantly higher mean percentage of brood survival was recorded in 16 bee-frame strength colonies (76.30%) than in 8 bee-frame strength colonies (72.65%). With respect to the exposure period of venom collection, significantly the highest mean brood survival percentage was observed in control (0 min exposure) colonies (78.60%) followed by colonies exposed for 30 min to venom collector (72.52%) being at par with colonies exposed for 60 min to venom collector (72.30%) (Figure 1). Higher brood survival in the colonies exposed to Bee Whisper 5.0 may probably be because it works on 3 volts compared to DPS-BVC-01 which operates on 9 volts. Brood survival in the exposure period of 30 or 60 min being at par shows that brood survival did not decrease significantly with an increase in exposure period to 60 min. Further, the decrease in larval brood survival by bee venom collection was only 6.08–6.30% compared to 38.06% reduction in larval brood survival due to lack of pollen in *A. mellifera* colonies as reported by Singh *et al* (2015). Brood survival is not significantly reduced by bee venom collection is also supported by the findings of Omar (2017) that brood rearing is not significantly affected by bee venom collection. Therefore, it is concluded that survival of brood in *A. mellifera* colonies exposed to DPS-BVC-01 bee venom collector was significantly lower than in Bee Whisper 5.0 but it increased with an increase in bee strength, whereas the exposure period did not affect brood survival.

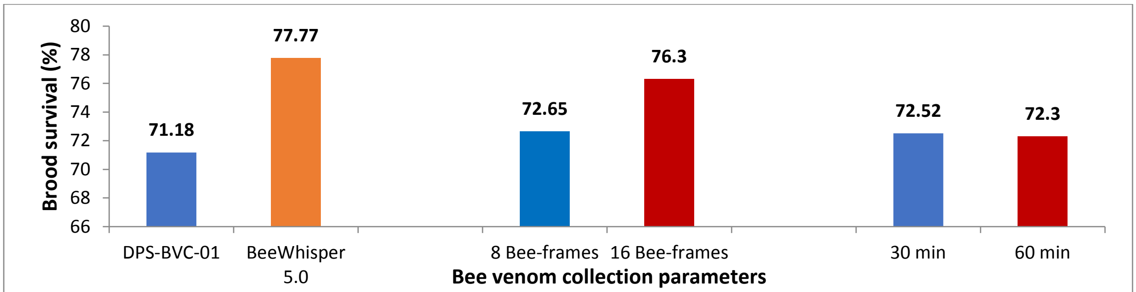

Figure 1 Effect of bee venom collector, bee strength, and exposure period on survival of larval brood in *A. mellifera* colonies

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3.49 Improving Nutritional Security Through Fodder and Fruit Production in Rainfed Areas

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Keywords: Nutritional Security, Fodder, Rainfed Areas, Bajra, Maize

1. Introduction

The annual forage requirement of our country is 1410 million tons. The present feed and fodder resources of India can meet only 48% of this requirement with a vast deficit (Anonymous, 2020). Increasing crop productivity to meet food, fodder, fuel, timber, and fruit requirements in rainfed areas is a great challenge; therefore, cultivation has to be extended to other available lands like orchards. In the present study, between the inter-row space in citrus orchards (Eureka lemon and kinnow mandrin) location-specific fodder crops were grown as intercrops to ensure efficient use of resources along with the introduction of new varieties of fodder and modern technology. Thus, the study aims to assess the impact of intercropping in *E. lemon* and kinnow on yield, fruit quality, and economics.

2. Materials and methods

Bajra and maize raised for both fodder and grain were intercropped in the inter-row spaces of the orchard to meet the food and fodder requirement of the family. The intercrops were sown 1 m away from the fruit trees on either side of the trunk leaving an area of 3.14 m^2 around each tree. Bajra and maize sowing was done with the onset of *monsoon*. Bajra crop grown for multipurpose use as the green fodder was harvested twice at 35–40 and at 60–70 days after sowing (DAS). After taking two green fodder cuts, the crop was allowed for grain formation with the application of an additional dose of urea @ 35 kg/ha each time and then harvested for both grain and stover. Maize crop was also planted for both grain and green fodder; after harvesting cobs, the stover was used as fodder for cattle. Proper scientific care and management of fruit trees was done as per the package and practices.

The average weights of fruits were calculated by selecting 10 fruits at random. Average fruit weight (g) was measured at harvest. Different segments from each fruit sample were taken, squeezed, and the juice obtained was used to determine the percentage of total soluble solids (TSS) by a hand refractometer. Total sugars, reducing sugars, acidity, and ascorbic acid content were measured according to the standard procedure of Ranganna (1986).

The fruit yield of *Kinnow mandrin* and *Eureka lemon* was estimated by multiplying the total number of fruits per tree by the average fresh weight of fruits during harvesting and expressed as kg per tree and then converted to kg/ha. The productivity of various components of the system either alone or in conjunction with fruits taken during the year (kg^{-1} ha^{-1} day^{-1}) was calculated in terms of maize equivalent yield (MEY) as:

$$\text{MEY} = \frac{Yi \times Pi}{P(p)}$$

Here, MEY is maize equivalent yield, Yi is the yield of different crops/components, Pi is the price of respective crops/components, and $P(p)$ is the price of the maize crop.

3. Results and discussion

Fruit and fodder yield

Dual-purpose field crops were introduced in the inter-row spaces of the orchard to meet the food and fodder requirement of the farm and to get additional income from the same land (Table 1). Maize grain and stover yield and bajra green fodder yield when intercropped were lower than that obtained in their pure stand. However, the yield of both fruit and fodder crops was much higher than obtained from other nearby farms, which was due to scientific interventions like the use of hybrid seeds, application of a recommended dose of fertilizers and manures to the fruit trees as per age of the tree, and foliar application by micronutrients carried out during the study period. Fruit yield of kinnow was higher than lemon yield. The fodder yield of bajra was higher than that of maize as three fodder cuts were taken in bajra. Both fruit and crop yields were also expressed as maize equivalent yield (MEQ) on a fodder basis and it was observed that the highest MEQ (3401 kg/ha) was recorded in sole bajra followed by kinnow + bajra and the lowest was recorded in sole maize. These crops provided additional income to farm families that helped farmers to meet their small revenue demands.

Table 1 Fodder and grain yield under different treatments of agri-horti system (mean of 3 years)

Treatments	Fruit yield (kg/ha)	Green fodder (kg/ha)	Stover yield (kg/ha)	Grain yield (kg/ha)	Fodder MEY (kg/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)
E. lemon	2010.0	–	–	–	–	15,210	45,090
Kinnow	2308.1	–	–	–	–	15,210	3,050
E. lemon + bajra	2274.2	1650*	2813	1340	2464	32,672	92,595
E. lemon + maize	2295.1	–	4240	2180	–	38,881	69,247
Kinnow + bajra	2496.2	1760*	3090	1500	2636	32,672	79,279
Kinnow + maize	2435.0	–	4980	2440	–	38,881	54,133
Sole bajra	–	2250	4370	2100	3414	17,466	65,169
Sole maize	–	–	7030	3470	698	23,771	38,171

*It includes both cuttings of green fodder
MEY = Maize equivalent yield

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Fruit quality and yield attributes

The intercropping of maize and bajra had a prominent effect on fruit weight and quality. The weight of *Kinnow mandrin* and *Eureka lemon* fruits was more when intercropped with bajra and maize in comparison to sole fruit trees (Table 2). It might be attributed to the vigorous growth and development of fruit trees under intercropping. Higher fruit TSS and other quality parameters are well related to higher moisture conservation and the maximum nutrient uptake under intercropping, as there was no physical barrier between the root systems of intercrops and trees. These results are in conformity with the findings of Kumar *et al*. (2016) in *Eureka lemon* under *kandi* conditions of Jammu.

Table 2 Effect of intercrops on physicochemical characteristics of *Eureka lemon* and *Kinnow mandarin* fruit in the agri-horti system (mean of 3 years)

Treatments	Fruit weight (g)	TSS (ºBrix)	Acidity (%)	Ascorbic acid (mg/100 mL)	Total sugars (%)	Reducing sugars (%)
Eureka lemon						
E. lemon	62.0	6.0	5.08	37.0	2.26	1.50
E. lemon + bajra	63.0	6.9	5.02	37.86	2.60	1.95
E. lemon+ maize	62.5	6.4	5.05	37.60	2.40	1.70
Kinnow mandarin						
Kinnow mandarin	102	11.0	1.45	20.0	8.20	5.4
K. mandarin + bajra	105	11.9	1.40	21.6	8.90	6.0
K. mandarin + maize	103	11.5	1.43	20.9	8.26	5.8

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Theme 4

Technological, Policy, Institutional, and Scaling Innovations

4.1 Adoption of Black Pepper Threshers by the Farmers of Kodagu District of Karnataka, India

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Keywords: Adoption; Black pepper threshers; Mechanization

1. Introduction

Black pepper (*Piper nigrum*) is a flowering vine in the family Piperaceae cultivated for its fruit, which is usually dried and used as a spice and seasoning, known as a peppercorn. India is the fifth largest pepper producer in the world with an export potential of 3.96 million USD. Karnataka and Kerala states of India produce 90% of the country's pepper with the Kodagu district of Karnataka being the highest producing area in India accounting for 23 tons of the total 92 tons of production (NHB, 2021). The threshing of harvested black pepper is a time-consuming, costly, and cumbersome job that accounts for 15% of the total cost of cultivation, and the quality of the berries that are harvested is impacted by any threshing delays which adversely affect the price. The pepper thresher invented by Gopal Krishna Sharma of Kerala has proven to be a boon for the pepper growing farmers, as pepper separation and cleaning can be done in minimum time, with less or no labor, and at minimum cost. Hence, an attempt has been made to study the awareness, source of awareness, rate of adoption, perceived attributes, and advantages and disadvantages of black pepper threshers in the study area.

2. Materials and methods

A descriptive research design was employed for the study. The study was conducted by using primary data collected from 90 pepper farmers in the Kodagu district of Karnataka using a convenient sampling method. Madikeri and Virajpet blocks of Kodagu district were selected and from each block three villages were selected, comprising 15 respondents from each village to make up the total sample size of 90. The data were collected through a well-structured online questionnaire in November and December 2021. The data were then compiled and suitable statistical tools were applied to arrive at the result.

3. Results and discussion

Out of the total respondents, 97.80% of them had an awareness about the pepper threshers with agricultural officers being their primary source of information followed by Spice Board and KVK. About 58% of the respondents had purchased pepper threshers and 20% of them were using community threshers. There was a surge in the purchase of machines in the years 2017 and 2018 when the machine became quite popular in the farming community. Farmers were also eligible for the subsidies sponsored by the government up to Rs 20,000. The farmers noticed advantages like saving time (50%), reduced cost of cultivation (33%), and easy handling (6%), which aligned with relative advantage, observability, and compatibility of Rogers diffusion of innovation theory (Rogers 2003). . On average, farmers had to spend Rs 3/kg for threshing pepper manually, which has been reduced to Rs 0.3/kg after the introduction of pepper thresher which has significantly reduced their cost of cultivation. Few of the respondents had noticed some disadvantages like breaking of berries and dusty particles in the final product. The study of the adoption of black pepper thresher in the Kodagu district of Karnataka is on par with the diffusion theory that diffusion follows an S-shaped curve and adoption follows the normal distribution curve (Figure 1). Karimunda and Paniyur varieties were the most popular ones in the study area and were compatible with their soil type and weather conditions. The study concluded that the farmers were knowing the availability of pepper threshers which would ease the processing of black pepper. The farmers found that pepper threshers significantly reduced their cost of cultivation and had a positive attitude toward the adoption of machinery on their farms. The majority of farmers had good ties with the agricultural department and were in constant contact with its officials.

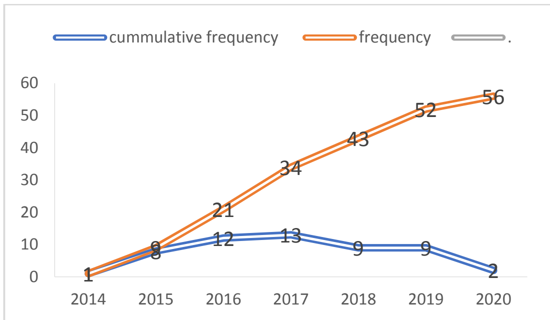

Figure 1 The diffusion curve and the number of new adopters along the same timeline

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4.2 Farmers' Intention Toward Adoption of Modern Agricultural Technologies Transferred Through Farmer Field Schools in Bangladesh

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Keywords: Adoption; Attitude; Farmer field school; Intention; Perceived behavioral control; Structural equation modelling; Subjective Norms; Theory of planned behavior

1. Introduction

The adoption of modern agricultural technologies has received a lot of attention in both developed and developing countries. They are the tools for increasing agricultural production and productivity, reducing poverty, and ensuring food security. Farmer field school (FFS) has now been implemented and adopted all over the world, and it helps to improve intermediate outcomes related to experiential learning and the adoption of modern agricultural technologies. However, the rate of adoption of these technologies is not as rapid as expected. Observations indicate that despite visible benefits, many technologies are not adopted by farmers (Mottaleb, 2018). On the other hand, the intention of farmers influenced the adoption of these technologies. The theory of planned behavior (TPB) has provided a useful framework for explaining the farmers' intention to adopt these technologies transferred through FFS. Thus, this paper aims to assess farmers' intention to adopt agricultural technologies by implementing the TPB. According to Ajzen (1991), TPB helps to understand how an individual behavior (in this case adoption decision) can be altered. It is a well-known conceptual model that explains individual intentions to perform a particular behavior through psychological constructs such as attitudes, subjective norms, and perceived behavioral control (Veisi, 2012).

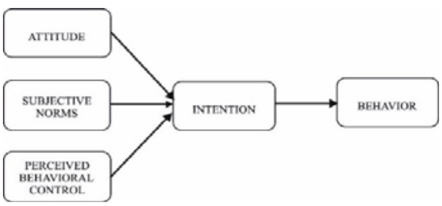

Figure 1 Theory of planned behavior
Source: Ajzen (1991)

2. Materials and Methods

The study was conducted at Kaliganj Upazila in Lalmonirhat district, the northern part of Bangladesh, where 52 IFM-FFS were implemented during 2013–2018. An experimental design was used in association with a cross-sectional survey. A total of 338 farmers (182 FFS and 156 non-FFS) were selected as a sample for the study. Finally, 10 technologies transferred through IFM-FFS were selected based on judge rating. Data were collected by the researcher through face-to-face interviews using a pre-tested structured interview schedule from August to November 2021. The interview schedule was formulated based on a series of activities, which included literature reviews, pilot study, and group discussions among academic experts, extension workers, and researchers from various research institutes and universities. Questions related to the TPB were developed using a manual for constructing an interview schedule based on the theory of planned behavior (Francis *et al*., 2004). In total, 19 statements directly based on the TPB were used to create indices of each of the four constructs: attitude, subjective norms, perceived behavioral control, and adoption. This study used SPSS (version 20) and STATA (version 14) software to analyze the data. To test the research hypotheses, a structural equation modelling (SEM) was constructed using STATA.

3. Results and discussion

The average mean score, standard deviation, and the correlation of all variables used in the SEM are presented in Table 1. The correlation matrix reveals that there are significant correlations between the variables. This suggests that all these variables are relevant for the analysis of causal relationships among variables by identifying direct and indirect effects using SEM (see Figure 2).

Table 1 Descriptive statistics and correlations ($N = 338$)

Variables	Average mean	SD	1	2	3	4	5
1. Attitude toward the behavior	3.873	0.320	1.00				
2. Subjective norms to perform the behavior	3.89	0.621	0.463**	1.00			
3. Perceived behavioral control	3.11	0.806	0.578**	0.566**	1.00		
4. Intention toward adoption (behavior)	2.53	0.191	0.541**	0.480**	0.567**	1.00	
5. Adoption of modern agricultural technologies (actual behavior)	0.555	0.176	0.622**	0.534**	0.659**	0.862**	1.00

**Correlation is significant at the 0.01 level.

The findings of the structural equation model predicting intention and adoption of modern agricultural technologies are shown in Figure 2. The fit indices revealed that the overall goodness-of-fit to the data was good.

The results show that attitude, subjective norms, and perceived behavioral control (PBC) all have positive and significant relationships with intention (behavior). The intention has a favorable and significant relationship with the adoption of modern agricultural technologies. These variables (attitude, subjective norms, and PBC) are also significantly and positively interrelated. The study clearly reveals that farmers' attitudes, subjective norms, and PBC are all important predictors of their intentions to adopt modern agricultural technologies and that intention

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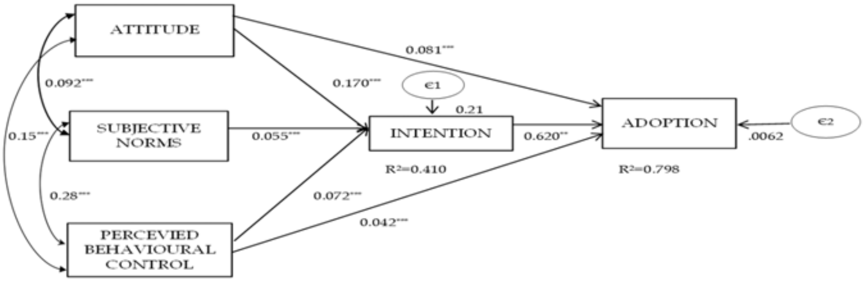
(behavior) is a strong predictor of adoption (actual behavior) of these technologies. Tama *et al*. (2021), Daxini *et al*. (2018), Zeweld *et al*. (2017), and Senger *et al*. (2017) found a similar result in their study. The findings indicate that farmers with favorable attitudes, expected subjective norms, and higher perceivable behavioral control were more likely than other farmers in the community to adopt agricultural technologies. Therefore, socio-psychological factors influencing the adoption, as outlined by TPB, may be considered while promoting the adoption of new technologies in the farming system. The findings of this study may be useful to the development of future research aimed at gaining a deeper understanding of psychological and other factors influencing technology adoption, especially within the context of Bangladesh.



Signif. codes: *** = $p < 0.01$; ** = $p < 0.05$; * = $p < 0.10$.
Model fit: chi2_ms = 3.073; CFI = 0.997; RMSEA = 0.078; SRMR = 0.008
Figure 2 Structure equation modelling (SEM)

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4.3 Economic Analysis of Sustainable Farm Income Through Integrated Farming Systems in Western Maharashtra

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Keywords: Economic analysis; Integrated Farming Systems (IFS); Sustainable farm income

1. Introduction

Indian agriculture is dominated by small holdings and smallholders cultivate 42% of the land and constitute 83% of the total landholdings. However, most of these farms produce more than one commodity and are operated largely by the farm families. The Integrated Farming System (IFS) refers to a combination of enterprises involving the raising of crops and livestock together. The IFS is seen as a potential way of raising and stabilizing productivity and profitability levels (Gopinath *et al*., 2014). The income from cropping alone on small and marginal farms is hardly sufficient to sustain the farmer's family. The IFS approach provides a solution to the farmers through sustainable income for a satisfactory living. Hence, this study was undertaken with specific objectives, namely, employment, income, expenditure pattern, and profitability of different farming systems.

2. Materials and methods

The present study was undertaken in all 10 districts of western Maharashtra. The sample for the study necessarily involved a multistage sampling design which was used for the selection of districts, tehsils, and villages. All farming systems that existed in western Maharashtra were listed and the four most prominent farming systems were selected for the study, namely: i) Crops only, ii) Crops+Goat (C+G), iii) Crops+Dairy (C+D), and iv) Crops+Dairy+Horticulture (C+D+H). From 10 districts of western Maharashtra, 13 tehsils which represent the diverse situation required for the study were selected for the present study. One village which widely adopted these four farming systems was selected from each tehsil and from each village 21 farmers were selected. As per the adoption proportionate, 60 farmers were selected from the Crops only farming system, 77 from C+G, 89 from C+D, and 47 from the C+D+H farming system, thus making a total sample size of 273 farmers. The data pertaining to the annual year 2020-21 were collected by the cost accounting method with the help of specially designed schedules for the purpose. Simple statistical tools, namely, percentages, weighted averages, ratios, and multiple linear production functions, were used for estimating the employment and income of the different farming systems.

3. Results and discussion

The per farm on-farm profit and the total profit in C+D+H farming system were high (Rs. 302,020.43 and Rs. 323, 258.20, respectively) as compared to Crops only, C+G, and C+D farming systems. It indicates that as the farmer shifts from Crops only to C+G and C+G to C+D and C+D to C+D+H farming systems, the income and profit continue to increase. In the C+D+H farming system, crops residues were used for feeding animals, while livestock manure was used for crops, so the cost of animal feed and chemical fertilizers was reduced. The per family on-farm employment was highest in C+D+H farming system, that is, 528.38 man-days, over the other farming systems. Dairy business and fruit crops were helpful to generate employment throughout the year. In the Crops only farming system, per family farm employment was 161.36 man-days, so for more income to cover expenditure, farmers had to rely more on off-farm employment. These findings were consistent with the study conducted by Kumari *et al* (2015). With regard to crops with dairy enterprise in addition to horticultural crops in the C+D+H farming system, the per farm annual expenditure was more compared to that of other farming systems. The highest incremental benefit-cost ratio (IBCR) obtained from the C+D+H farming system (2.19) indicated that the C+D+H farming system was economically profitable. The C+D+H farming system involves efficient recycling of farm wastes and better utilization of resources, generates employment, reduces risks, and ensures sustainability. Hence, the C+D+H farming system should be adopted on large scale to minimize the risk of crop losses due to uncertainties of weather conditions and fluctuating market prices, harness the efficiency of resources, and assure employment and income security for the farmers.

Table 1 Analysis of total farm income and expenditure (in Rs.)

Particulars	Farming systems							
	C		C+G		C+D		C+D+H	
	Income	Expenditure	Income	Expenditure	Income	Expenditure	Income	Expenditure
Per farm	194,753.57	122,853.61	489,426.14	299,285.30	609,178.20	360,535.85	707,554.35	405,533.92
On-farm profit	71,899.96		1,90,140.84		2,48,642.35		3,02,020.43	
Off-farm income	100,953.12		51,514.91		28,592.27		21,237.77	
Total profit	172,853.08		241,655.75		277,234.62		323,258.20	
Added per farm	–	–	294,672.57	176,431.69	119,752.06	61,250.55	98,376.15	44,998.07
Incremental benefit-cost ratio	–	–	1.67		1.96		2.19	

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4.4 Digital Extension Services and Factors Determining Their Utilization by Farm Women–A Study in Telangana State

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Keywords: Digital Extension Services; Empowerment

1. Introduction

There is substantial evidence that the number of women farmers participating in agriculture has increased throughout time. According to the Government of India's (GOI) Xth Agricultural Census (2015-16), the percentage of female operational holders expanded from 12.79% in 2010-11 to 13.87% in 2015-16, with similar percentages of 10.36% and 11.57% for operational holdings by the same. According to the Oxford Committee for Famine Relief reports (OXFAM), agriculture employs around 80% of all economically active women in India, with 33% working in agriculture and 48% working as self-employed farmers. This demonstrates that an increasing number of women are involved in agricultural activities and occupy multiple responsibilities. According to the FAO, if women farmers in developing countries have equal access to productive resources as males, their productivity can increase by 20–30%, and agricultural production can increase by 2.5–4%. It emphasizes the recent popularity of women farmers and suggests that in order to boost agriculture production, women need access to technologies and high-quality inputs. The Digital Extension Services (DES) programme allows farmers to use technology to improve their crops. As a result, the current research attempted to concentrate on the characteristics of Digital Extension Services. Identifying the extent to which farm women use Digital Extension Services is critical to increasing the rate of DES adoption.

2. Materials and methods

The current study was undertaken in the former districts of Southern, Central, and Northern Telangana zones, namely, Karimnagar, Medak, and Mahbubnagar, in the year 2021. A total of 120 women farmers who used the Digital Extension Services were included in the study. A semi-structured interview schedule was developed to explore the Attributes of Digital Extension Services determining the utilization of DES by farm women. The Garrett Ranking Technique was used to rank the internal and external factors that influence farm women's use of DES.

The obtained ranking from the respondents was translated into Garrett scores using Garrett's table. The scores of each individual were added for each internal factor and external factor, and then the total value of the scores and mean values of scores were calculated. The element with the highest mean value was deemed the most significant and given the highest ranking and vice versa. The factors influencing farm women's use of DES with the highest mean score were deemed the most important and given the highest ranking and vice versa.

3. Results and discussion

Table 1 Perceived attributes of Digital Extension Services of farm women

Statements	Mean score	Internal rank	External rank
Attributes of Digital Extension Service	71.30		I
Relative advantage	**72.55**	**I**	
Easy to adopt or follow	78.40	I	
Up-to-date nature of the advisories	77.45	IV	
Wider coverage of the advisories	77.52	III	
Relatively cheaper	78.52	II	
Compatibility	**38.55**	**V**	
Compatible with farmers' needs	56.88	X	
No –sociocultural barriers	55.54	XI	
Absence of complexity	**53.71**	**III**	
Simplicity of use of ICT tools	63.52	VII	
Requirement of no expertise	63.82	VI	
Trialability	**46.96**	**IV**	
Possible to try at a smaller level	58.05	IX	
No restriction on the user	58.65	VIII	
Observability	**62.20**	**II**	
Provision for immediate feedback	71.69	V	
Predictability	**25.35**	**VI**	
Easy to predict the outcome of the advisories	53.07	XII	
User-friendliness of Digital Extension Service	55.85		II
Content appropriateness	73.83	I	
Quality of the service	47.43	IV	
Relevancy of information	60.24	II	
Ease of application of advisories	26.99	VI	

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Timeliness of information	52.70	III	
Affordability of ICT-based extension services	37.79	V	
Supporting policy environment	43.55		III
Regular training facility for effective use and upscaling	50.00	II	
Financial support from the government	67.57	I	
Involvement of farmers in content development	32.74	III	
Personal Factors	28.27		IV
Interest	70.08	I	
Ability to use ICTs	55.91	II	
Education background	43.29	III	
Economic status of the individual	29.46	IV	

Easy to adopt or follow, relatively cheaper, wider coverage, up-to-date nature of the advisories, provision for immediate feedback, the requirement of no expertise, simplicity of use of ICT tools, no restriction on the user, provision to try at a smaller scale, compatible with farm women needs, no sociocultural barriers, and easy to predict the advisories' outcome were ranked 1–12 in the sub-internal ranking.

Observability, absence of complexity, trialability, compatibility, and predictability are ranked first, second, third, fourth, and fifth, respectively, in the internal ranking of the attributes of ICT relative advantage.

User-friendliness of ICT-based extension services, content, and information relevancy are among the internal rankings. Information quality and timeliness, as well as the affordability of ICT-based extension services and the simplicity of using advisory services, were ranked first, second and third. The findings were in agreement with Verma (2016).

Interest, capacity to use ICTs, educational background, and economic level of the individual placed first through fourth, respectively, among personal variables. The findings were in agreement with Verma (2016).

Financial support from the government, frequent training facilities for effective use and upscaling, and farmer involvement in content production are ranked first through third in terms of enabling policy environment. The findings were in agreement with Verma (2016).

The attributes of DES, an ICT-mediated extension, user-friendliness of ICT-based extension services, supporting policy environment, and personal factors were ranked first to fourth, respectively, based on the external ranking of the factors determining the utilization of Digital Extension Services by farm women. The findings were in agreement with Verma (2016).

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4.5 Evaluation of Growth and Yield of Wheat Varieties Under –Harad (*Terminalia Chebula* Retz.) Based Agroforestry System

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Keywords: Competition; Intercrop, *T. chebula*; Wheat; Yield attributes

1. Introduction

Agroforestry has been practiced for many centuries all over the world as a way to increase agricultural sustainability and to slow down the negative effects of agriculture (e.g., soil erosion) (Nair, 2011). There are an unlimited number of agroforestry systems in use all over the world (Joshi and Verma, 2012). Agroforestry aims at combining woody perennials with agricultural crops in such a way that positive ecological and economic interactions between components could take place. This can be made possible with some spatial arrangement or temporal sequencing of different components (Thevathasan and Gordon, 2004). Besides the selection of suitable tree species and crops, another important way to achieve beneficial interactions is by understanding parameters such as the minimal distance required between intercropped tree rows and crop plants to avoid significant competition for light and nutrients. Hence, the experiment aimed to ascertain the influence of distance from the base of the tree (harad) on the growth and yield of different wheat varieties.

2. Materials and methods

A field experiment was conducted at the research farm of the Division of Agroforestry, Chatha during the year 2018-19 with the aim to explore the possibility of growing different wheat varieties as an intercrop under the canopy of harad (*T. chebula* Retz.) trees planted at a spacing of 5 m × 4 m. The effect of the distance of intercrop from the tree base was studied to work out the optimum tree-crop combination with respect to the growth and yield of different wheat varieties. This experiment comprised three wheat varieties (WH-1080, JUW-598, and RSP -561) and two distances of intercrop (0–1 m) and (1–2 m) from the tree base. The observations were recorded on growth and yield parameters such as plant population, plant height, spike length, 1000 grain weight and grain yield, the number of tillers/plant, and the number of grains/spike.

3. Results and discussion

The study revealed that the shade of the tree canopy and distance from the tree had a significant effect on the growth, yield attributes, and yield of different wheat varieties under harad trees. The growth and yield of all the varieties of wheat were statistically lower as compared to sole cropping. Growth and yield parameters such as plant population, plant height, spike length, 1000 grain weight, and grain yield (except the number of tillers/plant and the number of grains/spike) were significantly affected under both shade and open conditions. Plant population was recorded maximum in treatment T_8 (JAUW-598, control). The height of wheat plants was reduced under shade and a maximum plant height of 105.22 cm was recorded in treatment T_7 (WH-1080, control), whereas the maximum spike length (13.91 cm), the number of tillers/plant (7.36), the number of grains/spike (33.62), and grain yield (42.46 q/ha) were recorded in treatment T_9, that is, variety RSP-561 grown under control conditions as compared to other varieties grown at two different distances as well as in open. Overall, the RSP-561 variety of wheat performed better among all the other varieties with a yield reduction of 47.83% and 12.15% at 0–1 m and 1–2 m, respectively, under shade as compared to open conditions. All wheat varieties performed better at a distance of 1–2 m as compared to 0–1 m distance from the tree base. The study concluded that wheat can be successfully grown at 1–2 m distance from the tree base as the amount of shade and competition for growth is less.

Table 1 Growth and yield of wheat varieties under harad (*T. chebula* Retz.) based agroforestry system

Parameters	Plant population/m^2	Plant height (cm)	Number of tillers/plant	Spike length (m)	Number of grains/spike	1000 grain weight (g)	Grain yield (q/ha)
T_1 (WH-1080, 0–1 m)	24.66	78.22	7.06	10.12	29.36	34.73	24.72
T_2 (WH-1080, 1–2 m)	25.66	84.23	7.22	11.02	31.01	35.02	30.23
T_3 (JAUW-598, 0–1 m)	27.33	79.80	6.91	10.32	29.69	30.34	22.69
T_4 (JAUW-598, 1–2 m)	35.33	82.44	6.49	11.14	32.03	34.29	32.24
T_5 (RSP-561, 0–1 m)	21.66	74.08	7.13	12.33	29.25	35.57	22.15
T_6 (RSP-561, 1–2 m)	38.66	80.18	7.17	13.04	30.90	38.79	37.30
T_7 (WH-1080, control)	39.33	105.22	7.01	11.48	32.80	39.82	35.72
T_8 (JAUW-598, control)	47.00	97.56	7.12	12.02	30.48	39.04	40.25
T_9 (RSP-561, control)	42.00	94.08	7.36	13.91	33.62	41.25	42.46
C.D. (0.05)	15.54	10.32	NS	2.01	NS	4.63	8.31
SE(m)±	5.14	3.41	0.33	0.66	1.51	1.53	2.74

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4.6 Constraints Faced by the Farmers in Commercial Cultivation of Vegetables in the Samba District

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Keywords: Livelihood; Transfer of technology; Production; Vegetables

1. Introduction

Vegetables are important constituents of agriculture for attaining food and nutritional security. India is bestowed with a huge diversity of vegetables which accounted for 59.20% of the total horticultural produce in the country in 2017-18. India, with its wide variability of climate and soil, has good potential for growing a wide range of vegetable crops. Production during 2022 was recorded 200 million tons, whereas it was less than 20 million tons during independence. Samba is one of the smallest districts of the Jammu and Kashmir and is situated on the range of Shivalik Hills alongside the National Highway on the bank of river Basantar. About two-thirds of the area of Samba is Kandi and rainfed. Samba is an agriculture-based place in Jammu and Kashmir. The total geographical area of the district Samba is 91,374 ha, out of which gross cultivated area is 71,454 ha. The principal crops of the district are wheat, rice, and maize. Besides this, farmers of the district Samba earn their livelihood from vegetable cultivation, animal husbandry, poultry, mushroom cultivation, horticulture, oilseeds, floriculture, pulses, fodder crops, and beekeeping. The area under vegetable cultivation is approximately 2000 ha. A number of vegetable crops such as knol-khol, peas, beans, tomato, brinjal, chilli, cauliflower, cabbage, onion, and okra are grown in the district. The farmers of the area are facing a lot of constraints like social, organizational, economic, and technology transfer in the cultivation of vegetables. Keeping this in view, the study was carried out related to constraints associated with vegetable cultivation and to overcome these constraints.

2. Materials and methods

The study was undertaken in three vegetable growing villages Rajpura, Harsaath, and Nud of the district during the year 2020-21. The villages were selected purposively and a random sampling technique was followed to select the respondent. It was decided to draw samples from all categories of farmers, that is, marginal, small and large farmers. Farmers growing vegetables for the commercial purpose were selected. A random technique was followed to select 20 vegetable growers from each village. Thus, a total of 60 vegetable growers were finally selected. For analysis of data, responses were secured on 3-point scales fitting to the statements as very much (3), much (2), and not so much (1). The results were calculated as the mean score for each of the constraints (Sharma *et al*., 2008).

$$\text{Mean score (MS)} = \frac{(\text{No. of VM} \times 3) + (\text{No. of M} \times 2) + (\text{No. of NM} \times 1)}{\text{Total no. of VM} + \text{M} + \text{NM}}$$

3. Results and discussion

Constraints in technology transfer: The score analysis in Table 1 revealed that the absence of proper postharvest technology (2.36), inadequate training programmes (2.26), lack of approach to demonstration (2.10), non-communication of location-specific recommendations (2.16), and inadequate follow-up services (2.15) for vegetable are the major constraints being faced by the marginal farmers as compared to small and big farmers of the area. The other constraints were low-level technical know-how, non-exposure to mass media, lack of land consolidation, and so on. However, most of them are related to government actions that need to be streamlined to make vegetable farming profitable. These findings have been supported by Samantaray *et al*. (2009) who have observed similar types of constraints being faced by the farmers of Odisha. Economic constraints: As many as eight economic constraints were identified which seemed to be a barrier to increasing the production and productivity of vegetables (Figure 1). Poor marketing facility (2.33) is the most important constraint, followed by the poor economic status of the farmers (2.26), low risk bearing capacity (2.26), poor transport facility (2.20), absence of storage facility (2.12), and high cost of production (2.12), which are being faced by the marginal farmers (Table 2). The subsequent factors were the non-availability of agriculture loans and complicated procedures to avail loans mentioned by the respondents under study. Corroborative results have been given by Sharma *et al*. (2008). It is evident from the study that the major constraints such as lack of postharvest technologies, absence of storage facilities, inadequate training programme, and inadequate demonstration of new technology are faced by the growers. Thus, there is a need to organize training programmes, proper demonstration of improved technologies, and introduction of postharvest technologies to encourage the farmers for vegetable production so that the farmers become more economically independent.

Table 1 Constraints in the transfer of technology to farmers

Technology transfer	Farmers			Mean score		
	Marginal	Small	Large	MF	SF	LF
Inadequate training of farmers	24	26	12	2.26	2.10	1.83
Inadequate demonstration of new technology	21	24	15	2.10	2.05	1.85
Inadequate follow-up services	23	23	14	2.15	2.00	1.85
Lack of location-specific recommendation	24	22	14	2.16	1.96	1.86
Lack of technical know-how	28	22	10	2.30	1.90	1.80
Lack of soil testing facilities	19	22	19	2.0	2.0	1.95
Inadequate availability of mass media sources of information	21	20	19	2.03	1.98	1.98
Lack of land consolidation	18	22	20	1.96	2.06	1.96
Lack of postharvest technology	28	26	6	2.36	1.96	1.66

MF=Marginal farmers, SF=Small farmers, BF=Large farmers, and MS=Mean score.

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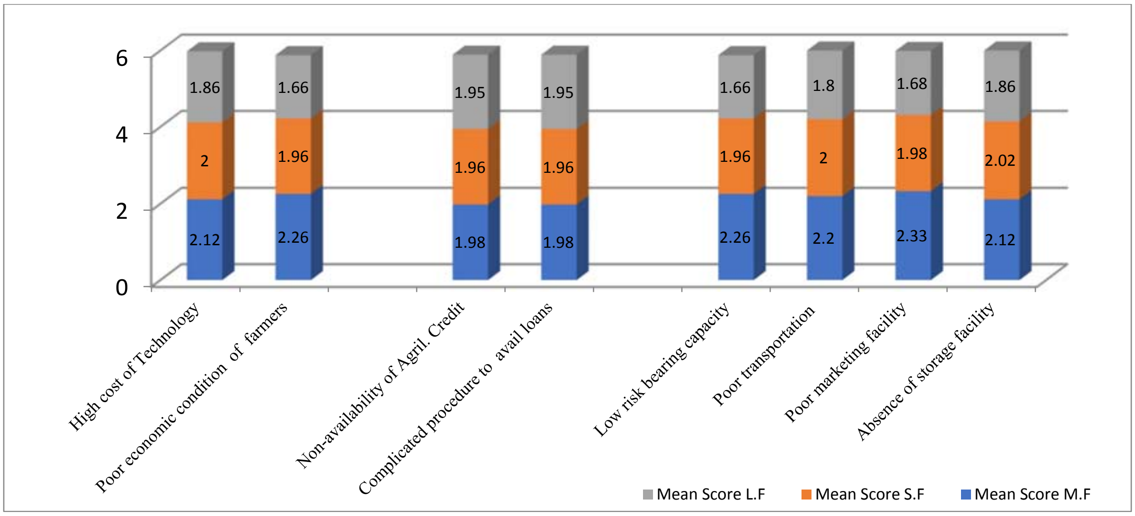

Figure 1 Economic constraints in increasing production

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4.7 Effect of Integrated Nutrient Management on Growth and Yield of Stevia (*Stevia rebaudiana* Bertoni)

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Keywords: *Azotobacter*; Integrated nutrient management; Stevia; Vermicompost

1. Introduction

S. rebaudiana Bertoni is a perennial herb belonging to the family Asteraceae, commonly known as the sweet herb of Paraguay or Mau Tulsi. Its leaves are widely used to sweeten tea, coffee, and other food additives and are in high demand because of low-calorie sweetness. Standardization of optimum doses of nutrients and their sources for enhanced yield without deteriorating soil health is of paramount importance before recommending the commercial cultivation of stevia under Jammu subtropical conditions.

2. Materials and methods

The present investigation was carried out by taking eight treatments and three replications under randomized block design (Table 1). To meet the requirement of N through organic sources, the doses of bulky manures [farmyard manure (FYM) and vermicompost (VC)] were calculated based on their respective nitrogen content. Nitrogen (N) was given in the form of urea and was applied with farmyard manure and vermicompost at the time of planting. *Azotobacter* was applied twice during the growth period of crop, that is, 200 g/acre at the time of planting and 200 g/acre before the onset of monsoon. Observations were recorded on 15 randomly selected plants per treatment (five plants per replication) in the last week of October. The observations were recorded on growth parameters and yield. After the termination of the fertilization trial, the concentration of major nutrients (NPK, %) was determined in the plants of each treatment. The available nutrient status of soil was determined after the harvest of the crop and the total NPK content in plant samples was determined by adopting standard techniques. The statistical analysis of data was carried out by using OPSTAT software.

3. Results and discussion

The application of various combinations of organic and inorganic nutrients significantly influenced the growth parameters and yield of stevia (Table 1). The results indicate that the application of organic sources of nutrients is necessary to achieve good growth and yield. The application of only chemical fertilizer(s), although improved the growth and yield over control, proved less effective compared to integrated nutrient management practices. Among the different combinations of fertilizers and manures, the application of vermicompost @ 1.5 t/ha along with ½ of RDN (30 kg N/ha) and *Azotobacter* (T_8) has significantly increased the growth and yield parameters over control (Table 1) and resulted in maximum plant height (66.17 cm), number of branches per plant (24.87), number of leaves per plant (284.68), fresh leaf yield (23.35 g), and dry leaf yield per plant (5.98 g) compared to other fertilizer combinations, but it is at par with leaf yield recorded in T_6. Higher values of yield parameters are observed in T_8 (vermicompost @ 1.5 t/ha in combination with 30 kg N and *Azotobacter*) and T_6 [30 kg N (½T_2) + VC @ 1.5 t/ha] with an estimated dry leaf yield of 4.78 and 4.32 q/ha, respectively. Kumar *et al*. (2012) have also recorded high leaf yield under the combined application of manures and fertilizers compared to alone application. Maximum contents of NPK in the soil after harvest of the crop were observed in T_3 (FYM @ 12 t/ha and *Azotobacter*) followed by T_4 (VC @ 3 t/ha along with *Azotobacter*). Integrated nutrient management comprising the use of VC or FYM in combination with inorganic fertilizers and biofertilizers was found the best combination of nutrient management compared to the sole application of organic or inorganic to increase the leaf yield in stevia under Jammu subtropics.

Table 1 Effect of fertilizers and manures on growth and yield parameters of stevia

Treatments	Plant height (cm)	No. of branches per plant	Stem diameter (mm)	No. of leaves per plant	Leaf yield per plant (g)		Estimated leaf yield per ha (q)	
					Fresh	Dry	Fresh	Dry
T_1 (Control)	48.08	11.86	8.34	157.73	12.82	3.03	10.25	2.42
T_2 [N @ 60 kg/ha (RDN*)]	59.09	18.19	8.82	216.56	17.88	4.76	14.30	3.81
T_3 (FYM @ 12 t/ha + *Azotobacter*)	54.33	15.03	8.93	184.21	15.05	3.98	12.03	3.18
T_4 (VC @ 3 t/ha + *Azotobacter*)	56.58	18.08	9.30	214.72	17.57	4.53	14.05	3.62
T_5 [30 kg N (½T_2) + FYM @ 6 t/ha]	62.14	19.06	9.59	228.07	18.25	4.59	14.60	3.67
T_6 [30 kg N (½T_2) + VC @ 1.5 t/ha	65.25	24.25	10.31	274.62	22.28	5.41	17.82	4.32
T_7 [30 kg N (½T_2) + FYM @ 6 t/ha + *Azotobacter*]	62.60	19.12	9.81	233.94	18.72	4.70	14.98	3.76
T_8 [30 kg N(½T_2) + VC @ 1.5 t/ha + *Azotobacter*]	66.17	24.87	10.56	284.68	23.35	5.98	18.68	4.78
$CD_{0.05}$	8.35	4.54	NS	31.41	3.52	0.64	2.82	0.51

*Recommended dose of nitrogen

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4.8 Effect of Different Plant Growth Regulators on *In Vitro* Seed Germination of *Citrus jambhiri* Lush.

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Keywords: Citrus; Growth regulators; Seed germination; Tissue culture

1. Introduction

Rough lemon (*C. jambhiri*) is the most commonly used rootstock for various scion cultivars of citrus all over the world. It is native to north-eastern India and highly useful rootstock because of its high degree of polyembryony. It forms a normal union with all scion varieties, develops a deep root system, produces heavy yields, and gives long life to trees when planted on suitable soil. It imparts resistance to tristeza and exocortis and is also tolerant to salt and drought. It is an important rootstock for a number of citrus fruit crops including oranges, grapefruits, lemons, and mandarins all over the world. Citrus seeds are recalcitrant and, therefore, have a very short viability period. An efficient *in vitro* seed germination of *C. reticulata* has been obtained from isolated seeds (Hassanein and Azooz, 2003). In this study, we optimized *in vitro* seed germination protocol in *C. jambhiri* by investigating different growth regulators.

2. Materials and methods

The study was carried out at Plant Tissue Culture Laboratory, Division of Fruit Science and School of Biotechnology in collaboration with the Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu from 2016 to 2018. The seeds were extracted from matures fruits, surface sterilized, and inoculated individually in 25 × 150 mm culture tubes containing 25 mL of MS medium supplemented with different concentrations of plant growth regulators such as kinetin, indole-3-acetic acid, and indole-3-butyric acid. The data were analyzed according to a completely randomized block design (CRD) and scored on a percentage to the arc sine transformation for the analysis of variance (ANOVA).

3. Results and discussion

Different growth regulators induced a significant effect on *in vitro* seed germination of *C. jambhiri.* The highest percentage of seed germination (94.73%) was obtained in seeds cultured on MS medium containing IBA (4.0 mg/L). The next best seed germination response of 89.37% and 86.34% was obtained in the MS medium with IBA (3.0 mg/L) and MS medium with KN (3.0 mg/L), respectively. The minimum *in vitro* seed germination of 45.11% was recorded in MS medium augmented with IAA (5.0 mg/L) (Table 1). Similar to our findings, Savita *et al.* (2010) also reported that IBA (4.0 mg/L) enhances seed germination in rough lemons. The conclusion of the present study reveals that the treatment of IBA @ 4.0 mg/L can be used for inducing higher seed germination of rough lemon seeds.

Table 1 Effect of different growth regulators concentrations on the *in vitro* seed germination of *C. jambhiri* Lush. inoculated on MS medium

Plant growth regulators	Concentration (mg/l)	Percent seed germination* Mean ± SE
MS medium + KN	1	65.57 ± 1.43^{c}
MS medium + KN	2	71.21 ± 2.14^{b}
MS medium + KN	3	86.34 ± 1.66^{a}
MS medium + K N	4	64.28 ± 1.33^{c}
MS medium + K N	5	49.18 ± 2.31^{d}
	F(df 3, 8)=98.119 HSD = 10.362	
MS medium + IAA	1	57.31 ± 3.84^{b}
MS medium + IAA	2	63.49 ± 1.39^{b}
MS medium + IAA	3	70.08 ± 2.30^{a}
MS medium + IAA	4	59.32 ± 3.21^{b}
MS medium + IAA	5	45.11 ± 1.44^{c}
	F(df 3, 8) = 40.361 HSD = 6.497	
MS medium + IBA	1	73.04 ± 2.66^{b}
MS medium + IBA	2	78.51 ± 1.33^{b}
MS medium + IBA	3	89.37 ± 3.23^{a}
MS medium + IBA	4	94.73 ± 2.61^{a}
MS medium + IBA	5	51.19 ± 1.66^{c}
	F(df 3, 8) = 91.866 HSD = 9.216	
MS basal medium (Control)	-	53.14 ± 2.56

*Out of 24 cultures inoculated for each concentration and each experiment was repeated three times.
MS = Murashige and Skoog, KN = kinetin, IAA = indole-3-acetic acid, IBA = indole-3-butyric acid.

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4.9 Optimization of Growth Media Amended with Different Hormone Concentrations for Growth of *Hericium erinaceus*

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Keywords: Cytokinin; Gibberellic acid and IAA; *H. erinaceus*; Mycelium growth

1. Introduction

In developing countries like India, mushroom progress is a boon in the field of food, medicine, and in generating employment. Mushrooms have been examined by the food and pharmaceutical industry as a source of medicinal compounds including phenolics, terpenes, tocopherols, and polysaccharides. *H.erinaceus*is an edible fungus belonging to the phylum Basidiomycota, class Agaricomycetes, order Russulales, and family Hericiaceae (Sokół *et al*., 2015). Among *Hericium* species, only *H.erinaceus* is currently being grown at a significant commercial level in indoor facilities. Artificial cultivation of *H.erinaceus* (Lion's mane) was first reported in China and is cultured in the artificial log using polypropylene bags and bottles (Imtiaj *et al*., 2008).Plant growth regulators and media also play an important role in the case of *in vitro* mycelial colony proliferation of mushrooms (Maniruzzaman, 2004). Therefore, the present experiment was carried out to investigate the effect of different concentrations of cytokinin, IAA, and gibberellic acid on mycelial colony proliferation of *H. erinaceus*.

2. Materials and methods

This experiment was conducted at SKUAST-Jammu. Different concentrations (10, 20, and 30 ppm)of cytokinin, gibberellic acid, and IAA were supplemented in different media (potato dextrose Agar (PDA), malt extract agar (MEA), sawdust extract agar (SDEA), wheat straw extract agar (WSEA), and rice straw extract agar (RSEA)) as a treatment.

Preparation of stock solution of hormone: Stock solution of hormones was prepared separately by dissolvingthe desired quantity of ingredients in an appropriate solvent. To prepare the stock solution of cytokinin, gibberellic acid, and IAA, 50 mg (concentrated) of each of the hormones was weighed and 1000 mL distilled water was added to make the final volume. The solution was then stored at 0°C for further use.

Preparation of medium: All the above-mentioned media were prepared by dissolving the prescribed quantities of the ingredients into the distilled water in order to make the required quantity of each medium (Aneja, 2002). In the case of saw dustextract agar, sawdust(200g) was boiled in a container using 500 mL of distilled water for 45 min. The extract of sawdust was strained through double layered muslin cloth and the extract was kept in a beaker separately. Twenty grams of agar-agar was boiled in 500 mLof water followed by the addition of 20 g of dextrose. Sawdust extract and agar liquid were mixed with constant stirring using a glass rod and the contents were made up to 1000 mLin a conical flask by adding more distilled water (Singh *et al*., 2009).The sameprocedure was followed for the preparation of wheat straw and rice straw extract agar medium. Media thus prepared were sterilized in the autoclave at 15 psi for 20 min.

3. Results and discussion

The influence of different solid media and concentrations of cytokinin, indole acetic acid, and gibberellic acid on the mycelia growth of *H. erinaceus* was studied and the data generated is presented in Table1. The effect of different solid agar media, namely, potato dextrose agar, malt extract agar, sawdust extract agar, wheat straw extract agar, and rice straw extract agar, and different concentrations of cytokinin, indole acetic acid, and gibberellic acid on the mycelial growth of *H. Erinaceus* was studied. The results reveal that all the selected media and concentrations of cytokinin significantly influenced the mycelial growth of *H.erinaceus*. The maximum colonial diameter growth of 85.5mm was recorded with potato dextrose agar at 30ppmgibberellic acid concentration followed by 84.80 and 84.70mm at 30ppm cytokinin on potatodextrose agar and malt extract agar, respectively. The least effective solid medium was rice straw extract agar showing mycelial growth of only 38.60mmat 10ppm indoleacetic acid.

With regard to average mycelium growth at different media, in the case of cytokinin treated media the data exhibited that the malt extract agar showed the maximum mycelium growth of 83.36mm,whereas in indole acetic acid treated media, potato dextrose agar showed the maximum mycelial growth of 57.73 mm. In the case of gibberellic acid treated media, potato dextrose agar showed the maximum mycelium growth of 82.6mm.

Table 1 *In vitro* evaluation for mycelial growth (mm) of *H.erinaceus* on different media amended with different concentrations of cytokinin, indoleacetic acid, and gibberellic acid

Hormone conc. (ppm)	Colony diameter(mm)														
	Cytokinin					Indole acetic acid					Gibberellic acid				
	PDA	MEA	SDEA	WSEA	RSEA	PDA	MEA	SDEA	WSEA	RSEA	PDA	MEA	SDEA	WSEA	RSEA
10	79.80	82.50	58.70	48.50	49.50	72.80	53.70	52.70	57.90	59.50	78.50	76.70	46.20	41.30	38.60
20	81.40	82.90	60.40	54.70	52.80	58.90	51.80	46.80	46.80	52.40	83.80	75.50	47.90	43.70	46.40
30	84.80	84.70	68.50	57.50	55.30	41.50	39.70	36.40	36.10	40.20	85.50	81.80	51.30	49.70	50.80
Mean	82	83.36	62.53	53.56	52.53	57.73	48.4	45.3	46.93	50.7	82.6	78	48.46	44.9	45.26

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4.10 Efficacy of Six Types of Biodegradable Containers in Nursery Raised with Teak Seedlings

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Keywords: Biodegradable; Container; Nursery; Seedling; Teak

1. Introduction

Plastic-based materials are widely used in the nursery production sector in both agriculture and forestry primarily as seedling containers. The economic feasibility, durability, easiness of handling, irrigation, and application of plant protection measures make it most popular among nursery containers. However, such massive use of plastic for plant container production causes serious environmental degradation due to longer periods of non-degradability or their non-degradability. Thus, there is a need to use biodegradable containers. There are advantages and disadvantages of using biodegradable containers in the nursery. However, consumer demand for environmentally conscious products and practices is on the rise and consumers are willing to pay more for eco-friendly products, such as plants grown in biodegradable containers (Behe *et al*., 2013). In the present study, the efficacy of some locally available biodegradable containers has been studied in a forest nursery raising teak seedlings.

2. Materials and methods

The investigation was carried out at the College of Forestry, Kerala Agricultural University, Thrissur, Kerala, India in 2020. The experimental site comes under the humid tropical zone. Six types of biodegradable containers were taken for the trial: nonwoven cloth bag, coco pot, mud pot, bamboo splits, cashew nut shell liquid treated cardboard, and coir root trainer. The experiment was done in a complete randomized design with four replications. Each treatment included 30 plants per replication. The data were compared under Duncan's Multiple Range test (DMRT). For this, 15-day-old uniform-sized teak seedlings were transplanted in different containers. Each container had an equivalent capacity of 12 cm × 15 cm filled with a soil mixture of soil:coir pith:vermicompost @ 2:1:1 by volume. The efficacy of different containers was studied in terms of growth and quality (Dickson *et al*., 1960) of seedlings monthly for 5 months and the economics of raising seedlings in them.

3. Results and discussion

The six different biodegradable containers resulted in seedlings of different qualities. Except for first month, in all other months seedling quality index varied significantly among the containers (Table 1). The quality index differed from 0.46 to 1.03 at 5-month age. Nonwoven bag (T_1) was found to be most efficient in producing superior quality seedlings, followed by bamboo splits (T_4). Mud pot (T_3) was witnessed to be the least efficient among the containers tested. The order of performance with regard to seedling quality was: $T_1 > T_4 > T_2 > T_5 > T_6 > T_3$. Seedling quality is often considered as the net effect of growth potential and the effective allocation of biomass to the aboveground and belowground. The containers with a higher seedling quality index indicate their better efficiency to support higher shoot growth and root growth as well as higher shoot biomass and root biomass. The economics of raising teak seedlings of 5-month-old in six biodegradable containers differed significantly (Table 2). In the table, the economics of raising seedlings in conventional polythene bags is also included for comparison. The benefit: cost ratio of raising a 5-month age teak seedling varied remarkably among different containers. It ranged from 0.30 to 2.60. The value was highest in the case of seedlings raised in a polythene bag (non-biodegradable), followed by degradable containers such as bamboo split pot, nonwoven bag, treated cardboard, coir peat pot, coco pot, and mud pot. This was primarily due to the variation in the cost of containers.

Table 1 Quality index of teak seedlings in different biodegradable containers

Name of container	Quality index of teak seedlings				
	1-month-old	2-month-old	3-month-old	4-month-old	5-month-old
Nonwoven bag (T_1)	0.10	0.30^{a}	0.64^{a}	0.83^{a}	1.03^{a}
Coco pot (T_2)	0.08	0.20^{bc}	0.45^{b}	0.59^{c}	0.77^{c}
Mud pot (T_3)	0.05	0.10^{e}	0.22^{d}	0.30^{f}	0.46^{f}
Bamboo split pot (T_4)	0.09	0.24^{b}	0.56^{a}	0.75^{b}	0.93^{b}
CNSL-treated cardboard pot (T_5)	0.07	0.16^{cd}	0.38^{bc}	0.52^{d}	0.69^{d}
Coir root trainer (T_6)	0.06	0.13^{de}	0.29^{cd}	0.41^{e}	0.60^{e}
$SE_{(m)}$	NS	0.01	0.03	0.02	0.02
CV	NS	13.8	14.9	6.25	4.3

Note: Values with at least one common letter are not significantly different.

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Table 2 Economics of raising teak seedlings (5-month-old) in different biodegradable containers

Name of container	Cost of one container (Rs)	Cost of soil mixture for one teak seedling (Rs)	Cost of labor and other inputs for one teak seedling (Rs)	Survival percentage of seedlings in 5 months (Rs)	Total cost of raising one 5-month-old teak seedling (Rs)	Sale price of one 5-month-old teak seedling (Rs)	Benefit:cost ratio
Nonwoven bag (T_1)	4.0	1.5	5.0	94	11.10	20.00	1.80
Coco pot (T_2)	55.0	1.5	5.0	98	62.70	20.00	0.31
Mud pot (T_3)	40.0	1.5	5.0	68	68.40	20.00	0.30
Bamboo split pot (T_4)	7.0	1.5	5.0	100	13.50	27.00	2.00
CNSL-treated cardboard pot (T_5)	8.0	1.5	5.0	88	16.50	20.00	1.21
Coir root trainer (T_6)	20.0	1.5	5.0	90	29.44	20.00	0.70
Polythene bag (check)	0.50	1.5	5.0	90	7.70	20.00	2.60

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4.11 Standardization of Fertilizer Doses and Weed Management for Profitable Cultivation of Elephant Garlic (*Allium ampeloprasum* L.)

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Keywords: Economics; Elephant garlic; Fertilization; Mulching; Weed management

1. Introduction

Elephant garlic or great headed garlic (*A. ampeloprasum* L.) is also an important species having 5 or 6 cloves that are quite large with papery skins and used for both culinary purposes and propagation. However, its cultivation is restricted to a few pockets of the Jammu region, owing to a lack of quality planting material, standardized package of practices, and economics of growing this crop. Keeping the importance of this crop under consideration, the following research experiment was conducted to address some issues to harness the full potential of this crop.

2. Materials and methods

The experiment was conducted at Sher-e-Kashmir of Agricultural Sciences & Technology of Jammu, Faculty of Agriculture, Division of Vegetable Science and Floriculture, Chatha, Jammu (J&K) during the Rabi season 2019-20. The experiment was laid out in RBD (factorial) fashion and replicated thrice on advanced line SJEG-1801. The experiment comprised four levels of fertilizers, namely, recommended dose of fertilizer of garlic (100:50:50 kg/ha N:P:K and 20 t/ha FYM), 20% less (80:40:40 kg/ha N:P:K and 16 t/ha FYM), 20% more (120:60:60 kg/ha N:P:K and 24 t/ha FYM), and 40% more (140:70:70 kg/ha N:P:K and 28 t/ha FYM), and four mulching treatments, namely, M_0: No mulch, M_1: Rice straw mulch, M_2: Sarkanda mulch, and M_3: Black polyethylene mulch.

3. Results and discussion

Maximum bulb weight (100.16 g), bulb yield per plot (9.01 kg), and maximum bulb yield (135.22 q/ha) were recorded in the treatment combination of a 20% increase in RDF of garlic with rice straw mulch. Fertilization at higher doses had a significant effect on the yield of external cloves. However, it was significantly higher at a 20% increased dose of RDF. At much higher rates (40% increased dose of RDF), a significant reduction in all the yield attributing parameters of external cloves per bulb was recorded. This clearly showed that elephant garlic being long duration and hardy crop than garlic (more than 2 months) requires 20% more fertilization with respect to N, P, K, and FYM for proper growth and development. Mulching and their interaction effect with fertilization revealed non-significant results in terms of the number and yield of external cloves.

Table 1 Effect of mulching, fertilization, and their interaction on yield, external cloves, and weed parameters of elephant garlic

Treatment	Bulb weight (g)	Bulb yield per plot (kg)	Total bulb yield (q/ha)	Number of external cloves/bulb	Yield of external cloves (kg/ha)	Days to harvest	Weed density (plants/m^2)	Weed index (%)	BCR
T_1M_0	67.19	6.05	90.70	5.00	742.50	200.25	160.66	32.96	2.56
T_1M_1	64.77	5.82	87.44	5.33	787.50	201.41	47.66	35.12	2.32
T_1M_2	68.09	613	91.93	5.83	855.00	133.08	41.66	31.98	2.76
T_1M_3	53.45	4.18	72.16	5.66	832.50	197.33	39.66	47.06	1.92
T_2M_0	73.88	6.65	99.74	6.06	886.50	NS	172.00	25.95	3.10
T_2M_1	83.15	7.48	112.25	6.80	985.50	197.33	50.33	17.43	3.30
T_2M_2	73.85	6.64	99.69	7.00	1012.50	200.33	43.33	26.60	3.30
T_2M_3	78.79	7.09	106.37	7.16	1035.00	197.33	36.66	20.80	3.11
T_3M_0	78.85	7.09	106.45	6.66	967.50	188.00	179.33	28.72	3.24
T_3M_1	100.16	9.01	135.22	8.33	1192.50	199.66	55.00	1.00	4.00
T_3M_2	99.24	8.93	133.98	5.93	868.50	197.33	45.66	2.00	3.81
T_3M_3	71.70	6.45	96.80	7.00	1012.50	197.33	43.66	21.10	2.71
T_4M_0	81.01	7.82	108.81	6.33	922.50	202.00	183.00	18.55	3.41
T_4M_1	86.95	7.82	117.38	6.50	945.50	204.33	59.00	13.18	3.14
T_4M_2	78.70	7.83	106.24	6.66	967.50	202.00	58.00	21.21	3.15
T_4M_3	81.56	7.34	110.11	6.33	963.00	206.66	50.33	12.91	2.89
C.D. (5%) (T×M)	13.40	1.18	18.24	NS	NS	8.33	NS	13.84	-

Minimum days to harvest were recorded in a treatment combination of 20% decrease in RDF with black polyethylene mulch. A minimum weed index was found in treatment with a 20% increase in RDF of garlic with rice straw mulch. The highest benefit-cost ratio of 1:4.0 was however obtained in treatment with a 20% increase in RDF of garlic with rice straw mulch, which resulted in a high net income of Rs 1,139,007 with a gross income of Rs 1,423,575 at the cultivation cost of Rs 284,568.

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4.12 Value Chain Assessment of Chinese Potato in Tamil Nadu: Challenges and Strategies

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Keywords: Challenges; Marketing channel; Plectranthus rotundifolius; Strategies; Value chain assessment

1. Introduction

Chinese potato [*P. rotundifolius* (Poir.) Spreng] is a tropical tuber crop meant primarily for direct consumption. The Chinese potato is grown in the monsoon season in India and is cultivated as part of an irrigated/rainfed production system. Tamil Nadu and Kerala are the leading Indian states in Chinese potato production. In 2017, the CTCRI launched an outreach programme in Tamil Nadu to promote the high-yielding Chinese potato variety 'Sree Dhara' by establishing demonstrations and seed villages. Significant changes are being observed in agricultural value chains in many developing nations upstream at the producer's level, midstream with traders, and downstream at the retail level. It has been argued that an efficient value chain would reduce the use of intermediaries in the chain and strengthen the value-added products with better technology and inputs, farm gate procurement, upgraded infrastructure and processing, and exports. Hence, the purpose of this study is to understand the changes that have been happening in the value chain of Chinese potato in Tamil Nadu. Keeping this in view, the present study was undertaken to map and understand the Chinese potato value chain and its linkages among various agents and to suggest strategies to improve the Chinese potato value chain in Tamil Nadu.

2. Materials and methods

This study is based on a primary survey conducted in Tenkasi and Tirunelveli districts of Tamil Nadu during 2021-22 using a well-structured interview schedule, focus group discussions, and key informant interviews from different value chain actors, namely, producers (200), aggregators (05), wholesale markets (10), wholesalers (05), retailers (15), and consumers (20). Thus, a total of 255 participants were covered in this study. These districts were purposively selected as the field interventions involving improved variety were implemented and these districts have over 50% of the area under Chinese potato. The multistage random sampling method was used for selecting the blocks, villages, and farmers. Descriptive statistics and econometric techniques were used to analyze the data. Additional variables such as input use, quantities sold, time of sales, type of buyers, and payment modalities were included for a better understanding of the price formation of Chinese potato at different levels.

3. Results and discussion

All the farmers sold their produce immediately after harvest. Market/mandi played a major role in channelizing Chinese potato and it accounted for 71.50%, followed by aggregators (25.25%), wholesalers (2.25%), and consumers (1%). Chinese potato is a seasonal crop and it is harvested mainly during November (13.34%), December (33.25%), January (26.56%), February (17.2%), and March (9.65%).

Aggregators, wholesale markets, and wholesalers are three prominent actors involved in the midstream of the Chinese potato value chain. As Chinese potato is a seasonal crop, it was estimated that 85% of the aggregators deal with Chinese potato along with other commodities. Commission agents have authorized traders in the wholesale markets who facilitate the sales of Chinese potato from producers to buyers. The wholesalers procure the Chinese potato from commission agents in the wholesale markets in bulk for sale in local and distant markets. The method of sale of Chinese potato in wholesale markets was the open auction method. Wholesaler survey was conducted among the respondents from Kerala and Tamil Nadu who came for buying Chinese potato from producers and the wholesale markets. About 85% of the wholesalers purchased Chinese potato from the wholesale market and the rest from the producers and aggregators.

Downstream value chain actors consist of retailers and consumers. All the retailers sold their Chinese potato through regular greengrocers or unorganized markets, that is, vegetable mandis and roadside markets that also sell other vegetables too. For the marketing of tubers, six types of marketing channels are being followed in Tamil Nadu (Table 1). Marketing channel II comprising farmers/ commission agents/traders at wholesale market-Wholesalers – Retailers - Consumers is more dominant with a share of 64% of the total farmers, where farmers directly take their produce to the market and sell it to wholesalers. Further, it was observed that the increasing number of market intermediaries has lowered the farmers' share in consumers' rupee (Prakash *et al*., 2018; Yogi *et al*., 2020).

Development of short duration and high-yielding varieties, strengthening research-extension-farmer linkages, improvement of the accessibility of credit facilities and crop insurance scheme, exploration of alternative markets, establishment of postharvest processing and storage facilities, rationalization of commission fees for marketing, and capacity building on market intelligence for the farmers and other stakeholders are warranted for the sustainable development of Chinese potato sector in the long run.

Table 1 Price spread of Chinese potato under different marketing channels (Rs/bag)

Particulars	Channel I	Channel II	Channel III	Channel IV	Channel V	Channel VI
Producers price	1540	1686	1470	1686	1686	2450
Marketing cost	724	677	543	477	307	–
Consumer price	3530	3570	3080	3220	2800	2450
Price spread	1266	1207	1067	1057	807	–
PSCR (%)	43.63	47.23	47.73	52.36	60.21	100

Note: One bag = 70 kg tubers and the price is the weighted average price calculated based on the grading of tubers such as small, medium, and large; PSCR = Producers share in consumers rupee.

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4.13 Effects of Shaking Frequency and Limb Diameter on Mechanical Shaker of Apricot (*Prunus armeniaca* L.)

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Keywords: Apricot; Limb diameter; Mechanical shaker; Shaking frequency

1. Introduction

Apricots (*P. armeniaca L.*) enjoy an outstanding position in Ladakh and the district Kargil is the major production hub of the fruit crop. Apricot is cultivated in Leh and Kargil districts over an area of 792 and 1514 ha generating a total of 1923 and 3775 MT, respectively (Ali *et al*., 2018). The crop being perishable in nature requires timely harvest without any delay. The harvesting of apricot is carried out either through hand picking or beating the limb with long sticks. A portable limb shaker with adjustable shaking frequency was used on different limb diameters of the apricot tree. The aim of this study was to determine the most suitable shaking frequency to obtain the maximum fruit removal with minimal leaf shattering and branch damage to the tree.

2. Materials and methods

An inertia-type portable limb shaker (Cifarelli SC800) was used for harvesting apricot and it was powered by a 2.5 hp, 2-stroke, and spark ignition engine and had a weight of 14.9 kg. The linearly vibrating boom was supported by a hollow boom guide. A Teflon bushing was provided inside the boom guide to reduce friction. The C-shaped clamp connected the boom to a tree limb. To avoid bruising to the limb's skin, the inner surface of the C-clamp was covered by rubber padding. A 3 × 3 factorial experiment with a completely randomized design was conducted to investigate the effects of shaking frequency and limb diameter on fruit detachment. Three levels of shaking frequency (7, 23, and 33 Hz) and three levels of limb diameter (<20, 20–40, and >40 mm) were investigated. Shaking was started at a shaking frequency of 33 Hz and the shaking frequency was changed in the further sets of the test. The results were observed and recorded after every set. In this way, evaluation was carried out at three levels and the optimum shaking frequency was selected at which a maximum number of fruits were harvested and mechanically bruised with efficiency.

3. Results and discussion

The interaction effect of shaking frequency was found significant on fruit removal for different limb diameters. Fruit removal percentage for different limb diameters increased with an increase in shaking frequency. At the shaking frequency at 33 Hz and limb diameter of less than 20 mm in combination, the average fruit removal percentage was 99.61%. The mean mechanical bruising percentage was found highest (21.20%) and lowest (10.71%) at shaking frequencies 33 and 7 Hz, respectively. Harvesting efficiency increased with an increase in limb diameter and was also found highest (89.22%) at a shaking frequency of 7 Hz and lowest (78.73%) at a shaking frequency of 33 Hz. The twig losses increased with an increase in shaking frequency and limb diameter and vice versa. Loghavi and Mohsini (2006) reported similar findings that at a shaking amplitude of 120 mm with the frequency of 10 Hz, fruit removal was 100% but leaf shattering and foliage breakage were excessive. The shelf life of apricot decreased with an increase in shaking frequency. Increasing shaking frequency (33 Hz) increased the fruit removal percentage (99.61 %) but consequently enhanced the mechanical bruising. At a shaking frequency of 33 Hz, higher harvesting loss, that is, damage to twigs, was observed. The study showed that apricot harvesting with a mechanical shaker is feasible and remunerative.

Table 1 Effect of shaking frequency and limb diameter on harvesting efficiency of apricot

Source of variation	DF	Sum of squares	Mean squares	F-calculated	C.D.	SE(d)	SE(m)	Significance
Shaking frequency	2	2570.30	1285.15	2516.99	0.299	0.151	0.107	0
Limb diameter	2	414.675	207.338	406.075	0.299	0.151	0.107	0
Shaking frequency × Limb diameter	4	73.114	18.278	35.799	0.517	0.261	0.184	0

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4.14 Mapping of Women Empowerment in Chinese Potato Cultivation in Tamil Nadu

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Keywords: Chinese potato; Gender mainstreaming; Mapping; Women empowerment

1. Introduction

Chinese potato (*Plectranthus rotundifolius*) is one of the important tropical tuber crops grown in India mainly for edible purposes. The tubers contain 18–20% starch with a characteristic flavor due to essential oils which are preferred by the consumers. It is mainly cultivated in Kerala, Tamil Nadu, and in tribal settlements throughout India (Jaganathan *et al*., 2020). Women account for 43% of the agricultural labor force in developing countries and slightly more than 30% in South Asia and India. The involvement of farm women in Chinese potato cultivation starting from planting to marketing is noteworthy. Most of the developmental interventions in agriculture fail to address the gender-specific needs of men and women. Keeping this in view, mapping of women empowerment in Chinese potato cultivation was done for formulating strategies for gender mainstreaming.

2. Materials and methods

An ex post facto research and survey design was used for mapping women empowerment among farmers in the Tenkasi and Tirunelveli districts of Tamil Nadu. Simple random sampling was employed for collecting data through conducting interviews, focus group discussions, and case studies from 132 Chinese potato growers (66 women and 66 men) from August to December 2021.

The Women's Empowerment Index in Agriculture was developed by International Food Policy Research Institute (IFPRI) and USAID's Feed the Future (FTF-USAID, 2012). This comprehensive index comprises sub-indicators to measure the inclusion levels of women in agriculture. The modified methodology was used for mapping the Women Empowerment Index in Chinese potato (WEICP) which consists of five domains, namely, production decision-making, access to productive resources, control over the use of income, community leadership, and time allocation, and each domain has sub-indicators of empowerment.

3. Results and discussion

The results revealed that the mean age of men was 46 years and women was 42 years. Nearly 40% of the men and around 36% of women had a high school education. Both men (98.48%) and women (96.97%) had agriculture as their main occupation as the area is dominated by agriculture. The nuclear family system is dominating (65.15%) and the number of family members was between four and six. Forty percent of women and 48% of men had more than 20 years of experience in farming. The mean landholding size was 1.73 ha and the mean area under Chinese potato cultivation was 0.62 ha. The aspiration level of both men (74.24%) and women (72.73%) was medium. A medium level of innovativeness was reported by men (83.33%) and women (63.64%). The majority of the women (83.33%) and men (71.21%) had a medium level of participation in Chinese potato cultivation. The mean score for overall participation of men was 2.21 and for women was 1.53. Women and men were having significant differences in their level of participation in Chinese potato cultivation at a 1% level.

The mean empowerment index of men was more than women in all indicators of five domains of empowerment and significant differences were observed between women and men for all the indicators. The empowerment index in Chinese potato was estimated to be 0.55 for women and 0.80 for men, which was significant at a 1% level.

Table 1 Empowerment index in Chinese potato

Empowerment indicators	Mean empowerment score		Chi^2 statistics	*P* value
	Women respondents (*n* = 66)	Men respondents (*n* = 66)		
Input in productive decisions	1.65	2.89	97.0352***	0.000
Autonomy in production	1.67	2.68	61.3489***	0.000
Ownership of assets	1.29	2.82	92.7158***	0.000
Purchase, sale, or transfer of assets	1.47	2.62	66.3161***	0.000
Access to and decisions on credit	1.73	2.29	35.2108***	0.000
Control over the use of income	1.67	2.20	35.8351***	0.000
Group membership	1.97	2.24	9.2540***	0.010
Speaking in public	1.74	2.18	17.4372***	0.000
Workload	1.67	2.09	20.5333***	0.000
Leisure time	1.64	1.98	13.0093***	0.001
Overall empowerment	1.65	2.40	95.59***	0.000
Women empowerment index	0.55	0.80		

***At 1 % level of significance.

Need for women in Chinese potato cultivation revealed that their first requirement was quality planting materials (mean value 2.73), followed by a demonstration of improved technologies (2.61), pre- and postharvest machinery for drudgery reduction (2.58), training on improved technologies (2.53), and subsidies/critical inputs (1.98). The preferences in Chinese potato were varieties with high yielding potential with a mean value of 2.97, followed by pest and disease resistance (2.71), good keeping quality (2.36), short duration varieties (2.18), suitable for cropping system (1.80), and good cooking quality (1.71).

The major constraints reported by the women were price fluctuation (2.65), non-availability of quality planting materials of improved varieties (2.30), pest and disease incidence (2.23), erratic rainfall/weather aberrations (2.06), lack of marketing facilities (1.94), lack of knowledge and

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access to crop loans and subsidies (1.71), and less access to extension/training programmes (1.42). Men were dominating in all the indicators of empowerment, and hence suitable technological, social, and economic interventions are required to empower farm women in all aspects of Chinese potato cultivation.

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4.15 Direct Seeding of Rice in Indian Punjab: Insights from a Primary Survey

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Keywords: Appraisal; COVID-19; Direct seeding; Punjab agriculture; Rice

1. Introduction

The intensification of agriculture in Indian Punjab, which significantly contributed to ensuring the nation's food security, has resulted in the over-exploitation of groundwater resources (Kaur and Vatta, 2015). The long-term sustainability of groundwater requires a shift toward less water-consuming crops and more water-efficient technologies and practices such as direct seeding rice (DSR). The COVID-19 lockdown created a severe labor shortage, reducing the area under paddy. The Government of Punjab distributed about 4000 DSR machines at subsidized rates and reportedly brought about 5 lakh ha under DSR. Apart from solving the labor crisis, the shift was likely to save a significant amount of groundwater resources (Vatta *et al.*, 2022). The present study was conducted in 2020 to examine the adoption of DER and its determinants.

2. Materials and methods

Multi-stage sampling technique was used, and 11 districts were selected randomly (out of 22 districts). Later, two blocks with the highest area under DSR in the district and five villages with significant adoption of DSR in the block were selected. Finally, 10 adopters and 5 non-adopters were chosen from each village. Hence, the study was based on the primary data collected from 1650 farmers (1100 adopters and 550 non-adopters of DSR) from 11 districts, 22 blocks, and 110 villages.

3. Results and discussion

The study revealed that DSR was adopted by relatively more educated farmers and those associated with Kisan Clubs, Farmer Producer Organizations (FPOs), and farmers' cooperatives. Most adopters were medium to large farmers with an average holding size of 8.8 ha (Table 1). The adoption of DSR was higher among the farmers with relatively lower access to irrigation as they had to irrigate more area per electric tube well. The adopters initially practiced almost half of the area under DSR, but nearly half of this area was ploughed back. The primary reasons for the adoption of DSR were the poor availability of labor for transplanting (97%), resultant higher wages for paddy transplanting (86%), and less access to irrigation water (33%). The non-adopters reported more confidence in well-established paddy transplantation technology and a lack of experience of the farmers with DSR, being a new technology. Non-availability of an effective DSR seed drill was another critical reason for its non-adoption. Poor initial germination (89.3%), high weed infestation (59.1%), poor crop look/establishment of the crop (48.8%), micronutrient deficiency (24.6%), and the problem of rodents (22.4%) were the primary reasons for ploughing back of DSR and switching again to transplanted paddy.

Table 1 Key factors associated with the adoption of direct seeding of rice in Indian Punjab

Parameter	Adopters	Non-adopters	Difference
Education (no. of years)	9.2	8.7	0.5**
Graduate farmers (%)	11.6	5.8	5.8***
Access to institutional sources for training (%)	45.2	28.7	16.5***
Operational area (ha)	8.8	5.9	2.9***
Average irrigated area per electric pump (ha)	4.6	3.3	1.3***
Farmers who believe DSR leads to cost savings (%)	77.0	68.0	9.0***
Paddy area initially brought under DSR (%)	48.2	NA	NA
Paddy area after ploughing back finally kept under DSR (%)	22.7	NA	NA

Note: *** and ** represent significance at 1% and 5% levels, respectively.
Source: Primary Survey

Most farmers did not rate DSR as a tough option and viewed it as a cost-saving technology, with an average expected saving of Rs 7750 per ha. Almost all farmers believed DSR to be water efficient. However, the farmers' perceptions about yield and fertilizer use efficiency of DSR varied and called for ramping up extension efforts on this aspect. There was partial adoption of recommended cultivation practices. Only about 20% of non-basmati growers and 32% of basmati growers followed the recommended sowing time (1st and 2nd fortnight of June, respectively). Almost 77% of paddy and 65% of basmati growers had sown the crop before the 15th of June. About 12% of non-basmati and 32% of basmati growers had sown the crop very early, that is, non-basmati in the first fortnight of May and basmati in the second fortnight of May. The DSR adopters faced rodents, termites, and excessive weed infestation problems at the initial stages of crop establishment. However, almost 85% of DSR adopters had shown willingness to continue the DSR, provided there were no significant yield losses.

To promote DSR, more educated and young farmers of the state should be motivated. More resources should be allocated for PAU, KVKs, and the Department of Agriculture and Farmers' Welfare for capacity building of the farmers. Special campaigns should be initiated in the regions with lower coverage of DSR, and there is a need to develop literature on success stories and disseminate them to the farmers through various extension mechanisms. There is a need to generate more awareness of standard DSR practices, their benefits, and the optimal time of sowing. Encouraging farmers to adhere to recommended time of sowing and discouraging early sowing will save groundwater resources. Various problems the farmers encounter, namely, excessive weed infestation, rodents, and termites, should be addressed.

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4.16 Discriminant Analysis and Artificial Neural Network for Seasonal Classification of Tomato Crop: A Comparative Study

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Keywords: Accuracy rate; Artificial neural network; Classification; Discriminant analysis; Kappa Statistics; Tomato

1. Introduction

Classification is beneficial for planning purposes in the field of agriculture. It can be done using statistical methods and machine learning methods. Discriminant analysis is a multivariate technique firstly introduced by R. A. Fisher, which is used for classifying observations into two or more groups based on variables measured on each sample. Artificial neural network (ANN) is a branch of artificial intelligence that is inspired by the human neural system and it considers classification as one of the most dynamic research and application areas. Its learning algorithms make it a very effective and useful tool for non-linear statistical data. In the present study, an effort has been made to study the seasonal classification of the tomato crop in the Jammu district. The main purpose of this research was to classify the tomato crop for the summer season and the winter season based on price, arrival, and turnover.

2. Materials and methods

The secondary data related to price, arrival, and turnover of tomato crop on a monthly basis for the last 10 financial years (2012–2022) were collected from the J&K Horticulture Planning & Marketing Department, Narwal Mandi, Jammu. After collecting data, two groups summer and winter seasons have been formulated as seasons of tomato crop have been considered as the dependent variable. The data set is randomly divided into training data and test data. Discriminant analysis model (Nagraja and Singh, 2018) and ANN model (Galdon *et al*., 2010) were fitted to data for the classification purpose of different crops. Classification ability performance of the different models is measured using accuracy rate, kappa statistics, average precision (Avgprecision), and average recall (Avgrecall):

$$\text{Accuracy rate} = \frac{\text{Correctly classified data}}{\text{Total data}} \times 100$$

$$\text{Kappa statistics, } \kappa = \frac{N \times \sum_i^l x_{ii} - \sum_i^l x_{ir} x_{ic}}{N^2 - \sum_i^l x_{ir} x_{ic}}$$

where x_{ii}, the count of cases, is in the main diagonal of confusion matrix; N is the number of examples; x_{ir} and x_{ic} are the rows and columns total counts, respectively. The confusion matrix used to find the values of Avgprecision and Avgrecall is given below:

	A	B
A	AA	AB
B	BA	BB

Here, A and B are two classes; AA and BB represent the correct prediction number of samples and AB is a predictive number of the original sample A which is incorrectly predicted as sample B. Similarly other items are defined.

So,

Avgprecision = [(AA/(AA+AB)) + ((BB/(BA + BB)]

Avgrecall = [(AA/(AA+ BA)] + [(BB/(AB + BB)]

3. Results and discussion

Table 1 Classification of tomato crop for different seasons using discriminant analysis and ANN

Sample	Observed	Predicted (discriminant analysis)			Predicted (artificial neural network)		
		Summer	Winter	Percent correct	Summer	Winter	Percent correct
Training (80%)	Summer	25	22	53.20%	21	26	44.70%
	Winter	24	25	51.00%	15	34	69.40%
	Overall Percent	51.00%	48.90%	52.10%	37.50%	62.50%	57.30%
Testing (20%)	Summer	9	4	69.23%	9	4	69.23%
	Winter	2	9	81.81%	3	8	72.72%
	Overall Percent	45.83%	54.17%	75.52%	50.00%	50.00%	70.98%

Dependent Variable: Season Code

In the training data set of discriminant analysis, 25 out of the 47 summer tomato crops are correctly classified with 53.20%, 25 out of the 49 winter tomato crops are classified correctly with 51.0%, and overall 52.10% of the training cases are correctly classified, whereas in training data set of ANN, 21 out of the 47 tomato crops of summer season are correctly classified with 44.7%, 34 out of the 49 tomato crops of winter are correctly classified with 69.4%, and overall 57.3% of the training cases are classified correctly.

In the testing data set of discriminant analysis, 9 out of 13 summer tomato crops are classified correctly with 69.23%, 9 out of 11 winter tomato crops are correctly classified with 81.81%, and overall 75.52% of the testing cases are correctly classified, whereas in testing data set of ANN, 9 out of 13 summer tomato crops are classified correctly with 69.23%, 8 out of 11 winter tomato crops are correctly classified with 72.72%, and overall 70.98% of the testing cases are classified correctly. The sample in testing dataset helps to validate the model.

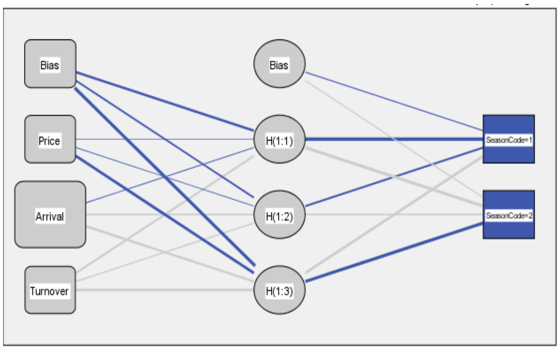

Figure 1 Multilayer perceptron neural network diagram

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Table 2 Classification ability of models for different characters of tomato crop for testing dataset

Criteria	Measures	Discriminant analysis	Multilayer perceptron neural network
Classification ability	Accuracy rate	75	70.8
	Kappa statistics	0.503	0.416
	Avgprecision	1.51	1.41
	Avgrecall	1.51	1.47

Classification ability measures such as accuracy rate, kappa statistics Avgprecision, and Avgrecall are used to compare different methods used for seasonal classification of tomato crop. The model having the highest value of these measures will be considered the best model for classification. In this study, the discriminant analysis model performed better compared to the ANN model for seasonal classification of tomato crop on the basis of different characters since it has larger values of classification ability measures.

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4.17 Prediction Approach in Repeated Measurement Survey

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Keywords: *ANOVA; Prediction approach; PPSWR; Repeated measures*

1. Introduction

Data with repeated measures occur frequently in biological research. In most situations, the repeated measures are either temporal or spatial. Perhaps the most frequent occurrence is in the growth measurements of plants or animals over time. Examples of temporal repeated measures are crop yields from multiple harvests, daily milk yields from individual cows, and weekly livestock prices at individual auction markets. Examples of spatial repeated measures are moisture determinations at several depths in soil core samples and measurements of a pollutant at numerous points on a line transect.

Statistical analysis of repeated measures data requires special attention due to the correlation structure, which may render the standard analysis of variance techniques invalid. For balanced data, multivariate analysis of variance methods can be employed and adjustments can be applied to univariate methods as means of accounting for the correlation structure. Repeated measures data will be called ‘balanced’ if every unit has complete data at the same time points.

2. Materials and methods

The data came from a large study of the effects of nutrition and exercise on the physical strengths of geriatric citizens. The concern here is with the exercise aspects of the study, which involved three weight training programs to which subjects were randomly assigned.

Each subject’s strength, as determined by the amount of weight of the subject, was measured every other day for two weeks. The first program was a control in which no training was employed (CONT). The second program utilized a weight training system in which the number of repetitions of the exercise was increased incrementally with time (R1). In the third program, the amount of weight was increased incrementally over time (W1). The systolic blood pressure of the subjects was also measured in repeated intervals; the systolic blood pressure of the subjects could be treated as the auxiliary variable as there is a significant correlation between the blood pressure and the study variable, that is, the weight of the subjects. The height of the subjects forms the size measure variable which can be used to draw the samples using PPSWR from the population of CONTD, R1, and W1.

The exercise therapy study is typical of many repeated measures designs in which subjects are randomly assigned to ‘treatment’ groups, and a response variable is measured repeatedly over time. A model for data from this type of study is as follows:

$$y_{ijk} = \mu_{ik} + \varepsilon_{ijk}$$

Here, y_{ijk} is the response of the *j*th subject in the *i*th treatment at the *k*th time, and μ_{ik} is the population mean for treatment *i* at time *k*.

The errors ε_{ijk} are assumed normally distributed with mean zero and $V(\varepsilon_{ijk})$ = V, where $\boldsymbol{\varepsilon_{ij}} = [\varepsilon_{ij1}, \varepsilon_{ij2}, \ldots, \varepsilon_{ijt}]$.

A key issue with repeated measures data is the structure of the covariance matrix V. Table 1 shows five particular structures in terms of mathematical conditions on $\sigma_{kk'}$ the element in row *k*, column *k'*, of V.

Structure	Restriction	Mathematical condition
Unstructured	No restrictions	V= $(\sigma_{kk'})$; positive definite
Spherical	Equal variances; zero covariances	$\sigma_{kk} = \sigma^2$ $\sigma_{kk'} = 0$
Compound symmetric	Equal variances; equal covariances	$\sigma_{kk} = \sigma^2$ $\sigma_{kk'} = \delta\sigma^2$
Huynh-Feldt	Unrestricted variances; restricted covariance	$\sigma_{kk} = 2\tau_k + \phi$ $\sigma_{kk'} = \tau_k + \tau_{k'}$
Autoregressive	Covariance function of time interval between repeated measures	$\sigma_{kk'} = \Theta_{\lvert k-k'\rvert}$

Let, the three populations, namely, CONTD, R1, and W1, be modeled as:

$Y_i = \beta X_i + \varepsilon_i$, $i = 1,2, \ldots, N$

Here, X_i’s are >0 values and are non-stochastic and ε_i’s are random variables such that $E_m(\varepsilon_i) = 0$, $Var_m(\varepsilon_i) = \sigma_i^2$, $Cov_m(\varepsilon_i, \varepsilon_j) = \rho_{ij}\sigma_i\sigma_j$, $\forall i = 1(1)N$, $and\ i \neq j = 1(1)N$.

Here, E_m, Var_m, and Cov_m are model dependent expectation, variance, and covariance operators, respectively.

The population total $Y = \sum_{i=1}^{N} Y_i$ can be bifurcated into two components:

$$Y = \sum_{i=1}^{N} Y_i = \sum_s Y_i + \sum_r Y_i$$

Here, $\sum_s Y_i$ is the part contained in the sample and $\sum_r Y_i$ is the remaining component not covered in the sample and is the value of a random variable, that is, needs to be predicted.

3. Results and discussion

For Control (CNTD) Population Size, N = 140, Sample Drawn by (PPSWR) Size n = 50. Based on this sample, the values of t_0 and M_0 for CONTD population are as follows:

$$\hat{\beta} = \frac{1}{n}\sum_s \frac{Y_s}{X_s} = 0.76$$

$$t_0 = \sum_s Y_i + \hat{\beta}\sum_r X_i = 4004 + (0.76 \times 9661) = 11346.36$$

$M_0 = Va(t_0 - Y)^2 = E_m(t_0 - Y)^2 = 213600.57$

For R1 population size, $N = 112$, sample drawn by (PPSWR) size $n = 35$. Based on this sample, the values of t_0 and M_0 for R1 population are as follows:

$$\hat{\beta} = \frac{1}{n}\sum_s \frac{Y_s}{X_s} = 0.75$$

$$t_0 = \sum_s Y_i + \hat{\beta}\sum_r X_i = 2810 + (0.75 \times 8376) = 9092$$

$M_0 = Va(t_0 - Y)^2 = E_m(t_0 - Y)^2 = 366381.03$

For W1 population size, $N = 91$, sample drawn by (PPSWR) size n = 30. Based on this sample, the values of t_0 and M_0 for W1 population are as follows:

$$\hat{\beta} = \frac{1}{n}\sum_s \frac{Y_s}{X_s} = 0.74$$

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$$t_0 = \sum_s Y_i + \hat{\beta} \sum_r X_i = 2810 + (0.75 \times 8376) = 7265.12$$

$$M_0 = Va(t_0 - Y)^2 = E_m(t_0 - Y)^2 = 259863.088$$

In order to estimate the variance σ^2 and the intraclass correlation coefficient ρ, ANOVA estimators were used for all the three populations.

Here, we have seen that for data with repeated measures, the prediction approach is a viable method that can be applied for the prediction of population parameters and also the standard deviation σ and the intraclass correlation coefficient ρ can be estimated through the ANOVA estimators. Thus, for correlated populations, this method provides a viable and better alternative.

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4.18 Future Projection of India's Gross Domestic Product Through ARIMA Approach

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Keywords: ARIMA; Box Jenkins; Future projection; GDP

1. Introduction

The gross domestic product isthe monetary value of all finished goods and services made within a country during a specific period (International Monetary Fund). GDP tells us the country's current aggregate production of goods and services. It is often considered the best measure of how well the economy is performing. The global economy had a nominal GDP of Rs7019.1 trillion in the year 2020, Rs7497.6 trillion in the year 2021, and now, based on the IMF's most recent predictions, will be close to Rs.8295.3 trillion by the end of the year 2022. Global economic estimates are being lowered as a result of recent conflicts, supply chain obstructions, and the ensuing inflation. Before being revised, the first estimate for 2022 annual global GDP growth was 4.4%; the new estimate is 3.6%. With aRs2017.9 trillion GDP, the United States remains the world's largest economy and accounts for about a quarter of the world's total output. China, with a GDP of Rs.1597 trillion, comes close behind, while India, with a □3.3 trillion GDP, is sixth on the list (Koop, 2022).The GDP of agriculture and allied sectors has been declining since 1991 and is at 18.8% in the present scenario (Anonymous, 2021). Also, incomes in agricultural and allied sectors have remained low compared to the other two sectors, which has led to the out-migration of people from rural agricultural backgrounds in favor of urban manufacturing and service sector jobs (Anonymous, 2020). By keeping the above facts in view, the fluctuation in the GDP of the economy within the last seven decades has been studied through the time series model.

2. Materials and methods

The technique that is based on time series components, especially based on irregular components, is ARIMA (Box and Jenkins, 1970). Before applying it, the stationarity of the data is required; this has been tested by the Augmented Dickey-Fuller test (ADF). The ADF test is the same as the Dickey-Fuller test, but it is applied to the model.$\Delta y_t = \alpha + \beta_t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \ldots + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t$.Here,$\alpha$ is the constant, β is the coefficient on a time trend, and p is the lag order of the autoregressive process;if stationary is not achieved, then different methods are used. After the stationarity of the data, the ARMA has been applied to the study. The ARIMA model has been applied to forecast the GDP of India (Mahajan*et al*., 2018).

$$Y_t = \alpha + \sum_{p=1}^{n} \varphi_p Y_{t-p} + \epsilon_t + \sum_{q=1}^{n} \theta_p \epsilon_{t-q}$$

Here, Y_t= GDP in crore rupees at period t, Y_{t-p}= GDP in crore rupees at period $t-p$, ϵ_{t-p} = random shock at period $t-q$, ϵ_t= random error at period t, and the estimated parameters are α, φ_p, and θ_q.

3. Result and Discussion

The time series model for the gross domestic product of India – the summary statistics for the last seven decades of the GDP data –showed that there is high variability in the data related to the GDP.

Table 1 Summary statistics of the GDP of India for the last seven decades andparameter estimate of the ARIMA (1, 2, 1) model

Parameter / GDP (Rs in lakh crore)	Mean	Median	Std. deviation (CV%)	ARIMA model Term(lag)	Estimate	AIC(SBC)
Before 2006	10.03	7.45	7.23 (72.00)	AR1 (1)	–0.37*	2035.38 (2042.12)
After 2006	117.18	99.21	64.35(54.00)	MA1 (1)	0.70**	
Overall (1950–2022)	35.33	1036	55.43	Intercept (0)	22,801.92	

*Significant at 5% **Significance at 1%

Table 1 shows the GDP of India before 2006, that is, from 1950 to 2006, with a mean of Rs10.03 lakhcrore, a median of Rs7.45 lakh crore, and a standard deviation of Rs7.23 lakh crore, and CV is found to be 72%. A sudden change in the GDP was observedwhenthe Indian economy boomed afterward,that is, from the year 2006 to 2022; the mean, median, standard deviation, and CV are Rs117.18 lakh crore, Rs99.21 lakh crore, Rs64.35 lakh crore, and 54%, respectively. The overall summary statistics of GDP include a mean of Rs35.33 lakh croreand a standard deviation of Rs55.43 lakh crore. After the globalization and liberation in 1991, the GDP of the country started growing at minimum rates, but after 2005-06 the country's GDP showed off the chart growth and now Indian economy is world's 5th largest economy, as the GDP of India in the year 2005-06 was about Rs 34 lakh crore. As per Table 1, the parameters AR and MA are negatively (–0.37**) and positively (0.70**) significant, respectively. The proposed model is adequate, stable, and invertible. The proposed model is:

$$\hat{Y}_t = 22801.92 + 2Y_{t-1} - Y_{t-2} - 0.37(Y_{t-1} - Y_{t-2}) - 0.70e_{t-1}$$

Further, the stationarity of the data is achieved through different techniques which are tested through ADF. The best model was found to be ARIMA (1, 2, 1) based on minimum AIC (2035.38) and SBC (2042.12) among the other models. As per the proposed model, the GDP will increase and reach the target of five trillion economies by the year 2039-40 and according to the upper confidence limit, India will reach the targeted milestone by the year 2034-35.

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4.19 Sericulture Enterprising as an Instrument for Generating Employment and Entrepreneurship among Women

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Keywords: Entrepreneurship; Sericulture; Women

1. Introduction

Sericulture provides multiple economic enterprise establishment opportunities, including small-scale and micro-cottage based. Entrepreneurship development in sericulture can act as a fostering element for increasing rural entrepreneurship, especially among women. With low capital investment, sericulture provides high returns, eco-friendly products, and assured returns. In addition to economic independence, it also serves as a means for social empowerment of rural women as well as contributes toward green agriculture and business practices, particularly in the hill economies like the Union Territory of Jammu and Kashmir. Blessed with a rich agrarian resource base along with topographical conditions, it offers significant scope for being a national hub for sericulture entrepreneurship development. Currently, sericulture farming is practiced in around all the 20 districts of the Union Territory of Jammu and Kashmir. About 30,455 families are practicing sericulture as a subsidiary occupation in the region and producing around 973 MTs of cocoons and generating an income of about Rs 2224 lakh annually (Anonymous, 2016). Most of the involvement in these establishments is gender specific. However, due to the dearth of gender-based studies in respect to sericulture in the region, there has been a knowledge and research gap. Within this background, the current study has been conducted to examine the women's participation and involvement in the sericulture enterprise of the Jammu region.

2. Materials and methods

The current study has been conducted in three prominent sericulture-based districts of the Jammu region, that is, Rajouri, Udhampur, and Kathua. These three districts have the highest number of silkworm rearers as well as cocoon producers in Jammu province. Using the multistage sampling technique, the first stage involved the selection of the districts, followed by the second stage of selecting two development blocks from each district, and in the last stage a total of 18 villages (3 from each block) and 270 silkworm rearers (90 from each district, 45 from each block, and 15 from each village) were selected based on simple random sampling technique. The primary data for accomplishing the objectives of the study were collected from the silkworm rearers using well-designed structured pretested schedule by personal visits to the households through the survey method. Also, a comparison between the two (i.e., men and women) was made by comparing the man-days (MD) generated between the two categories.

3. Results and discussion

The operation and gender-wise labor utilization in the three studied districts are presented in Table 1. The data analysis reveals that Kathua district had employment generation through sericulture enterprising around 11.58 MD followed by Rajouri with 10.62 MD and Udhampur with 10.52 MD. Among the three districts, Kathua provided the highest women involvement and participation in the various operational activities of sericulture enterprising, that is, around 6.74 MD, followed by Udhampur with 6.45 MD and Kathua with 6.02 MD. One of the significant observations from the data analysis was the absence of women's involvement and participation in the sale of cocoons and procurement of disease-free layings (DFLs) operational activities of sericulture enterprising. A homogeneous pattern has been observed concerning the women's involvement and participation in the various operational activities of sericulture enterprising at the inter-district level. Women's contribution across the three districts has been prominent in the three activities, that is, harvesting of mulberry leaves activity followed by bed cleaning and harvesting of cocoons. At aggregate levels, the sericulture enterprising is providing around 11.49 MD, out of which 6.67 MD are for females and 4.82 MD are for males. Thus, sericulture enterprising is considerably women driven in the three districts. The findings of the study can be instrumental in understanding gender-specific contributions in sericulture-based enterprises. It also provides for mapping the role of sericulture in the economic and social empowerment of women. Besides, it can also provide insights for devising schemes/policies for increasing attraction for sericulture entrepreneurship among women in rural areas.

The labor utilization and man-days generated through this enterprise in the three districts highlighted that it created higher man-days for females as compared to their male counterparts. The activities like procurement of disease-free layings, collection of mulberry twigs from trees, and sale of cocoons (outdoor activities) generated higher man-days for males while separation of leaves from bushes, chopping of leaves, feeding of leaves, bed cleaning, and harvesting of cocoons (homebound activities) generated more employment for females. So the study concludes that women are playing a pivotal role in sericulture enterprise as is clear from the employment generated as well as their performance in various sericultural operations.

Table 1 Operation-wise labor utilization in Kathua, Rajouri, and Udhampur districts (man-days/ounce)

Sr. No.	Operation	Kathua			Rajouri			Udhampur			Overall		
		M	F	Total	M	F	Total	M	F	Total	M	F	Total
1.	Procurement DFLs	0.57 (11.80)	0.00 (0.00)	0.57 (4.92)	0.65 (14.13)	0.00 (0.00)	0.65 (6.12)	0.48(11.79)	0.00 (0.00)	0.48 (4.56)	0.65 (13.48)	0.00 (0.00)	0.65 (5.66)
2.	Collection of mulberry twigs	1.99 (41.20)	0.93 (13.80)	2.92 (25.21)	1.80 (39.13)	0.72 (11.96)	2.52 (23.72)	1.75 (42.99)	0.80 (12.40)	2.55 (24.24)	1.99 (41.29)	0.80 (11.99)	2.79 (24.28)

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Sr. No.	Operation	Kathua			Rajouri			Udhampur			Overall		
		M	F	Total	M	F	Total	M	F	Total	M	F	Total
3.	Separation of leaves from bushes	0.12 (2.48)	1.26 (18.69)	1.38 (11.92)	0.24 (5.22)	1.32(21.92)	1.57 (14.78)	0.21 (5.16)	1.22 (18.91)	1.43 (13.59)	0.24 (4.98)	1.24 (18.59)	1.48 (12.88)
4.	Chopping of leaves	0.19 (3.93)	0.31 (4.60)	0.50 (4.32)	0.12 (2.61)	0.44 (7.31)	0.56 (5.27)	0.21 (5.16)	0.49 (7.60)	0.70 (6.65)	0.10 (2.07)	0.49 (7.35)	0.59 (5.13)
5.	Feeding of leaves	0.18 (3.73)	1.37 (20.33)	1.55 (13.38)	0.15 (3.26)	0.91 (15.12)	1.06 (9.98)	0.14 (3.44)	1.17 (18.14)	1.31 (12.45)	0.21 (4.36)	1.23 (18.44)	1.44 (12.53)
6.	Bed cleaning	0.16 (3.31)	1.35 (20.03)	1.52 (13.13)	0.20 (4.35)	1.15 (19.10)	1.35 (12.71)	0.15 (3.68)	1.29 (20.00)	1.44 (13.69)	0.17 (3.53)	1.29 (19.34)	1.46 (12.71)
7.	Harvesting of cocoons	0.49 (10.14)	1.14 (16.91)	1.63 (14.07)	0.30 (6.52)	1.09 (18.11)	1.39 (13.09)	0.20 (4.91)	1.12 (17.36)	1.32 (12.55)	0.29 (6.02)	1.13 (16.94)	1.42 (12.36)
8.	Drying of cocoons	0.19 (3.93)	0.26 (3.86)	0.45 (3.87)	0.39 (8.47)	0.25 (4.15)	0.64 (6.03)	0.10 (2.46)	0.11 (1.70)	0.21 (2.00)	0.14 (2.90)	0.22 (3.30)	0.36 (3.13)
9.	Cocoons sorting	0.18 (3.73)	0.12 (1.78)	0.30 (2.59)	0.11(2.39)	0.14 (2.32)	0.25 (2.35)	0.29 (7.12)	0.28 (4.34)	0.57 (5.42)	0.28 (5.81)	0.27 (4.05)	0.55 (4.79)
10.	Sale of cocoons	0.76(15.73)	0.00 (0.00)	0.76 (6.56)	0.64 (13.91)	0.00 (0.00)	0.63 (5.93)	0.51(12.53)	0.00 (0.00)	0.51 (4.85)	0.75(15.56)	0.00 (0.00)	0.75 (6.53)
	Total	4.83 (100.00)	6.74 (100.00)	11.58 (100.00)	4.60 (100.00)	6.02 (100.00)	10.62 (100.00)	4.07 (100.00)	6.45 (100.00)	10.52 (100.0)	4.82 (100.00)	6.67 (100.00)	11.49 (100.00)

Note: Figures in parentheses indicate percentages of the total; **Source:** Author's estimation

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4.20 Impact of Hybrid Rice Technology in Enhancing the Farm Income of Farmers in Jammu District of Union Territory of J&K

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Keywords: Farm Income; Hybrid rice; Impact; Productivity

1. Introduction

Agriculture plays a major role in economic growth and development. As the provider of food, it is a cornerstone of human existence. Farm income is an important component of a household's total annual income whose major occupation is agriculture. Enhancing farm income is a must to meet the ever-increasing cost of production and also to attract rural youths toward the agriculture profession. Farm income can be increased by achieving the higher productivity of different crops, which in turn primarily depends upon the adoption of improved and hybrid varieties of different crops having higher productivity potential. The present study is an attempt to study the impact of hybrid rice technology in achieving higher productivity and enhancing farm income as compared to non-hybrid rice varieties. Rice is an important cereal crop grown in the study area and plays a major role in enhancing farm income. Higher rice productivity per unit area can be attained with hybrid rice technology. According to International Rice Research Institute (IRRI), rice that has been crossbred from two extremely dissimilar parents is known as hybrid rice. It can yield significantly more yield than other non-hybrid rice varieties. China is the leading producer of rice followed by India in second position and Indonesia in third position. According to the recent data of the Directorate of Agriculture, Jammu, the total area under hybrid rice in the Jammu division is 12,533 ha. Hybrid rice technology in the study area is still gaining momentum among the farming community and needs support from field extension functionaries to accelerate its adoption so that farmers may achieve higher productivity of rice crop which in turn will impact their farm income.

2. Materials and methods

An ex post facto research design was employed for the study. Purposive sampling technique was employed for the selection of three agricultural subdivisions, namely, Marh, Akhnoor, and R.S. Pura of Jammu division of Jammu and Kashmir UT because of the maximum area under hybrid rice cultivation and proportionate random sampling technique was put forth for selection of 150 number of hybrid rice growers. These 150 selected respondents belonged to 26 villages from three subdivisions of the Jammu district. Descriptive statistics and a linear regression model were used for the analysis of the data.

3. Results and discussion

During the year 2021, the overall average productivity of all the three sub-divisions was 33.00 q/ha, which was almost half the quantity of the average productivity obtained in the year 2020, which was 67.00 q/ha. Among the non-hybrid varieties, average productivity was found least among Pusa-1121, which was 10.66 q/ha, while Basmati-370 had the highest productivity, which was 13.98 q/ha. Sharbati, on the other hand, had an average of 11.29 q/ha productivity in the year 2021. The benefit-cost ratio (BCR) for two consecutive years was calculated (i.e., 2020 and 2021). The results show that the BCR of hybrid rice cultivation in the year 2021 was 1.08, which was less in comparison to 2020's BCR, which was 2.23. On the other hand, BCR for non-hybrid rice variety (i.e., Basmati-370) in the year 2021 was 1.34, which was again less in comparison to 2020's BCR of 1.74. The results showed that during the normal crop year 2020 farmers obtained Rs 120,600 /ha as compared to Rs 86,400/ha, which is Rs 34,200 higher income from the cultivation of hybrid rice varieties as compared to non-hybrid rice varieties. It was also supported by findings of the study which was conducted by Gogoi *et al.* (2020) and where farmers obtained a higher return from hybrid rice cultivation (2.30) than traditional rice (1.66). Variety-wise (hybrid and non-hybrid varieties), one-way analysis of variance (ANOVA) in mean difference of their productivity in 2021 was done, where a significant difference was found in the productivity of hybrid and non-hybrid rice varieties mainly Basmati-370 and Pusa-1121 (p = .002) with F value of 5.11.

Table 1 Economic returns from hybrid rice cultivation and significance of production difference between hybrid and non-hybrid rice

Varieties	District-wise percentage of respondents			Overall percentage
	R.S. Pura (n = 38)	Akhnoor (n = 13)	Marh (n = 99)	(n = 150)
Hybrid varieties productivity (q/ha)				
In 2020	78	63	64	67
In 2021	20	41	36	33
Non-hybrid varieties productivity (q/ha) in 2021				
Basmati-370	13.37	25.38	11.23	13.98
Pusa-1121	9.79	0	11.24	10.66
Coarse variety (Sharbati)	10.00	0	11.61	11.29
Non-hybrid varieties productivity (q/ha) in 2020				
Basmati-370	28	27	26	27
Pusa-1121	36	0	31	33
Coarse variety (Sharbati)	40	0	39	39
Cost of production (Rs/ha)				
Parameter	Hybrid rice	Basmati-370	Sharbati	Pusa-1121

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Cost of production (Rs/ha)	54,075	49,390	48,623	53,154
Varieties	District-wise percentage of respondents			Overall percentage (*n* = 150)
	R.S. Pura (*n* = 38)	Akhnoor (n = 13)	Marh (*n* = 99)	
Economic returns from hybrid and non-hybrid varieties				
Parameter	Hybrid rice	Basmati-370	Sharbati	Pusa-1121
BCR= T.R/T.C.C (2021)	1.08	1.34	0.85	1.07
BCR= T.R/T.C.C (2020)	2.23	1.74	1.92	2.00
Gross return (Rs/ha) in 2020	120,600	86,400	–	–
ANOVA (one-way analysis of variance in a mean difference of productivity between hybrid and non-hybrid rice varieties				
Hybrid and non-hybrid varieties (Basmati-370 and PUSA-1121)		p=0.001, F = 5.11		

BCR=Benefit-cost ratio, T.R.= Total returns, and T.C.C.= Total cost of cultivation.

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4.21 Growth and Production Performance of Carps in Jammu District Under Composite Fish Farming: A Field Study

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Keywords: Carp performance; Composite fish culture; Fish growth

1. Introduction

India has observed tremendous growth in fish production by exhibiting a production increase from 0.75 million metric tons (MMT) during 1950-51 to the current production of 14.3 MMT. Indian major carps, namely, catla, rohu, and mrigal, contribute maximum toward total freshwater aquaculture production (Paul and Giri, 2015). Composite fish culture ensures higher production in comparison to monoculture in extensive and semi-intensive systems because all the available natural food in the pond is utilized. Since the fish farmers are not well aware of the stocking management practices, that is, stocking ratio and stocking density of fish in the pond, there is a need to demonstrate the management practices to achieve maximum production. With this background, the study was conducted in a fish farmer's pond (earthen) under a composite fish farming system with six species to investigate the growth and production performance of carps at different locations under agro-climatic conditions in the Jammu district.

2. Materials and methods

The study (production cycle of 1 year) was conducted at farmer's ponds located in the Jammu district (32°43'58.7928"N and 74°51'51.3828"E) of Jammu & Kashmir (J&K). Six earthen ponds of 1000 m^2 with a water depth of 1.5 m were selected for the study. Standard pond preparation procedures (cleaning, liming @ 200 kg/ha, organic manure 10,000 kg/ha) were followed.

Mix seeds of six species (average body weight 7.3±3.10 g, average length 5.0±1.86 cm) were procured from a government hatchery, J&K and stocked @ 10,000/ha. The ponds were stocked by farmers as per their practice with six species combinations, that is, catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*) @ 2:2:2:1.5:1 ratio. Feeding was done with supplementary feed @ 3% body weight initially for 3 months and later on @ 1.5% throughout the study period (9 months). Samples of 20 fish from each pond at quarterly intervals were collected for a year. At experiment termination, the fish were harvested and weighed (total yield) of each replicate within groups and counted for calculation of weight gain (WG), feed conversion ratio (FCR), feed conversion efficiency (FCE), specific growth rate (SGR), and survival rate. The growth and production were taken as the main parameter to assess the performance. Pond water samples were collected bimonthly for water analysis. All statistical analyses of data were carried out using the SPSS Version 16.

3. Results and discussion

All water quality parameters were within the suitable range (temperature 10.90–44.60°C, transparency 20–60 cm, pH 6.40–8.40, dissolved oxygen concentrations 2.3–6.90 mg/L) (Bhatnagar and Devi, 2013). The survival rate (%) of carps varied from 34.08 to 82.50 with significantly higher values for common carp and minimum for catla. It may be due to the hardy nature and survival of common carp at lower oxygen levels during the rainy season.

Table 1 Performance of different carps under composite fish culture at farmers' field

Fish species	No. of seeds stocked	Initial weight (g)	Final weight (g)	Initial biomass (g)	Final biomass (g)	% weight gain	% survival rate	Specific growth rate	Growth index	Income (Rs)
Catla	200	6.87	862.50	1373.3	58,671	13,048	34.08	0.59	43.93	8800.65
Rohu	200	7.42	714.33	1483.3	63,682	10,001	44.58	0.55	43.93	9552.30
Mrigal	200	6.22	615.67	1243.3	48,358	99,577	39.25	0.56	38.32	7253.70
Silver Carp	150	8.83	961.00	1325.0	52,706	10,900	36.55	0.57	39.15	7905.90
Grass carp	150	7.12	1232.8	1067.5	109,200	17,569	59.00	0.62	103.77	16,380.00
Common carp	100	9.13	767.50	913.33	63,288	86,021	82.50	0.54	70.44	9493.20

Among the species, the final weight of grass carp was significantly ($p \leq 0.05$) higher (1232.8±38.33 g) followed by silver carp (961.00±29.08 g), catla (862.50±27.92 g), common carp (767.50±17.78 g), rohu (714.33±8.56 g), and mrigal (615.67±10.02 g). The highest weight gain of grass carp was due to the presence of grass in ponds and availability of green fodder @ 4% of body weight for fish which is mostly spared from animal feed. Likewise, the SGR of grass carp was significantly higher ($p < 0.05$) as compared to all other treatments. The combined net production was 395.91 kg/ha/year, with a net profit of Rs 59,385.75 (@ Rs 150/kg) and a maximum profit of Rs 16,380 from grass carp followed by rohu, common carp, catla, silver carp, and mrigal (Table 1). The study indicated grass carp as one of the fastest growing fish under agro-climatic conditions of Jammu in composite fish culture. Further, the findings of the present study are in consonance with the huge demand for seed of grass carp in J&K. The demonstration study at the farmer level will certainly help the fish farmers in adopting composite fish culture with best management practices with special reference to stocking management.

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4.22 A Comparative Study of Social Media Tools in Dissemination of Information Related to Organic Dairy Farming in Subtropics of Jammu Region of UT of J&K (India)

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Keywords: Difference-in-differences (DiD); Information dissemination; Organic dairy farming; Social media; Web module; WhatsApp

1. Introduction

The plant and animal produce treated with synthetic chemicals and drugs serves as a slow poison for humans, slowly killing our health and future generations. So, all around the world, 187 countries out of 195 countries of the world are reverting to chemical-free farming, that is, organic farming (FiBL and IFOAM Year Book, 2021). Thus, organic farming strives for sustainability, ensures crops and livestock production, which does not have any harmful residues, and brings enterprise methods that are sustainable and maintain harmony with nature (Darnhofer *et al.*, 2010). Singh *et al*. (2018) reported that traditional extension communication techniques have several drawbacks since they need a significant amount of time and effort to convey messages. When communications finally reach the end-user, their quality is severely damaged and degraded. As a result, there is an urgent need to develop needs-based, cost-effective, and easily accessible ways of disseminating information that can serve the largest possible audience at any point in time. This can be addressed by using social media tools like WhatsApp and developing web-based information and communication technologies (ICTs). Therefore, to disseminate holistic information on dairy farming in general and organic dairy farming in particular, an ICT-enabled web module on organic dairy farming (WMODF) was developed. Similarly, a WhatsApp group of dairy farmers was created to share need-based information and to get feedback. Social media tool ‘WhatsApp group of dairy farmers’ gave an interactive platform to discuss the issues and prospects of dairy farming in general and organic dairy farming in particular with different stakeholders and have addressed and provided solutions to farmers’ queries by the experts. The impact of the Web module and WhatsApp was measured using the method of difference-in-differences (DiD) quasi-experimental non-equivalent control group (pretest and posttest).

2. Materials and methods

An interactive IT-enabled need-based WMODF (Web Module for Organic Dairy Farming) was developed for providing holistic information on organic dairy farming (ODF) to dairy farmers. The web module was designed according to the information needs of dairy farmers, covering all the aspects of organic dairy farming such as origin and conversion period, breeds and breeding management, animal housing management, dairy animal nutrition, animal health care practices, animal disease prevention and control, welfare practices, and organic certification process.

The web pages on organic dairy farming were created in English (universal language) and a Google-enabled translator which can translate it into other regional languages. The information was provided in text, charts, diagrams, and flowcharts with appropriate pictures and external links. The developed WMODF was uploaded on the website of SKUAST-Jammu under the *Kisan Hiteshi* web portal.

The experimental study was undertaken to see the potential of Web Module and WhatsApp group in information sharing and dissemination of information related to dairy farming in general and organic dairy farming in particular among dairy farmers of ‘experimental’ [Organic Farming Cluster (OFC)] and ‘control’ [Non-Organic Farming Cluster (Non-OFC)] groups. A separate WhatsApp group for OFC and non-OFC dairy farmers was created for the study, namely, ‘E-organic dairy farming’ and ‘C-organic dairy farming’, respectively.

The impact of the Web module and WhatsApp was measured using the method of difference-in-differences (DiD) quasi-experimental non-equivalent control group (pretest and posttest). For impact measurement, 25 respondents each from experimental (OFC) and control (non-OFC) were randomly selected who had an android/IOS mobile phone with internet connectivity. The knowledge of these respondents about organic dairy farming, taken initially with the help of a developed and standardized knowledge test for organic dairy farming, was taken as ‘pretest’ knowledge, whereas knowledge of the same 25 respondents each from OFC and non-OFC after a gap of 3 months of upload of the web module on the University website and creation of the WhatsApp group was taken as ‘posttest’ knowledge.

3. Results and discussion

A perusal of Table 1 indicates that the impact of the web module was measured using the method of difference-in-differences (DiD) quasi-experimental control group (pretest/posttest). The change in the average knowledge score of the posttest and pretest for dairy farmers of OFC was 2.96, whereas a score of 0.96 was found for non-OFC dairy farmers. Thus, the overall change in average knowledge due to the web module on ODF between OFC and non-OFC dairy farmers was 2.00, and the difference was statistically significant.

Similarly, the impact of the WhatsApp group on organic dairy farming was measured using the difference-in-differences (DiD) quasi-experimental control group (pretest/posttest) method. The change in average knowledge score of the posttest and pretest for dairy farmers of OFC was 8.44, whereas a score of 3.76 was found for non-OFC dairy farmers. The overall change in average knowledge due to the WhatsApp group on ODF between OFC and non-OFC dairy farmers was 4.68, and the difference was found to be statistically significant.

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Table 1 Impact of web module and WhatsApp messages on the knowledge of farmers about organic dairy practices

Social media tools	OFC Dairy farmers (n = 25)			Non-OFC Dairy farmers (n = 25)			DiD (D1 – D2)	Statistic (p value)
	Average knowledge score (Pretest[1])	Average knowledge score (Posttest)	Difference between (D1)	Average knowledge score (Pretest[2])	Average knowledge score (Posttest)	Difference between (D2)	(D1 – D2)	
Web wodule Information	15.52	18.48	2.96	8.80	9.76	0.96	2.00	$t = 2.573^*$ (0.006)
WhatsApp messages	14.48	22.92	8.44	8.80	12.56	3.76	4.68	$t = 3.684^*$ (0.000)

*Significant at $p \leq 0.05$. DiD = Difference-in-differences.

ICT tool WhatsApp was found to be more effective in information dissemination on dairy farming in general and organic dairy farming in particular among the OFC and non-OFC dairy farmers with a difference-in-differences (DiD) score of 4.68 compared to the Web module with DiD score of 2.00 only.

The study concluded with the impression that using social media tools like WhatsApp and developing a web-based module will be effective among dairy farmers and to a major extent will solve the problems of need-based information on organic dairy farming.

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4.23 Effectiveness of Trainings Organized by Punjab Agricultural Management and Extension Training Institute for Extension Personnel in Punjab State

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Keywords: Extension personnel; PAMETI; Training effectiveness

1. Introduction

The extension personnel are a vital link between research, organizations and farmers. Extension personnel need to update their knowledge and skills continuously so as to effectively serve the clientele. Therefore, the extension service must provide a reasonable and regular training opportunity for extension personnel (Anonymous, 2003). To enhance the skill of extension personnel, each state has been authorized by one State Agricultural Management and Extension Training Institute (SAMETI). It is known as the Punjab Agricultural Management and Extension Training Institute (PAMETI) in the case of Punjab. PAMETI is conducting various trainings for extension personnel for enhancing their knowledge, attitude, and skill. An effective training programme achieves its goals such as measuring whether the desired changes in knowledge, skills, and attitudes occurred (Haneef *et al*., 2020). So, the present study was organized to study the effectiveness of selected trainings organized by PAMETI for enhancing the core competencies of extension personnel.

2. Materials and methods

Five competency development, training programmes organized by PAMETI in 2017-18 were selected by purposive sampling for the study. A set of 24 trainees each from 5 training programmes were randomly selected from the list procured from PAMETI for this study. Thus, a sample of 120 trainees of PAMETI, PAU, and Ludhiana was contacted for the final data collection.

Computation of training effectiveness index: Strongly agree, agree, undecided, disagree, and strongly disagree responses were elicited along a five-point continuum with corresponding scores of 5, 4, 3, 2, and 1. The training effectiveness index was used to assess the effectiveness of training (Aishwarya, 2018).

$$U_{ij} = \frac{Y_{ij} - Min\,Y_{ij}}{Max\,Y_j - Min\,Y_j}$$

Here,
U_{ij} = Unit score of the *i*th trainee on *j*th parameter
Y_{ij} = Value of the *i*th trainee on the *j*th parameter
Max Y_j = Maximum score on the *j*th parameter
Min Y_j = Minimum score on the *j*th parameter
The total index score of all the indicators was used to determine the trainees' status. The range method was used to categorize trainees into low, medium, and high categories.

3. Results and discussion

Most (52.00 %) of the trainees were perceived to lie in the high category of applicability and utility of the training programmes conducted by PAMETI, whereas most (60.00%) of the trainees were in the medium category of relevance and most (64.00%) of the trainees were in the medium category of timeliness of the training programmes. Most (41.00%) of the trainees were found in the high category of knowledge, attitude, and skill of the training programmes, whereas most (48.00%) of the trainees were in the high category of conviction and 43.00% of the trainees were in the medium category of job performance and satisfaction. Nearly 60% of the trainees were in the medium category of the overall training effectiveness index followed by 29.00% in the high category and 12.00% in the low category. To make training more effective, training programmes should be based on an assessment of what people need. It has to be done in a planned way, taking into account things like who needs to be trained, what they need to be trained, and how the training process will be supported and matched with strategic goals.

Table 1 Distribution of trainees according to different parameters to measure training effectiveness and overall training effectiveness index (*n* = 120)

Parameters	Categories	Frequency	Percentage
Applicability and utility	Low (13-15)	10	8.00
	Medium (16-18)	48	40.00
	High (19-21)	62	52.00
Relevance	Low (15-16)	9	8.00
	Medium (17-18)	72	60.00
	High (19-20)	39	33.00
Timeliness	Low (10-11)	9	8.00
	Medium (12-13)	77	64.00
	High (14-15)	34	28.00
Knowledge, attitude, and skill	Low (10-11)	27	22.50
	Medium (12-13)	44	37.00
	High (14-15)	49	41.00
Conviction	Low (10-11)	17	14.00
	Medium (12-13)	46	38.00
	High (14-15)	57	48.00
Improvement in job performance and satisfaction	Low (10-11)	21	18.00
	Medium (12-13)	51	43.00
	High (14-15)	48	40.00
Overall training Effectiveness index	Low (0.76-0.81)	14	12.00
	Medium (0.82-0.87)	71	59.00
	High (0.88-0.93)	35	29.00

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4.24 Effect of Rootstock Planting, Scion Type, and Time of Grafting on Success of Walnut Propagation Under Polyhouse Condition

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Keywords: Rootstock planting; Scion type; Time of grafting; Walnut

1. Introduction

Walnut (*Juglans regia* L.) is one of the most important nutritious nut crops grown around the world in temperate climates. India is one of the major producers as well as exporters of walnuts and enjoys a good demand in the international market due to its superior quality. Jammu and Kashmir is a leading walnut producing state in India. This dominance is partially due to the unique climatic conditions of the Jammu and Kashmir. According to official estimates, around 2.66 lakh metric tons of walnuts are harvested from an area of 89,000 ha, while the productivity of walnuts in J&K is 2.98 tons/ha. About 98% of the walnuts exported from India are cultivated in Jammu and Kashmir. Despite the fact that Jammu and Kashmir has a monopoly on cultivation, the productivity is very low. One of the main reasons for the low productivity is staggering planting due to lack of quality planting material, poor success rate of grafting, and climatic fluctuations among other factors. The objective of this study was to improve grafting success and subsequent growth of grafted plants under polyhouse conditions.

2. Materials and methods

The present study was carried out in the Experimental Farm of the Division of Fruit Science, SKUAST-K, Shalimar during the years 2018 and 2019. The experiment was laid out in a factorial randomized complete block design. In this study, seedling rootstocks of uniform size were planted at three different timings (2nd fortnight of November, 2nd fortnight of December 2017, and 2nd fortnight of January 2018) and grafted with two different scion types (middle portion of current season growth with 3–5 buds and current season growth (3–5 buds) with a small piece of 2-year-old wood) on two different dates (3rd week of February and 1st week of March 2018) under polyhouse conditions.

3. Results and discussion

Walnut graft success percent was significantly influenced by time of rootstock planting, scion type, and time of grafting. Among the three rootstocks' planting time, the maximum final graft success (69.05%) was obtained in November planting. Minimum final graft success (40.91%) was recorded when rootstock was planted during January and this might be due to the reason that some of the grafts failed to survive due to weak union. These results are in line with Joshi *et al*. (2014). Scion type also influenced the final graft success percent. The maximum final graft success (58.00%) was obtained with scion type having middle portion of current season growth with 3–5 buds. This may be due to the presence of more reserve foods in young scion and actively growing tissues that enhanced final graft success. Time of grafting also exhibited a significant influence on final graft success percent. The maximum final graft success (63.54%) was obtained when the grafting was performed during 3rd week of February. It might be due to the favorable temperature and humidity which have a pronounced effect on the production of callus tissue, necessary for good graft union formation (Hartmann *et al*., 1997). Maximum graft success (75.23%) was found when rootstock was planted during the 2nd fortnight of November and grafting was performed during the 3rd week of February with scion type having a middle portion of current season growth with 3–5 buds.

Table 1 Effect of rootstock planting time, scion type, and grafting period on final graft success in walnut

Scion type	S_1		Sub mean	S_2		Sub mean	Mean	Factor mean	
Time of grafting/ Rootstock planting time	t_1	t_2		t_1	t_2			t_1	t_2
2nd fortnight of November	75.23	67.66	71.45	70.00	63.34	66.66	69.05	72.61	65.49
2nd fortnight of December	60.53	58.66	59.60	60.66	56.67	58.66	59.13	64.06	59.07
2nd fortnight of January	45.33	40.00	42.67	43.34	35.00	39.16	40.91	44.33	37.5
Mean	60.36	55.44	58.00	58.00	51.67	54.83		63.54	56.89

S_1=Middle portion of current season growth with 3–5 buds, S_2 = Current season growth with a small piece of 2-year-old wood.
t_1= 3rd week of February, t_2 = 1st week of March.

C.D ($p \leq 0.05$): 0.64
Time of rootstock planting (R.P)
Scion type (S): 0.52
Time of grafting (t): 0.52

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Theme 5

Policy Regulation for Sustainable Agri-food Systems

5.1 Role of Bio-stimulant and Bee Hotel in Sustainable Production of Red Gram (*Cajanus cajan* L.): A Case Study

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Keywords: Bee hotel; Homobrassinolide; Megachile; Red gram

1. Introduction

Red gram, commonly known as Tur or Arhar *(C. cajan* L.) in India, is the second most important pulse crop in the country. It is consumed on a large scale mainly in South Asia and is a major source of protein for the population of the subcontinent. Production of pigeon pea faces a series of constraints, which include its inherent physiological limitations, lower germination percentage, source limitation, low leaf area development, indeterminate growth habit, C3 photosynthetic apparatus, slow initial dry matter accumulation, hormone inhibitors, the decline in nodule activity, and diversion of metabolic energy to sinks for protein synthesis. Some of these limitations can be effectively resolved through agronomic techniques such as the application of growth hormones (Deol *et al*., 2018), augmenting the pollinator population in the crop field. In legumes, reproductive structures are covered by keel petals, and solitary bee *Megachile* can effectively pollinate this by tripping mechanism. Prashanth (2009) showed that by providing nesting sites for *M. lanata*, the pod set can be significantly improved in red gram. Therefore, the present study was undertaken to examine the role of bio-stimulant (Homobrassinolide 0.04% EC or HBR) and augmented population of *Megachile* sp. (bee hotel) on red gram productivity.

2. Materials and methods

Figure 1 Bee hotel installed and *Megachile* occupied in the existing wooden cavities

Details of the experimental site: The experiment was carried out in the Gulbarga district of Karnataka during the Kharif season (June to December 2021). The experimental site is located at latitude 17.5676°N, longitude 76.5662°E. and the rainfall was 836 mm in 2021. In this study, 82 respondents were selected for the study, and among them 41 were asked to follow the application HBR, sun hemp seed (border crop) and maintain a wooden solitary bee nest (considered as treatment). The remaining 41 respondents were told to follow the existing farmers' practice (considered as control).

Bee hotel and sun hemp seed distribution: In the Gulbarga district, we had installed 250 bee hotels (wooden nest structures having dimensions of 1.5' × 1.5' and cavities of 6–8 mm width and 10 mm depth) (Figure 1). Sun hemp seeds of 1.5 kg/ha were given to the farmers and we keep educating them about the importance of this concept. Farmers were asked to sow the sun hemp on the border of the field at the time of red gram sowing so that sun hemp would flower prior to the red gram and help to augment the *Megachile* bees to nest in the installed bee hotels.

Application of HBR 0.04% EC: Soon red gram started flowering and farmers who used bee hotel and sown sun hemp were asked to spray HBR 0.04% EC (Brand Name Double) @ 100 mL/acre with the second application @ 50 mL/acre at 15 DAS. Data collection: The following data were collected: yield per acre, test weight, seed quality and chaffiness, and so on.

3. Results and discussion

The difference in the red gram yield between the treated plot and the control plot was assessed by paired t test. The results showed a significant difference (t=8.41, df=81, $p \leq 0.01$) in terms of yield between treatment and control. The results indicated that the increased mean red gram yield (1230 kg/ha) was higher than that of the existing farmers' practice (893 kg/ha). Similarly, red gram grains of the treated plot had a significantly higher test weight (t=13.74, df=41, $p \leq 0.01$), which was 126 g compared to 117 g from the existing practice (Figure 2).

The present study showed that the application of HBR 0.04% EC in red gram crop significantly enhances flower bearing, pod setting, and the quality of grain (i.e., color, uniform size, less chaffiness) (Figure 3). This could be attributed to the adoption of additional agronomic practices such as HBR, bee hotel, and border cropping with sun hemp. These findings are supported by Kutschera and Wang (2012), who reported that HBRs are known to delay the senescence process and thereby a greater number of productive flowers will be retained in the plant for a longer duration, which ultimately enhances the fruit development in the crop.

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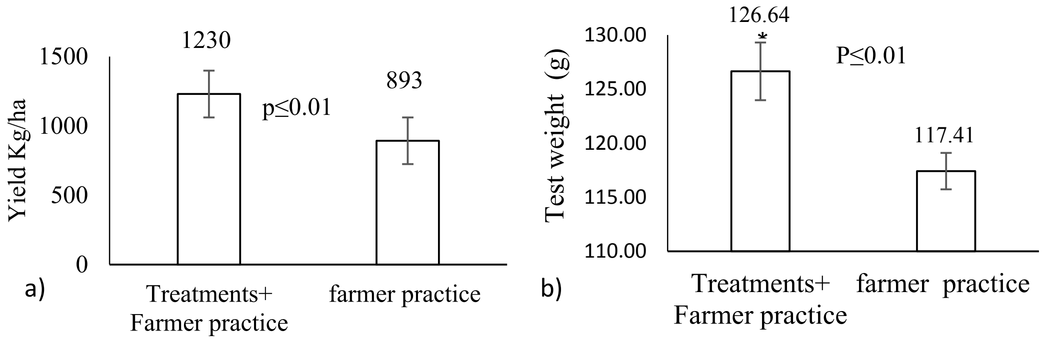

Figure 2 (a) Yield difference per acre. (b) Test weight of a red gram

Like HBR, bees also play a major role in increasing yield by pollination. Data show that wild bees contribute USD 3251/ha for their pollination services worldwide (Kleijn *et al.*, 2015). In our study, the application of HBR and bee hotel showed a positive correlation with seed set in red gram compared to existing farmers' practice.

In the current study, the individual effect of the HBR and bee hotel could not be assessed due to some constraints.

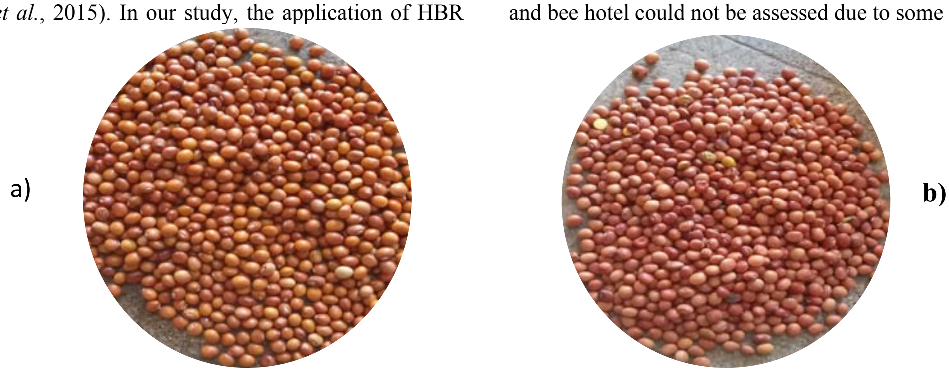

Figure 3. (a) Treated+farmer practice. (b) Only farmers' practice

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5.2 Socioeconomic Factors Determining Extraction of Non-timber Forest Products in the Jammu Region of Jammu and Kashmir

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Keywords: Collection; Income; Non-timber forest products; Socioeconomic factors

1. Introduction

Non-timber forest products (NTFPs) refer to a wide array of economic or subsistence materials that come from forests, excluding timber. These are also termed non-wood, minor, and secondary forest products. These include a wide range of edibles and non-edibles, such as fruits, seeds, leaves, nuts, bushmeat, roots, tubers, fibers, resins, latex, sticks, ropes, and construction materials like bamboos and rattans, and a host of others. All of these are an important source of livelihood for rural populations all over the world. Globally, there are 1.6 billion people who rely on forests (World Bank, 2004). The dependence of forest dwellers on forest resources differs considerably among individuals in terms of tribe, caste, class and among and within communities and households by sex and age (Babulo *et al*., 2009). The contribution of forests to local livelihoods and the national economy is significant but largely undocumented. In this research, we address the question, 'Which socioeconomic factors affect the participation of households in the collection of NTFPs'.

2. Materials and methods

The present study was conducted in the forest area of the Jammu region of Jammu and Kashmir. A multistage sampling plan was followed for selecting the ultimate sampling units, that is, *150 collectors and 150 non-collectors*. The East Forest Circle from the Jammu region was selected as it covers all the three agroclimatic zones, namely, subtropical, intermediate, and temperate. Three forest divisions, namely, Basholi, Ramnagar, and Udhampur, were selected from the East Circle by employing a random selection procedure without replacement. From each randomly selected forest division, one forest range having the maximum NTFPs availability, in terms of both variety and quantity, was selected. The snowball sampling procedure was used to select the sample of collectors of forest produce. Thus from each selected forest range, 50 collectors and 50 non-collectors were selected and interviewed, thereby making a total sample size of 150 collectors and 150 non-collectors. Data were collected from the sampled respondents on the pretested interview schedule by contacting them personally in their fields or at their homes. Analysis of collected data was performed using SPSS 16.0 (Statistical Package for Social Sciences) using binary logistic regression analysis.

3. Results and discussion

The decision to collect NTFPs was dependent upon many factors, such as the age of the respondent, education of the respondent, type of house, occupation, size of landholding, extension contact, source of information, off-farm income, literacy index, family size, and irrigated landholding. In the present study, the age of respondents negatively and significantly affected the decision to collect NTFPs, which means only young people were involved in the collection of NTFPs; this may be because the collection area was far away from the home and had tough terrains, thereby posing difficulty for an aged person to collect NTFPs. It is concluded that NTFPs are important for poor households. For the young age group persons in the area of study, the possible reason for the collection was that their income was improved through the selling of NTFPs (Table 1).

Table 1 Socioeconomic variables determining participation of households in NTFP collection

Dependent variable	Independent variables	Coefficient (ß)	S.E.	Wald	*p* value	Model summary
Participation vs nonparticipation in the collection of NTFPs	Constant	–7.663	2.624	8.527	0.003	Nagelkerke $R^{2=}0.0.675$ –2 log-likelihood=204.022 χ^2=211.867 p =0.001
	Age	–0.096	0.022	18.185	0.001	
	Education	–0.296	0.080	13.697	0.001	
	Extension contact	3.676	1.181	9.690	0.002	
	Source of information	1.314	0.221	35.225	0.001	
	Off-farm income	0.000	0.000	8.847	0.003	
	Type of house	–2.067	0.383	29.153	0.001	
	Literacy index	0.572	0.264	4.696	0.030	
	Primary occupation	–1.294	0.654	3.911	0.048	
	Family size	0.252	0.121	4.365	0.037	
	Landholding	0.143	0.470	0.092	0.762	
	Irrigated landholding	–4.567	1.833	6.205	0.013	
	On-farm income	0.000	0.000	0.466	0.495	
	Family type	0.817	0.524	2.431	0.119	

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5.3 Sustainable Round the Year Green Fodder Production Modules for Subtropical Conditions ofJammu

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Keywords: Fodder modules; Green fodder; Sustainability

1. Introduction

Seasonal feed and fodder shortages are the major challenges affecting livestock productivity. At present, India faces a deficit of 23.4% in dry fodder,11.24% in green fodder, and 28.9% for concentrates. The livestock population is growing rapidly and the area under fodder cultivation has remained static (4%)(Roy *et al*.,2019).To meet this gap of demand and supply, the need of the time is to adopt the practices of land use with multiple crops in a sustainable manner, enhancing fodder productivity, utilizing unconventional sources of fodder, pasture, and grassland management and fodder preservation. Keeping the above points in view, the present investigation was undertaken with an objective to develop sustainable round the year green fodder production modules for feeding dairy animals.

2. Materials and methods

The experimental plan was executed and laid down at the research farm of Instructional Livestock Farm Centre, R.S. Pura, FVSc & AH, Sher-e-Kashmir University of Sciences and Technology, Jammu in an area of approximately 2.5 ha by making blocks of an area of 0.8/0.4 ha accordingly. Different sources, namely, seasonal fodders, perennial fodders grasses, trees, and supplemental fodder Azollawere tried. The data presented in the article were taken during the years 2017-18 and 2018-19. In*kharif* seasonmaize (*Zea mays*) +cowpea(*Vignaunguiculata* L. Walp.), swankhi (*Echinochloafrumentacea*), bajra (*Pennisetumglaucum*), cowpea (*V.unguiculata* L. Walp.), sorghum (*Sorghum bicolor* L. Morlch.) fodders were sown and in *rabi* season berseem (*Trifoliumalexandrinum*) +mustard (*Brassica campestris*, var. Sarson), berseem (*T.alexandrinum*) +oats (*Avena sativa*), and oats (*A.sativa*) were sown. In perennial fodders, grasses like hybrid Napier (*P.purpureum*) and para grass (*Brachiariamutica*)and in fodder tree spp. *Bauhiniavariegata* and *Albizia*spp. were taken as boundary plantations 5m apart from each other. The supplemental fodder *Azollapinnata* was grown from waste pits and drains. The package and practice of the subtropical Jammu region were followed along with staggered planting at the intervals of 15 days to seasonal fodder. The data were analyzed by using analysis of variance (ANOVA) under randomized block design with the help of the software OPSTAT at a probability level of 5%.

3. Results and discussion

The results regarding the Maize+Cowpea+ Berseem+ Mustard module allotted to a 0.8ha area revealed that this module produced green fodder of 1198q/0.80 ha/year and supplied fodder in July, September, December, January, February, and April. The significantly highest system productivity (149,750 kg/ha/year), net returns (Rs 114,860.72), B:C ratio (3.29), monetary efficiency (Rs 318.17/ha/day), production efficiency (414.81 kg/ha/day), LUE (98.90%), and energy productivity (9.28kg/MJ) were found in this system. The system also increased organic carbon(8%), available N(4–5%), available P(3–4%), and available K(2–3%) after completion of the cycle followed by the sorghum-oats module yielding993.07q/0.80 ha/year of green fodder annually with availability during August, September, October, November, December, February, March, and April and having system productivity of 124,134 kg/ha/year, B:C ratio of 3.11,energy productivity of 10.80, monetary efficiency of Rs 303.09/ha/day, and production efficiency of 400 kg/ha/day. Further, it buildsup soil organic carbon (5–6%), available N (2–5%), available P (4–5%), and available K (2–7%). Swankhi, Cowpea, Bajra-Berseem+ Oats module produced 448q/0.50 ha/year of green fodder in the months of August, September, October, December, February, March, and April and had significantly lowest system productivity (89,700 kg/ha/year),B:C ratio (1.83), energy productivity (6.53 kg/MJ), monetary efficiency (Rs 182.34 ha/day), and production efficiency(282.07 kg/ha/day)but with improved soil organic carbon content, available N, available P, and available K to the tune of11.0%,3.0%, 1.5% and 2.5%, respectively, over their initial level. Perennial fodder module (0.4 ha) produced 581.85q/0.40 ha/year of green fodder annually during May, June, October, and November. Hybrid Napier recorded significantly highest system productivity (154,285 kg/ha), net returns (Rs 120,425.71), B:C ratio (3.55), monetary efficiency(Rs 329.93/ha/day), and production efficiency (422 kg/ha/day).Among fodder trees, *B.variegata* outyielded. This module buildsup organic carbon (11%), available N (6%), available P(5%), and available K(10%).The supplemental fodder module, namely, Azolla contributed 365 kg in system productivity, 5.80 in energy productivity, and 1kg/ha/day in production efficiency.

Hence, green fodder production modules developed under Northwestern Himalayas that included diverse sources of fodders, namely, annual, perennial grasses, fodder trees, and supplemental fodder along with management techniques of staggered planting ensured the round year availability of quality fodder.

Table 1 Evaluation of different fodder modules

Modules	System productivity (kg/ha/year)	System cost of cultivation (Rs)	Total net returns (Rs)	B:C ratio	Energy productivity (kg/MJ)	Monetary efficiency (Rs/ha/day)	LUE (%)	Production efficiency (kg/ha/day)
Maize+ cowpea-Berseem+ mustard	149,750	34,889.28	114,860.72	3.29	9.28	318.17	98.90	414.81
Swankhi, Cowpea, Bajra-Berseem+Oats	89,700	31,716.40	57,983.60	1.83	6.53	182.34	87.12	282.07
Sorghum-oats	124,134	30,176.00	93,958	3.11	10.80	303.09	84.93	400.00

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Modules	System productivity (kg/ha/year)	System cost of cultivation (Rs)	Total net returns (Rs)	B:C ratio	Energy productivity (kg/MJ)	Monetary efficiency (Rs/ha/day)	LUE (%)	Production efficiency (kg/ha/day)
Perennial fodder	–	–	–	–				
Hybrid Napier	154,285	33,860	120,425.71	3.55	10.57	329.93	100.00	422
Paragrass	74,000	23,709	50,291	2.12	10.79	137.78	100.00	203
C.D	13,519	–	–	–	–	–	–	–
S.E(m)+	4486	–	–	–	–	–	–	–
Fodder trees (20No.)		–	120	–	0.76	0.33	100	0.33
B.variegata (10 No.)	80	–	–	–	–	–	–	–
Albizzia (10No.)	40	–	–	–	–	–	–	–
Azolla	365	–	365	–	5.80	1.00	100	1.00

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5.4 A Review on Indispensable Role of Indian Propolis and Its Pharmacological Significance

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Keywords: Beekeeper; Honeybees; Pharmacology; Phytochemical; Propolis

1. Introduction

Propolis is a natural material produced by honeybees from substances collected from various plant sources. Bees collect resinous exudates from various plant parts and modify with their enzymes to propolis. It is used by the bees to prevent the spread of microbial infections, preserving dead animals that enter the hives, and as construction material for the hives. Because of its waxy and slimy properties, bees use propolis in the construction and repair of their hives, and this act as a protective barrier against external invaders.

It is also popular folk medicine having a wide spectrum of biological activities. It has also been used as a health food product in major continents like Asian, American, and European countries. Current antimicrobial applications of propolis include formulations for the common cold, wound healing, therapy of burns, acne, and some viral infection like herpes.

The composition of propolis has been extensively studied worldwide, and remarkably most of the studies reported common and unique region-specific phytochemical compositions. Based on floral source and phytochemical profile, propolis is generally classified into Poplar (temperate), Birch, Tropical, Mediterranean, and Pacific types of propolis (Salatino *et al*., 2005). The chemical composition of propolis is dependent on its geographical and floral origins. Raw propolis is generally reported to comprise more than about 300 constituents with diverse pharmacological activities (Huang *et al*., 2014)

Propolis market is expected to generate revenues of USD 845.5 million by 2030, with a CAGR of approximately 6.23% from 2022 to 2030 (MRF, 2022). The Indian apiculture market reached a value of Rs 20,480 million in 2021. Looking forward, the apiculture market is expected to reach Rs 40,161 million by 2027, exhibiting a CAGR of 11.73% during 2022–2027 (IMARC, 2022). In this, honey currently represents the biggest segment. However, there is no market for propolis products in India. A single honeybee colony produces 10–300 g of propolis in a year, but still beekeepers are reluctant to collect this product (Habip and Cengiz, 2021). Non-collection of this hive product is attributed to lack of market for this product in India. Only a few private firms used to procure this product from beekeepers. The price of propolis worldwide varies according to origin and quality. In the international market, its price ranges between USD 20 and USD 150 per kilogram. The international market can be tapped for selling this product for better income generation. Worldwide propolis has incredible popularity, but in India propolis has not been broadly studied or reported except a few regions of India. India, being a vast country, has numerous varieties of propolis differing in chemical compositions and medicinal values. Hence, this review gathers major findings on the pharmacological properties of propolis focusing on its antimicrobial, antitumor, antioxidative, and anti-inflammatory properties.

2. Materials and methods

Keywords including propolis, pharmacology, medicine, flavonoids, phenol, honeybees, antimicrobial, antitumor, anticarcinogenic, antioxidative, and chemical compounds were searched on ScienceDirect, PubMed, Google Scholar, Embase, and other databases in order to find published papers till July 2022. Then, a manual search was conducted to find more related articles.

3. Results and discussion

In this study, 4140 articles were obtained: 2472 papers in the field of pharmacology of propolis components, 834 articles on the pharmacology and medical therapeutic properties, and 65 articles on the propolis component in Indian regions. Among selected reference articles, only English and full-text articles were used, and duplicate resources were excluded. Finally, 76 articles were included in the present study.

People of India have had a long connection with beekeeping and honey since ancient times. India accounts for 7% of the world's flora and has the potential to keep about 200 million bee colonies that can produce over 10 million tons of honey and other bee products. Beekeeping is an important activity that provides economic support to rural communities by generating additional income with an integrated farming system. In India, beekeeping is mostly practiced as a full-time occupation along with agriculture activities. The well-known primary products of beekeeping are honey and wax, but pollen, propolis, royal jelly, and bee venom are also marketable primary bee products.

According to the published literature, active research on Indian propolis started in the last decade. The first research publication on Indian propolis appeared in 2004. So far, only a few bioactivities have been evaluated in Indian propolis. Various studies have found that propolis has antioxidant, antimicrobial, anti-inflammatory, and antitumor properties.

Currently, there is no concrete information available on these compounds in Indian propolis, according to the environment, location, and seasonal factors. There are several potential factors, for example, pesticides, microorganisms, or predators (e.g., wasps and hornets) that lead to hives harm. Lack of scientific information and appropriate evaluation of the product could thus be the main reasons why very little propolis is produced in India.

Propolis production is almost a neglected practice among Indian beekeepers due to a lack of awareness about its value and market potential. Hence, beekeeping plays a vital role in rural development by generating revenue from honey and other bee products. The lack of scientific investigations and lack of awareness about the quality of indigenous propolis or Indian propolis endorses that there is

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an urgent necessity to initiate scientific research programs to explore the potential of original Indian propolis.

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5.5 Impact of Market Access on Input Use and Agricultural Productivity of Major Farming System in North-Western Himalayas

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Keywords: Farming system; Market access; Three-stage least square

1. Introduction

The north-western Himalayan region of India comprising Jammu and Kashmir, Himachal Pradesh, and Uttarakhand has been endowed with a wide range of agro-climatic conditions. A large number of crops can be cultivated in this region, but there is a disadvantage to small landholdings. These hilly states have almost reached a plateau in so far as cultivable land is concerned, and as a result it would be increasingly difficult to produce enough food for meeting the requirements of the growing population. Hence, the emphasis has to be on increasing productivity, besides diversification toward high-value crops. Thus, the farming system approach is seen as a potential way of raising and stabilizing the productivity and profitability levels of the farmers and thereby improving their livelihood security. The integration of agriculture farm enterprises leads to greater output, financial security, ecological balance, and environmental protection.

2. Materials and methods

This study was carried out in the hills of Himachal Pradesh, one of the most popular north-western Himalayan states of India. The stratified multistage random sampling technique was used to select a sample size of 240 farmers. Both primary and secondary data were collected. The impact of market access on input use and agricultural productivity was examined using a simultaneous equations model having three basic equations with three endogenous variables, namely, aggregate productivity (AP), per hectare fertilizers use (FERT), and plant protection chemicals (PPC).

$$AP = f_1(FERT, PPC, ACV, AF, MA, LBR) \quad \ldots (1)$$
$$FERT = f_2(ACV, AF, MA, FYM) \quad \ldots (2)$$
$$PPC = f_3(ACV, AF, MA, EXTN) \quad \ldots (3)$$

In Eq. (2), the fertilizer use was hypothesized to be influenced by the area under crops and vegetables (ACV), the area under fruits (AF), physical market access (MA), and the use of farmyard manure (FYM). The use of plant protection chemicals was hypothesized to be influenced by the area under crops and vegetables, the area under fruits, market access, and the number of visits of extension agents (EXTN) in the study area (Eq. 3). The three-stage least square (3SLS) procedure was used to estimate these equations as it provides more efficient estimates (Cameron and Trivedi, 2005).

3. Results and discussion

The major farming system practiced by the farmers in the study area was Crops + Vegetables + Fruits + Dairy (C+V+F+D) practiced by 45% of the total sampled farmers, followed by C+F+D (20%), C+V+D (15%), V+F+D (10%), C+D (8%), and F+D (2%) (Table 1). The estimates of the simultaneous equation model (Table 2) for the major farming system (C+V+F+D) revealed that the use of fertilizers (42.67), the area under crops and vegetables (4401.92), and the area under fruits (6750.26) were significantly positive determinants of aggregate agricultural productivity and indicated that aggregate productivity will increase with per unit increase in the respective variables. The statistically significant coefficient of market access (–3195.79) indicated that if the time taken to market decreases, the agricultural productivity increases. The coefficients of the area under crops and vegetables (47.32) and area under fruits (119.91) were having a significantly positive effect on fertilizer use, while farmyard manure (–0.09) was negatively related to fertilizer use. Further, the significantly negative coefficient of market access (–34.47) indicated the inverse relationship between time taken to reach the market and fertilizer use. The results also revealed that if the area under fruits and the number of extension visits in the study area increase, the use of plant protection chemicals also increases significantly under this farming system. The value of R^2 revealed that 74%, 92%, and 90% of the variation in the dependent variable was indicated by the selected independent variables in aggregate productivity, fertilizers use, and plant protection chemical use equations, respectively. These findings are supported by Katungi *et al*. (2011) and Aku *et al*. (2018).

Table 1 Different farming systems practiced by the farmers in the study area

Farming systems	C+V+F+D	C+F+D	C+V+D	V+F+D	C+D	F+D
Proportion of farmers	45	20	15	10	8	2

C= Crops (cereals, pulses, and fodder crops), V=Vegetables, F=Fruits, D=Dairy.

Table 2 Estimates of simultaneous equation model for C+V+F+D farming system in the study area

Explanatory variables	Dependent variables					
	Productivity		Fertilizer use		Plant protection chemical use	
	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic
FERT	42.67	2.68**	–	–	–	–
PPC	6.32	1.37	–	–	–	–
ACV	4401.92	6.75**	47.32	5.15**	–43.21	–1.23
AF	6750.26	2.83**	119.91	15.57**	205.17	9.27**
MA	–3195.79	–5.71**	–34.47	–3.38**	–4.86	–0.14
FYM	–	–	–0.09	–2.98**	–	–
LBR	–101.75	–1.26	–	–	–	–
EXTN	–	–	–	–	909.20	2.25*
R^2	0.74		0.92		0.90	

Note: The superscripts * and ** denote significance at 5% and 1% levels of probability, respectively.

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5.6 Habitat Manipulation for the Management of Major Insect Pests of Cauliflower

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Keywords: Cauliflower; Farmscaping; Incidence

1. Introduction

Habitat manipulation, the key element of farmscaping, has emerged as paradigm for considering pest management approaches that are based on cultural practices informed by ecological knowledge of arthropod pest management. Farmscaping reduces the load of pesticides, lowering the cost and risks associated with indiscriminate application of pesticides. Cauliflower, *Brassica oleracea* var. botrytis L., is one of the important crops grown for table as well as for seed production purpose. It is attacked by various insect pests like cabbage butterfly, diamondback moth, cabbage aphid, painted bug, cabbage head borer, and tobacco caterpillar. Suitable weather factors also enhance the buildup of insect pests very rapidly (Rolania *et al*., 2018). Intercropping affects the pest by microclimate through changes in crop canopies (Bach and Tabashnik, 1990). Keeping these facts in view, the present study was conducted.

2. Materials and methods

The experiment was laid out in uniformly sized plots measuring 4.5 × 3m (13.5 sq. m) in randomized block design containing seven treatments [cauliflower+marigold (2:1), cauliflower+coriander (2:1), cauliflower+mustard (2:1) as intercrop, cauliflower+fennel (2:1), cauliflower+fenugreek (2:1), cauliflower+mustard as trap crop and control] with three replications during 2021 and 2022 at Haryana (India). The row-to-row distance and plant to plant spacing for cauliflower were 60 and 45 cm, respectively. The population of aphid was recorded on three plant leaves randomly selected by numerical count method using one inch^2 leaf area with the help of magnifying lens. Population of diamondback moth, tobacco caterpillar, and cabbage butterfly were recorded on five randomly selected plants by counting the number of larvae per plant by adopting the direct visual count method. The associated natural enemies like syrphid flies (maggot) and coccinellids were recorded by visual count technique from five randomly selected plants. The meteorological data were procured from Department of Agrometeorology CCSHAU, Hisar Haryana. Suitable statistical analyses were done for comparison and correlation of the data.

3. Results and discussion

The results showed that the seasonal mean populations of major insect pests of cauliflower were relatively less under different farm scaping practices in comparison to sole crop (Table 1). During study period, we have observed aphid, cabbage butterfly, diamondback moth (DBM), and tobacco caterpillar. Minimum aphid population was recorded in cauliflower intercropped with coriander (2:1) that was significantly less in comparison to all the treatments except cauliflower+mustard (2:1). Similarly, Lal *et al*. (2002) studied the influence of intercropping cabbage with garlic, Indian mustard, tomato, marigold or berseem and observed that aphid population was lower in all intercropped than sole crop of cabbage. A very low population of diamondback moth (DBM) and cabbage butterfly was recorded during both years. Srinivasan and Krishnamoorthy (1991) recommended Indian mustard acts as trap crop for the management of DBM. Maximum B:C ratio (2.49 and 2.52) was recorded in cauliflower+marigold (2:1) treatment during both the year. The correlation study with weather parameters shows that aphid population had significant positive correlation with maximum temperature (r=0.915), minimum temperature (r=0.936), and PAN evaporation (r=0.931), while it had significant negative correlation with morning (r=734) and evening (r=812) relative humidity. Sachan and Srivastava (1972) reported that aphids appear on cabbage crop in the month of November. Population remains low until middle of December after which it starts increasing. Rise in temperature to some extent after winter months favors its multiplication but further rise in temperature after March onwards had an adverse effect on population. Cabbage butterfly and coccinellids had a significant positive correlation with the minimum temperature, maximum temperature, morning relative humidity, PAN evaporation, and total rainfall.

Table 1 Mean population of aphid, coccinellid beetles, and syrphid fly on cauliflower under different habitat

Treatments	Aphid/plant		Coccinellids /plant		Syrphid fly	
	2021	2022	2021	2022	2021	2021
Cauliflower+marigold (2:1)	14.15 (3.89)	19.07 (4.48)	5.78 (2.60)	1.67 (1.63)	1.15 (1.47)	1.00 (1.41)
Cauliflower+coriander (2:1)	11.93 (3.59)	14.41 (3.92)	8.10 (3.01)	3.78 (2.19)	2.11 (1.76)	1.81 (1.68)
Cauliflower+mustard (2:1) as intercrop	12.63 (3.69)	15.48 (4.06)	6.63 (2.76)	1.89 (1.70)	1.37 (1.54)	0.70 (1.31)
Cauliflower+fennel (2:1)	13.84 (3.85)	18.41 (4.41)	5.99 (2.64)	1.89 (1.70)	1.15 (1.46)	0.56 (1.25)
Cauliflower+fenugreek (2:1)	14.10 (3.88)	17.52 (4.30)	5.62 (2.57)	1.93 (1.71)	1.07 (1.44)	1.04 (1.42)
Cauliflower+mustard as trap crop	12.51 (3.67)	15.67 (4.08)	7.32 (2.88)	1.96 (1.72)	1.52 (1.59)	0.74 (1.32)
Control	17.69 (4.32)	27.93 (5.38)	0.93 (1.39)	2.00 (1.73)	0.30 (1.14)	0.26 (1.12)
CD at 5%	0.20	0.13	0.12	0.13	0.11	0.13

Note: Figures in parenthesis are square root transformed.

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5.7 Opinion of Input Dealers about DAESI (Diploma in Agricultural Extension Services for Input Dealers) Programme in Rajasthan

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Keywords: DAESI; Input dealers; Opinion

1. Introduction

The extension worker to farmer ratio in India is 1:5000, which is far wider than in Ethiopia (1:476) and China (1:625) (Davis *et al.*, 2010). This shows that it is very difficult for an extension worker to provide extension services to all the farmers effectively. The majority of the information is provided by input dealers to the farmers directly. Therefore, the National Institute of Agriculture Extension Management (MANAGE) designed a 1-year diploma course titled ‘Diploma in Agricultural Extension Services for Input Dealers (DAESI)’ in 2003, which imparts relevant and location-specific agricultural education to equip these input dealers with sufficient knowledge to transform them into para-extension professionals so as to enable them to address the day-to-day problems being faced by the farmers at the field level. The study is expected to help the custodians to plan and implement this programme in such a way that the input dealers could derive maximum benefits out of this programme and achieve the predetermined objectives.

2. Materials and methods

The present study was conducted in the NTIs (Nodal Training Institutes) under the jurisdiction of Sri Karan Narendra Agriculture University, Jobner, District Jaipur (Rajasthan) that includes eight districts, that is, Jaipur, Sikar, Alwar, Dausa, Tonk, Ajmer, Bharatpur, and Dholpur, which had organized DAESI programme during 2019 to 2020. As per the data collected from the state coordinator DAESI, SIAM, Durgapura Jaipur, Rajasthan, it was evident that 10 DAESI trainings were ongoing at the time of data collection (May 2020) in the operational area of SKNAU, Jobner. These 10 trainings were organized by three different types of NTIs, that is, five by SIAMs, four by KVKs, and one by the ARS. In order to select the NTIs, it was realized that sufficient time should be given to the respondents for building some opinions about the programme. Therefore, it was decided that only those NTIs where at least 50.00% of the classes (20 theory and 4 field visits) have been completed by the time of data collection (May 2020) will be included in the present study. It was found that out of the 10 NTIs, 7 NTIs, namely, SIAM, Jaipur (1st and 2nd batch), SIAM, Tonk (1st and 2nd batch), KVK, Bansur, KVK, Tabiji, and ARS, Alwar have completed their 50% courses by the time of data collection. Therefore, three NTIs, namely, SIAM, Jaipur 2nd batch, KVK Tabiji, Ajmer, and ARS Navgaon, Alwar, were selected randomly for the present study. Under each batch of the DAESI programme, the number of trainees is restricted to 40 input dealers only. As this number was not too large, all the 40 input dealers from three selected NTIs, that is, SIAM 2nd batch, Jaipur, KVK Ajmer, and ARS Navgaon, Alwar, were included in the study, making a total of 120 respondents. A questionnaire containing all possible components of a good training programme was prepared and the responses of input dealers were recorded as strongly agree, agree, and disagree and scores 3, 2, and 1 were assigned, respectively. A higher opinion score means a more favorable opinion.

3. Results and discussion

The overall opinion of the input dealers represents the total scores obtained by an input dealer in all the statements under various components of opinion in the questionnaire. The score obtained by an individual dealer in all the statements related to opinion was summed up and maximum and minimum scores were obtained. The minimum score obtained by the input dealers under the present study was 125 and the maximum was 219. Based on this, three groups, namely, less favorable opinion, favorable opinion, and most favorable opinion, were formulated. The results revealed that as a whole, more than half of the input dealers (60.00 per cent) have expressed the most favorable opinion towards the DAESI programme followed by 21.66% who have expressed a favorable opinion. Only 18.33% have expressed a less favorable opinion about the DAESI programme. In order to assess the significant difference between the opinions of the input dealers from different NTIs (Nodal Training Institutes) about the DAESI programme, one-way ANOVA was used. It is evident from the results presented in Table 1 that there is no significant difference between the opinions of the input dealers from different NTIs about the DAESI training programme, which is an encouraging sign. This further indicates that the DAESI programme is so nicely planned and all the NTIs irrespective of their mandates and experience are organizing the programme very efficiently and that is why no significant difference was found between the opinions of the input dealers from the three different NTIs.

Table 1 Difference between the opinions of the input dealers from different NTIs about the DAESI programme

Dependent variable	(I)	(J)	Mean difference (I – J)	Standard error	***p*** value	Modal summary
Opinion of input dealers regarding the DAESI programme	KVK Ajmer	ARS Alwar	–2.375	6.23449	0.704	
		SIAM Jaipur	–0.525	6.23449	0.933	
	ARS Alwar	KVK Ajmer	2.375	6.23449	0.704	
		SIAM Jaipur	1.850	6.23449	0.767	*F*=0.080
		KVK Ajmer	0.525	6.23449	0.933	*p*= 0.923
	SIAM Jaipur	ARS Alwar	–1.850	6.23449	0.767	

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5.8 Economics of Natural Farming System in Sirmaur and Solan districts of Himachal Pradesh, India

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Keywords: Conventional Farming; Economics; Natural farming

1. Introduction

The present form of agriculture is overburdened with costly inorganic chemicals, fertilizers, and pesticides and results in the pollution of groundwater and various ecosystems. As a consequence, if a farmer with a small landholding invests in these costly inputs, he/she is exposed to high monetary risks and is inevitably caught in the debt cycle. The adverse impacts of chemical farming on soil health and the environment force us to have other approaches that can lead to better outcomes without harmful effects. One of the approaches is natural farming, which addresses many agricultural issues starting from climate change, low investment, reduction in poverty, food safety improvements, biodiversity protection, and planning for sustainable growth in the country. The government of Himachal Pradesh has recently launched the Prakirtik Kheti Khushhal Kissan scheme to promote natural farming in the state. Therefore, very less data is available on the cost of cultivation of various crop combinations under natural farming. Keeping in view this factor, the present study was undertaken to study the economics of natural farming system in Sirmaur and Solan districts of Himachal Pradesh, India.

2. Materials and methods

A total of 60 farmers each from Sirmaur and Solan districts were selected randomly for the present study. CACP cost concepts were used to estimate the cost of cultivation of different crop combinations. Crop equivalent yield (CEY), net returns, and output-input ratio were also used in the study.

3. Results and discussion

In natural farming system, many types of crops were cultivated in a multiple or mixed cropping. So it was very difficult to compare the yield of multiple crops with a single crop. Crop equivalent yield (CEY) of multiple cropping sequences was calculated by converting the yield of different intercrops/crops into the equivalent yield of any one crop based on the price of the produce (Francis, 1986). The data presented in Table 1 reveals that in the Sirmaur area, CEY of different crops, that is, Cereals-Vegetables-Pulses, Cereals-Vegetables, Vegetables, Sugarcane-Vegetables-Turmeric, Cereals-Vegetables-Pulses, Cereals-Vegetables, and Cereal-Vegetables-oilseeds were 74, 157, 173, 1308, 65, 66, and 40 q/ha, respectively. In Solan area, crop combinations practiced were Cereals-Vegetables, Vegetables, Cereals-Vegetables-Pulses, and Cereals-Vegetables and CEY in these combinations was 193, 208, 60, and 74 q/ha, respectively. The cost of cultivation was highest in crop combination Vegetables (Rs 61,106 /ha) in Sirmaur and highest for crop combination Cereals-Vegetables (Rs 59,288/ ha) in Solan. The net returns were highest in the crop combination Sugarcane-Vegetables-Turmeric (Rs 325,070/ ha) in Sirmaur district and highest for crop combination Vegetables (Rs 245,648/ha) in Solan. The output-input ratio was more than 2 for the maximum crop combination in the study area. So, this can be concluded from the study that natural farming can be a viable alternative for the farmers.

Table 1 District-wise costs and returns from natural farming system

Crops	District							
	Sirmaur				Solan			
	CEY (q/ha)	Cost of cultivation (Rs /ha)	Net returns (Rs /ha)	Output-input ratio	CEY (q/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	Output-input ratio
Cereals-Vegetables-Pulses	74.32	53,812	78,498	2.46	–	–	–	–
Cereals-Vegetables	157.19	58,116	84,775	2.46	193.91	55,056	98,752	2.79
Vegetables	173.42	61,106	178,205	3.92	208.45	55,323	245,648	5.44
Sugarcane-Vegetables-Turmeric	1308.19	59,691	325,070	6.45	–	–	–	–
Cereals-Vegetables-Pulses	65.99	52,174	76,040	2.46	60.75	55,511	54,895	1.99
Cereals-Vegetables	66.76	37,315	82,034	3.20	74.51	59,288	90,507	2.53
Cereal, vegetable and oilseed crop	40.51	31,027	40,278	2.30	–	–	–	–

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5.9 Factors Affecting Input Use in Maize Crop in Jammu Region

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Keywords: Dependent variables and independent variables; Maize

1. Introduction

Maize (*Zea mays* L.) is one of the most important crops in the world agricultural economy grown over an area of 177 million hectares with a production of 967 million tons (India Maize Summit, 2014). India ranks fourth in the area and sixth in the production of maize. As maize has yield potential far higher than any other cereal, it is referred to as the miracle crop or the 'Queen of Cereal' (Anonymous, 2011). The productivity of maize largely depends on optimal management of inputs such as fertilizers, irrigation, and herbicides. The productivity of maize can be enhanced by optimal use of inputs as per the recommendations made by research institutes.

In J&K, future increases in maize production to meet domestic demand will have to rely on improvements in yield per hectare rather than on the expansion of maize production area. Enhanced maize productivity can be achieved by increased use of modern production techniques such as the adoption of hybrid maize varieties and the optimum use of fertilizers application.

2. Materials and methods

The present study was conducted in five districts, namely, Doda, Kathua, Poonch, Rajouri, and Udhampur, of the Jammu region in which 220 respondents were selected by multi-stage random sampling. The main objective of the study was to identify the factors affecting input use in maize crop in the study area.

Binary logistic regression model: Binary logistic regression model was applied to identify the independent variables influencing the dependent variables where the dependent variable was dichotomous.

$$L_n\left[{}^{p}/_{1-p}\right] = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_kx_k$$

Here,

p=represents the probability of an event

b_0=y intercept (constant), and

x_1 to x_k represent the independent variables included in the model.

3. Results and discussion

Factors affecting input use in maize crop: The independent variables taken in the study were age, education, family size, annual income, social participation, landholding, the distance of the village from input store, the number of fragments, the type of seed (hybrid/non-hybrid), and knowledge score. The variables significantly impacted the input use in maize crop are listed in Table 1.

Seed: Out of all the independent variables, annual income and knowledge of respondents about maize cultivation practices significantly affected the farmers' decisions of seed selection (hybrid/non-hybrid). These two variables favor the adoption of hybrid seeds. The model applied has the log-likelihood value of 203.696 and a chi-square value of 11.785, which were significant at p=0.001. The Nagelkerke's R^2 indicates that there is an 11.4% variation in the use of hybrid/non-hybrid seeds as explained by the variables selected for the analysis (Table 1).

Urea: The model applied has the log-likelihood value of 47.006 and a chi-square value of 34.347 which was significant at p=0.000. Nagelkerke's R^2 value was 0.468 which indicates that there is a 46.8% variation in the use of urea as explained by the variables selected for the analysis. The variable type of seeds (hybrid/non-hybrid) and the distance of the fertilizer store from the village significantly affected the urea use decision (Table 1).

DAP: The model applied has the log-likelihood value of 225.00 and a chi-square value of 17.646; Nagelkerke's R^2 value was 0.203 which indicates that there is a 20.3% variation in the use of DAP as explained by the variables selected for the analysis. The variable type of seed (p<0.05) and the distance of the village from the fertilizer store (p<0.01) significantly affected the decision to use DAP (Table 1).

MOP: The model applied has the log-likelihood value of 199.749 and a chi-square value of 31.074. Nagelkerke's R^2 value was 0.203 which indicates that there is a 20.3% variation in the use of MOP as explained by the variables selected for the analysis. The variable type of seeds (hybrid/non-hybrid) and knowledge score of the respondent significantly affected the farmers' decision to use MOP (Table 1).

Herbicide: The model applied has the log-likelihood value of 166.196 and a chi-square value of 16.291. The results indicate that Nagelkerlie's R^2 value was 0.127 which means that there is a 12.7% variation in the use of the herbicide as explained by the variables selected for the analysis. The variable knowledge (p<0.01) significantly affected the decision to use herbicide (Table 1).

Table 1 Factors affecting input use (binary logistic model)

Input	Factors affecting input use	Coefficient (B)	S.E.	Wald	p value	Model summary
Seed	Annual income	.000	.000	7.379	<0.01	–2 log-likelihood=203.696
	Knowledge score	.049	.021	5.428	<0.05	Nagelkerke's R^2=.114
	Constant	–1.465	.986	2.209	>0.05	Chi-square value=11.785 p<0.01
Urea	Type of seed	3.286	.856	14.736	<0.01	–2 log-likelihood=47.006[b]
	Distance of fertilizer store (km)	.330	.131	6.396	<0.05	Nagelkerke's R^2=.468 Chi-square value=34.347
	Constant	–.241	.578	.174	>0.05	p<0.01
DAP	Experience	–.027	.012	5.230	<0.05	-2 log-likelihood=225.060[b]
	Social participation	–.334	.263	1.624	>0.05	Nagelkerke's R^2=.279
	Landholding	.518	.199	6.753	<0.01	Chi-square value=17.646

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	Type of seed	2.232	.399	31.320	<0.01	p<0.05
	Constant	–.612	.511	1.436	> 0.05	
MOP	Type of seed	2.544	1.036	6.034	< 0.05	–2 log-likelihood=199.749[b]
	Knowledge score	.048	.020	5.789	<0.05	Nagelkerke's R^2=.203
	Distance	–.078	.028	7.483	<0.01	Chi-square value=31.074
	Constant	–5.294	1.398	14.339	<0.01	p<0.01
Herbicide	Knowledge score	.092	.024	14.258	<0.01	–2 log-likelihood=166.196 Nagelkerke's R^2=.127
	Constant	–6.353	1.283	24.533	<0.01	Chi-square value=16.291 p<0.01

[b:]maximum likelihood estimate

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5.10 A Study on Socioeconomic Conditions of Rubber Plantation Farmers in the State of Tripura India

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Keywords: Rubber plantation; Socioeconomic; Tribal farmers; Tripura; Smallholders

1. Introduction

Rubber farming has increased quickly throughout South-East Asia over the last decade to fulfill the demand for natural rubber (*Hevea brasiliensis*), particularly in China and India. In Tripura, rubber is grown as a commercial crop. Tripura's government gets a significant amount of revenue from this cash crop. Kerala and Tripura are the two states well-known for their rubber production (DESP 2019). Tripura is India's second largest producer of natural rubber after Kerala (Economic Review of Tripura, 2018-19). The Tripura State Government, with assistance from the Rubber Board of India and World Bank, has implemented a rehabilitation program known as the Rubber Plantation Scheme (RPS) for the *jhumias* in order to address issues such as land alienation and low socioeconomic development. Despite good socioeconomic and livelihood opportunities, the mass-scale rubber plantation shows the importance of smallholder farmers in land-use changes. The risks of this land-use change may be high as rubber plantations have often been associated with various environmental issues including biodiversity loss and disturbing the soil quality and groundwater reserve (Panda and Sarkar, 2020).

2. Materials and methods

The two districts, namely, 'Sephaijala' and 'Gomti', in Tripura out of eight districts and two blocks from each district were chosen for the present study. Four rubber plantation centers (Tripura Forest Development and Plantation Corporation & Tripura Rehabilitation Plantation Corporation), one from each block, were identified through a pilot study. The centers provided a list of 320 rubber farmers, and those farmers were subsequently chosen at random for the study. A total of 125 (79 from Sephaijala district and 46 from Gomti district) rubber growers' responses were finalized after screening out 160 rubber farmers' responses due to incomplete surveys and the responses gathered from the respondents were taken for further analysis.

3. Results and discussion

Table 1 Analysis of socioeconomic variable and income (n=125)

Variable		Classification	Percentage
Income	Approx. monthly household income (INR)	Less than 10,000	24.8
		10,000–20,000	44.8
		20,000–30,000	19.2
		More than 30,000	11.2
	Secondary source of income	Yes	40
		No	60
	Other sources of income	Agricultural activities	12
		Dairy farming	10
		NTFP collection	76
		MGNREGA worker	54
		Fisheries	8
		Govt. worker (Tappers)	6
		Shop owner	6
		Poultry farming	16
		Govt. employee	6
		House help	2
		Private employee	24
		Businessman	16
	Percentage contribution of income from rubber plantation	0-25%	6.4
		25-50%	8
		50-75%	24
		75-100%	61.6
Education	Highest education level of head of household	Illiterate	24
		Primary	16
		Secondary	50.4
		Senior secondary	6.4
		Undergraduate	2.4
		Postgraduate	0.8
	Rubber plantation training	Yes	39.2
		No	60.8
Education	Highest education level of the head of household	Illiterate	24
		Primary	16
		Secondary	50.4
		Senior secondary	6.4
		Undergraduate	2.4
		Postgraduate	0.8
	Rubber plantation training	Yes	39.2
		No	60.8

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Living condition	Type of house	Kutcha house	51.2
		Semi-pucca house	32.8
		Pucca house	16
	Household possessions	TV	88
		Telephone	2.4
		Two-wheeler	29.6
		Mobile phone	99.2
		Gas stove	93.6
		Radio	0
	Possession of land	Yes	96
		No	4
	Area of land under rubber plantation	Less than 5 acre	94.4
		5–10 acre	4
		10–15 acre	1.6
	Total area of Land	Less than 5 acre	90.4
		5–10 acre	8.8
		10–15 acre	0.8
	Type of Land	Patta land	7.5
		Jyot Land	6.7
		Khas land	80
		Land on rent/lease	3.3
		Other	2.5

Source: Primary data

Income and socioeconomic condition

About 44.8% earn between Rs 10,000 and Rs 20,000 per month and 11.2% earn more than Rs. 30,000 per month. The reality of smallholders draws the result that 60% of households do not have secondary sources of income, whereas 40% of households have additional sources of income. About 61.6% were those households in which income from rubber contributes 75–100% to their monthly income while 24% were having 50–75% rubber income contribution to their total monthly income.

Human capital

Study shows that 24% of the 125 sample respondents are illiterate, 16% are educated up to primary education, 50.4% are educated up to secondary education, and 0.8% are graduates. 39.2% of respondents received rubber cultivation/tapping instruction from various organizations, whereas 60.8% did not get any training.

Living condition and socioeconomic condition

From Table 1, around 51.2% of the respondents live in 'kuttcha house', 32.8% of the respondents live in 'semi-pucca' house, and 16% of the respondents live in the 'pucca' house. About 96% of the respondents have possession of land. The results showed that the existence of rubber plantations influenced the lives of the surrounding communities. The presence of rubber plantations had widened employment prospects and raised local incomes, aided with infrastructure facilities of the farmers. Nevertheless, it is undeniable that beneficial effects have also brought about a number of social changes within the society.

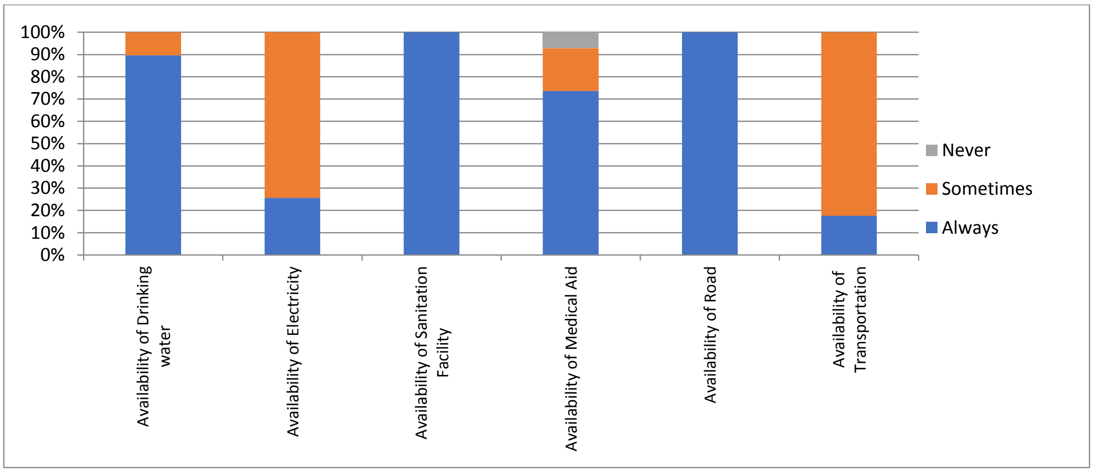

Figure 1 Status of basic amenities of rubber farmers
Source: Primary data

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5.11 Sustainable Dairy Production Systems at Farm-level in Punjab

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Keywords: Dairy farming; Economic sustainability; Groundwater and greenhouse gas emissions; Sustainability

1. Introduction

The livestock sector contributes around 10% to the total GDP and 40.61% to the agricultural GDP of Punjab state. The total livestock population in the state is 6.99 million, out of which cattle and buffalo constitute 93.71% of the total population. Punjab ranks sixth in total milk production (13.35 MT in 2019-20) in the country. Milk contributes to the major share in the total value of output from livestock, that is, 82.51% in the year 2017-18. Dairy farming contributes to Sustainable Development Goals, including SDG 2: Zero hunger, SDG 3: Good health and well-being, and SDG 8: Good jobs and economic growth (Segerkvist *et al*., 2020). However, to accomplish SDGs, the current dairy production systems need to be sustainable in three dimensions, that is, environmental, economic, and social, within the system boundary of farm to the grave. The welfare of livestock, farm size, feed and fodder sustainability, and public health impact are among the important parameters to determine the economic viability of dairy farms. The Sustainable Development Goals are set to achieve sustainable dairy production systems through the development and review of sustainable strategy, improvement plan, integrated monitoring system, implementation, and impact evaluation. Therefore, we analyzed the sustainability dimensions (i.e., environmental, economic, and social) at the farm level in Punjab.

2. Materials and methods

In order to achieve these objectives, the primary study was conducted on the cattle and buffalo dairy farms at GADVASU, Ludhiana to calculate fixed and variable costs at the farms. Fixed cost includes depreciation on animals, sheds, equipment, machinery, insurance of livestock, and interest on capital. Variable costs include the cost of feed and fodder, labor expenses (both family and hired labor), veterinary expenses, diesel expenses, and other recurring expenses like repairing of shed, equipment, machinery, electricity, and water charges.

3. Results and discussion

The results showed that the consumption of plant protein declined by 15.6% while consumption of animal-based protein increased by 39.7% from 1981 to 2011. Small and medium dairy farms constitute 62% of the share of milk production in the state. The groundwater resources are being overused to an extent of 14.56 BCM. Over the last two decades, CH_4 emissions from enteric fermentation and manure management from cattle have increased by 61.18% each. The cost of producing one quintal of green fodder is increased by 9.7%, dry fodder by 36.7%, and concentrate by 23.2% from 2020-21 to 2021-22. The milk prices by Milkfed increased by 7.81% for cow milk and 9.09% for buffalo milk with a 25.4% increase in per animal per day cost from 2020-21 to 2021-22. Sustainability is required in areas that are environmentally less flourished and economically viable. Policies that are ecologically sound, commercially feasible, and socially acceptable need to be established. Sufficient availability of feed and fodder needs to be addressed. National socioeconomic policies for agriculture including labor and biodiversity policies should be implemented.

Table 1 Economics of milk production in Punjab

Particulars	Domestic	Small	Medium	Large	Overall
Cattle					
Milk yield (litre)	7.20	9.00	11.94	15.36	10.48
Cost of milk production (Rs/litre/farm/day)	25.60	23.80	21.60	19.91	22.32
Dairy enterprise profit (Rs/litre)	–3.12	–1.48	2.92	4.92	1.02
Dairy enterprise profit excluding labor (Rs/litre)	0.47	1.12	4.10	6.10	3.88
Buffalo					
milk yield (litre)	5.95	7.73	8.62	9.66	7.71
Cost of milk production (Rs/litre/farm/day)	35.01	33.22	29.91	27.91	29.72
Dairy enterprise profit (Rs/litre)	–4.37	–2.12	3.98	5.99	2.65
Dairy enterprise profit excluding labor (Rs/litre)	–0.02	1.32	5.52	7.32	4.62

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Theme 6

Biodiversity Conservation and Management

6.1 Effects of Trash Management of Sugarcaneon Soil Organic Carbon Buildup and Sustaining Yields of Successive Ratoon Crops in Khammam District of Telangana

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Keywords: Bulk density; Organic carbon; Sugarcane; Trash shredding

1. Introduction

In the conventional practice, the sugarcane trash after harvesting is usually burnt in the field, which ultimately leads to loss of nutrients and degrades soil fertility and the environment. High C:N ratio, high fibercontent, and lack of proper composting techniques prolong the decomposition of trash in the field. Besides the loss of organic matter and plant nutrients, the burning of crop residues results inan increase inatmospheric pollution due to the emission of toxic gases such asmethane and carbon dioxide. In situ trash management can be a good alternative option to mitigate these problems.Similarly, the mechanical handling and incorporation of trash will help to enhance crop yield and improve soil health. The objective of this study was to find out the impact of trash management strategies on the cane yield, organic carbon,and bulk density of the soil.

2. Materials and methods

The adoptive research was conducted at the farmers' field on "Evaluation of Trash Shredding on Successive Ratoon Crops in Sugarcane in Khammam District of Telangana." The demonstration was conducted during 2017–2020 with plant crops and two ratoon crops in five locations with four treatments, namely: T_1– trash burnt, T_2– trash removed, T_3 – trash retained, and T_4–trash shredded. The experiment was laid in a randomized block design with five replications. The soil was sandy loam with a pH of 7.38; organic C, 0.54%; available N, 240 kg/ha; P, 48 kg/ha; and K, 300 kg/ha[1]. The sugarcane crop (Co 86032) was planted under 90 cm spacing on April 21,2017 and harvested on February 20, 2018. Subsequently, two ratoon crops were raised in succession with the above-mentioned trash management practices. The recommendeddose of fertilizers, that is, 280:60:120 kg $N:P_2O_5:K_2O$ per ha, was adopted. A fulldose of P was applied in furrows before planting and N and K were applied in two splits in plant crops as well as ratoon crops followed by irrigation of the main crop through the furrow method and flood irrigation to the ratoon crop, respectively. After harvesting of the crops, soil samples were analyzed for organic carbon and soil bulk density.

3. Results and discussion

Trash shredding and retaining as mulch each year in the ratoon crop for 2years increased the soil organic carbon by 0.09% and 0.06%, respectively, while trash burning decreased it by 0.06% (Table 1). Trash shredding and retainedconserved soil moisture and regulated soil temperature might create a congenial, edaphic environment for accelerated activity of soil microorganisms that in turn would have enhanced decomposition of root residues and trash. On the other hand, trash burning not only destroyed the littered residues in the field but also sterilized the topsoil, thus killing the microbes responsible for decomposing root residues left under the soil. The bulk density of the soil increased after successive harvests of the crop in plots with trash burning or removal, but it decreased where trash was shredded and retained (Table 1). These results confirm the findings of Dahiya*et al*.(2003) who reported a decline in soil organic matter with an increase in soil bulk density. Yadav*et al*. (2009) found higher organic carbon and nitrogen contents in the soil after trash incorporation than in the trash burnt soil. Cane yield of all the ratoon crops significantly increased in plots where trash was shredded and trash retained as mulch compared to plots with trash burning and removal (Table 1).

Table 1 Effects of different trash management practices on cane yield (tons/ha), soil organic carbon content (%), and bulk density (g/cm^3) after successive harvests of sugarcane in a ratoon system

Treatments	Cane yield (t/ha)			Organic carbon content (%)			Soil bulk density (g/cm^3)		
	Plant crop	Ratoon 1	Ratoon 2	Plant crop	Ratoon 1	Ratoon 2	Plant crop	Ratoon 1	Ratoon 2
T_1– trashburnt	108.6	110.7	105.4	0.54	0.52	0.48	1.43	1.50	1.55
T_2– trash removed	108.6	111.4	107.5	0.54	0.56	0.52	1.43	1.47	1.50
T_3– trash retained	108.6	113.8	114.6	0.54	0.58	0.60	1.43	1.43	1.39
T_4– trash shredding	108.6	120.5	123.8	0.54	0.60	0.63	1.43	1.40	1.35
CD (at 5%)	–	4.2	7.0	–	0.04	0.06	–	0.04	0.06

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6.2 Floristic Diversity of *Santalum album* L. Populations in Mid Hill Zone of Himachal Pradesh

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1. Introduction

Santalum album L. (Chandana) is a widely accepted fragrant tree belonging to the family Santalaceae, native to the tropical belt of peninsular India, Eastern Indonesia, and Northern Australia. It is mostly (90%) grown in states such as Karnataka and Tamil Nadu. In Himachal Pradesh, it is found in some areas of the districts of Bilaspur and Kangra mainly in the Jawala Ji region. Sandalwood is an evergreen, semi root parasite tree that can parasitize over 300 species ranging from grasses to other sandalwood species (Rocha *et al*. 2017). Site-specific ecological studies of this species are essential for its long-term survival in a particular area. A survey was accomplished on the phytosociological and natural regeneration status of sandalwood in the district Kangra, Himachal Pradesh in five natural populations in 2020-21 for studying the distribution pattern, natural regeneration status, and ecological status in relation to edaphic and woody plant association of *S. album*.

2. Materials and methods

Five natural populations, namely, Banoh, Khariya, Amb Khatta, Selra, and Jawala Ji, of *S. album* L. distributed in the district Kangra, Himachal Pradesh were selected for the survey. The investigations on status of plant diversity and regeneration in natural populations of the study area using community analysis was carried out during the rainy season of 2020-21. The vegetation data were quantitatively analyzed for density, percent frequency, and abundance. Relative frequency, relative density, and relative basal area were determined by following methods of Phillips, importance value index by Curtis, indices of similarity and dissimilarity by using formulae as per Mishra and Sorensen, species richness as per Margalef's index of richness (D_{mg}) method, diversity as per Shannon–Wiener, and index of diversity as per Simpson. The adequacy of regeneration of *S. album* within its natural population was judged based on a number of established plants in a unit area.

3. Results and discussions

The major tree species that represented the natural populations of *S. album* L. in one or another among the five locations are *Acacia catechu*, *Albizia chinensis*, *A. lebbeck*, *G. optiva*, *L. leucocephala*, and *Dalbergia Sissoo*. Maximum values for parameters such as density, abundance, basal area, percent frequency, and IVI (importance value index) were observed in the case of *S. album* L. in four out of five locations, namely, Banoh, Khariya, Selra, and Jawala Ji. Also, the *S. album* was the dominant species in all the areas covered. In general, the *S. album* was an older crop in their habitat. Among shrub species, the highest values for the abovementioned parameters were for *Lantana camara* L. in all the five locations surveyed. *L. camara* and *Murraya koenigii* were observed as dominant and co-dominant shrubs species, respectively, in all five locations.

Population-wise descending order of tree species diversity was in Khairya, Jawala Ji, Selra, Amb Katta, and Banoh. Species diversity of shrubs ranged from 0.68 to 1.00, the maximum value was recorded for Selra and the minimum for Khairya and Jawala Ji. Zegeye *et al*. (2006) in their study in Ethiopia found that such high diversity was due to low disturbance, habitat conditions, and species characteristics. Among all the locations surveyed, the maximum values for tree species dominance and tree species richness were recorded for Banoh and Selra, respectively, whereas in the case of shrubs the highest values for dominance and richness were observed for Jawala Ji and Banoh. The population-wise equitability in tree and shrub species was observed to be highest in Selra. In all the natural populations covered during the survey, Banoh registered a maximum number of recruits, whereas in the case of unestablished regeneration, Banoh consisted of a maximum number. Jawala Ji recorded the maximum values for established regenerations, establishment index, stocking, established stocking percent, and regeneration success percent (Table 1).

Table 1 Regeneration studies of *Santalum album* L. in its natural populations

Location	Recruits/ha	Unestablished /ha	Established/ha	Establishment index (I_1)	Stocking index (I_2)	Established stocking percent	Regenerat-ion success percentage
Banoh	175.00	125.00	50.00	0.18	0.03	1.91	3.25
Khairiya	125.00	75.00	50.00	0.20	0.03	2.09	2.75
Amb Katta	75.00	75.00	25.00	0.10	0.02	1.00	1.75
Selra	125.00	75.00	50.00	0.25	0.03	2.13	2.75
Jawala Ji	75.00	75.00	75.00	0.33	0.04	3.33	3.75

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6.3 Effects of Land Configuration and Planting Methods on Growth and Yield of *Kharif* Onion (*Allium cepa*L.)

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Keywords: Growth; Land configuration; Onion; Planting methods; Yield

1. Introduction

Onion (*Allium cepa*L.), popularly known as the "Queen of Kitchen," is a hardy bulbous crop grown all over the world. *Kharif*onion bulb production is a peculiarity of Maharashtrastatein the country. Land configuration, namely,flatbed, broad bed furrow, ridge, and furrows, plays a major role in increasing the productivity of onionsbesides maximizing infiltration, minimizing erosion, and improving water use efficiency and aeration of different crops. Planting onion on raised beds significantly increases plant height, thenumber of leaves per plant,and bulb yield as compared to flat planting. Considering all these facts in view, the present study was undertaken to investigate the "Effect of land configuration and planting methods on growthand yield of *Kharif*onion (*Allium cepa L.*)."

2. Materials and methods

A field experiment was undertaken during *Kharif* 2019 at PGI Farm, Mahatma PhuleKrishiVidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra). The experiment was laid out in a completely randomized block design with four replications and six treatments involving T_1–Broadcasting on a flatbed, T_2–Line sowing on a flatbed, T_3- Broadcasting on broad bed furrow, T_4–Line sowing on broad bed furrow, T_5–Transplanting on ridges and furrows, and T_6–Transplanting on a flatbed. The size of BBF was 90 cm at the base and 60 cm at the top and ridges and furrows were opened at 30 cm. Under the line sowing treatment, spacing of 15 cm × 10 cm was maintained on flatbed and also in ridges and furrows treatment, while for broad bed furrow treatment, the spacing of 10 cm × 10 cm was maintained.The soil of the experimental field was sandy loam in texture and low in available nitrogen (190.63 kg/ha), low in available phosphorus (12.80 kg/ha), high in available potassium (436.20 kg/ha), and moderately alkaline in reaction (pH 8.25).Transplanting was done later in the remaining land configuration treatments at a spacing of 15 cm × 10 cm. The recommended fertilizer dose used was 100:50:50 kg/haN, P_2O_5, K_2O, and the seed rate was 10 kg/ha.

3. Results and discussion

The transplanting on ridges and furrows recorded significantly higher plant height, a number of functional leaves per plant, and dry matterand neck thickness at harvest.Similarly, the maximum polar diameter, equatorial diameter, average bulb weight, bulb yield,and leaf yieldwere recorded on ridges and furrows, which wereat par with transplanting on a flatbed. The higher bulb yield on ridges and furrows and transplanting of onion seedlingsmight be because ridges and furrowsprovidecontinuous soil aeration, optimum moisture, and available nutrients throughout the crop growth period. Transplanting of seedlings facilitates the immediate absorption of moisture and nutrients. The combined effect of these factors helpsto enhanceall the growth and yield attributes,which resulted in increased bulb yield of onion. These results are in accordance with that of Kadari*et al.* (2019).

The highest gross returns and net monetary returns were recorded in transplanting on ridges and furrows. But the highest benefit:cost ratio was recorded with line sowing on broad bed furrow. The maximum reduction in the cost of cultivation was observed with line sowing on a flatbedwhile in respect of reduction in net monetary returns, it could be seen that minimum reduction in monetary gains was found with transplanting on a flatbed followed by line sowing on broad bed furrow. This might be due to a reduction in the cost of transplanting (Rs. 15,000/ha) where maximum manpower was required. Based on the reduction in the cost of cultivation and net monetary returns, the line sowing on broad bed furrow was found next best treatment after transplanting on ridge and furrow method. Therefore, under laborconstraint situations, the line sowing on broad bed furrow could be an alternative land configuration and the planting method for onion cultivation in the *Kharif*season. These results corroborate that of Kadari*et al.* (2019).

Table 1 Effect of land configuration on growth, yield, and economicsof onion

Treat-ment	Plant height (cm)	Number of leaves per plant	Average weight of bulbs (g)	Bulb yield(t/ha)	Leaves yield(t/ ha)	Cost of cultivation(Rs/ha)	Gross monetar-yreturns (Rs/ha)	Net monetary returns(Rs/ha)	B:Cratio	Reduction in cost ofcultivation over T_5 (Rs/ha)	Reduction in netmonetaryreturn over T_5(Rs/ha)
T_1	44.5	7.35	73.00	17.44	1.10	59819	139075	79256	2.32	17,710	37,100
T_2	48.0	7.74	74.46	19.00	1.14	56329	154400	98071	2.74	21,200	18,285
T_3	45.2	7.44	75.14	18.01	1.13	60819	143935	83116	2.37	16,710	33,240
T_4	49.1	7.79	76.51	19.98	1.15	57329	163450	106121	2.85	20,200	10,235
T_5	54.0	8.55	79.86	23.39	1.21	77529	193885	116356	2.50	–	–
T_6	52.2	8.39	76.68	22.20	1.18	76529	183345	106816	2.40	1000	9540
S.E (m)±	0.29	0.06	0.30	0.13	0.01	–	1071.40	1071.40	–	–	–
CD at 5%	0.88	0.20	0.91	0.41	0.03	–	3229.55	3229.55	–	–	–

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6.4 Bayesian Estimation for the Parameters of Predator-Prey Model Using Non-informative Prior

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Keywords: Loss functions; Metropolis-Hastings algorithm; Predator-prey models; Real data analysis

1. Introduction

In population ecology, parameter estimation for the functional response of predators to prey quantity is a critical methodological problem in the classical and Bayesian paradigms (Gilioli *et al*. 2008). For predator-prey, we have used the mixture of the logistic growth model and the Lotka-Volterra model (Lotka, 1920;Volterra, 1926).Here, we propose Bayes estimators for the parametersof the predator-prey model using non-informative prior. The Bayes estimators of the parameters are obtained under different loss functions. The efficiency of the proposed estimators isobtained and compared with existing estimators based on simulated risk, and their applicability is shown through a real data set. We have done the simulation study using R software.

2. Materials and methods

Our goal in this article is to go over some of the most frequent models for describing the growth of a single species. The goal is to look at how the models behave over time as the population grows. There are two elements of these models that are of particular importance. The first is growing pace and the second is reaching a steady state (equilibrium). There may be no such equilibrium in some models, while there may be several equilibria in others. The population size at which the growth rate is zero is known as equilibrium. A stable equilibrium occurs when the system returns to a steady state after a little deviation from the equilibrium. Otherwise, it is referred to as unsteady.The logistic predator-prey model is represented by the following equation:

$$\frac{dP}{dt} = rP\left(1 - \frac{P}{K}\right) - c_1PN,$$
$$\frac{dN}{dt} = (c_2NP - dN),$$

where P is prey population, N is predator population, r is per capita growth rate of prey, d is the death rate of a predator, K is carrying capacity, and c_1 and c_2 are the interaction rate between prey and predator, respectively. Bayesian parameter estimation in coupled ordinary differential equations (ODEs) is challenging due to the high computational cost of numerical integration. In gradient matching a separate data,the model is introduced with the property that its gradient may be calculated easily. Parameter estimation is then achieved by requiring consistency between the gradients computed from the data model and those specified by the ODE. We propose a Gaussian process model that directly links state derivative information with system observations, simplifying previous approaches and improving estimation accuracy.

3. Results and discussion

Results based on the table that when the sample size of preys is fixed and the predator population increases, Bayesian estimates increase as well as the risk. Length of HPD credible interval increases. When there is variation in prey sample size, Bayesian estimates are increased but risk decreases. We have seen that the variation of prey and predator sample size then it will obtain the stationary situation which means both prey and predator survive together with time-series data. As the number of prey increases, there is more food available for the predators, thus allowing the predator population to increase as well. When the predator population grows to a threshold level, there is an increase in the killing of preys such that the prey population begins to decline.This is followed by a decline in the predator population owing to the scarcity of food. When the predator population is low, the prey population size begins to increase due, at least in part, to low predation pressure, starting the cycle again.In Table 1, we have considered the value of σ_x^2 and $\sigma_y^2$to be 0.09; for the further analytical study, we have chosen various moderate and highvalues. The validation and implication of ourresearch are based on the use of predator-prey models for ecological problems. This is very important to control and predictthe population equilibrium because forest loss and degradation are major issues faced inconservation throughout the world. It is a fascinating discipline because everyone is usually interested in knowing about theirsurroundings. The basic application of ourresearch is to attain an equilibrium situationfor predators and preyswith consideration of the time interval.

Table 1 Bayes estimate of parameters posterior mean, median,and mode with their risk and HPD credible interval (σ_x^2=0.09, r=1.8, c_1=0.2, K=120, c_2=0.1, d =0.8, σ_y^2=0.09)

X	Y	Parameter	Posterior mean	Posterior median	Posterior mode	HPD
50	10	σ_x^2	0.06226	0.05861	0.04219	(0.04002,0.09408)
		r	1.80085	1.80067	1.87709	(1.48977,2.11134)
		c_1	0.16791	0.15715	0.37827	(0.02108,0.33315)
		K	122.65118	122.65084	122.67814	(114.85378,130.47716)
		c_2	0.10815	0.10462	0.08548	(0.03633,0.19049)
		d	0.77879	0.77878	0.79752	(0.6613,0.89599)
		σ_y^2	0.0783	0.07214	0.05004	(0.04711,0.12658)
	20	σ_x^2	0.06561	0.06057	0.04218	(0.03974,0.10537)
		r	1.81774	1.81804	2.01364	(1.46524,2.16976)
		c_1	0.18098	0.16815	0.43289	(0.01811,0.3656)
		K	119.12336	119.21834	119.08505	(111.57478,126.70548)
		c_2	0.11509	0.10956	0.14357	(0.03422,0.20701)
		d	0.78459	0.78454	0.81492	(0.64085,0.92825)
		σ_y^2	0.08562	0.07619	0.05049	(0.04715,0.15189)

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X	Y	Parameter	Posterior mean	Posterior median	Posterior mode	HPD
	30	σ_x^2	0.06985	0.06288	0.04223	(0.03957,0.12036)
		r	1.81165	1.81157	2.02014	(1.40321,2.2222)
		c_1	0.20228	0.18708	0.49093	(0.01837,0.41299)
		K	120.49482	120.49564	120.48626	(110.12416,130.85354)
		c_2	0.12483	0.11773	0.21612	(0.02772,0.23379)
		d	0.79187	0.79181	0.85016	(0.61846,0.96573)
		σ_y^2	0.09271	0.07958	0.05052	(0.04719,0.17894)

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6.5 Role of Agroforestry Practices in Biodiversity Conservation and Meeting Rural Needs

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1. Introduction

Agroforestry (AF) is a land use system that provides a sound ecological basis for increasing crop productivity, more dependable economic returns, and greater diversity (Amatya *et al.*, 2018; Salinas, 2016). AF in Nepal is important because of its potential for the production of food, fodder, wood, and minor forest products that can generate income for the poor people and for its value in environmental conservation (Amatya *et al.*, 2018).

2. Materials and methods

The study was carried out in MakawanpurGadi rural municipality of Makawanpur district, Nepal. The major objectives of the study wereto assess the status of farm tree diversity, determine the most preferred AF tree species, and analyze the contribution of existing AF practices in meeting rural needs. On-field visits, key informant interviews, questionnaire surveyswith schedule, and group discussions were used for data collection. Shannon-Wiener Diversity Index (SWDI) was used to assess the status of farm tree diversity, and Likert scale was used to analyze the perception of local farmers about the contribution of AF in meeting rural needs.

3. Results and discussion

A total of 119 numbers of plant species were found in the study area. Both the species richness and evenness werehigher in Bari land than in Khet.Annual consumption of forages by livestock was high, whereas medicinal plantconsumption was very low compared to other forest products. At the household level, the contribution of fodder, fruit, fuelwood, and medicinal plants was found satisfactory, for which AF practices were the prime sources. Participatory multiple use criteria wereused for the selection of the most preferred farm tree species. *Leucaenaleucocephala*, *Ficuslacor*, *Artocarpuslakoocha*, *Litseamonopetala*, and *Meliaazedarach* were the five most preferred agroforestry tree species in the study area.

Table 1 Ranking of AF tree species in the study area

Description	Species									
Response frequency (Rj)	64	45	74	28	21	8	15	13	35	8
Sum of ranks (Tj)	204	147	257	94	60	22	45	29	88	21
Square of Sum of ranks (Tj)²	41,616	21,609	66,049	8836	3600	484	2045	841	7741	441
Sums of the square of ranks (ΣRj²)	752	542	995	378	220	69	175	93	270	124
Mean of ranks	2.46	1.77	3.09	1.13	0.72	0.26	0.54	0.35	1.06	0.25
Final ranks	2	3	1	4	6	10	7	8	5	9

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6.6 Existing Agroforestry System and its Component in Reasi District of Jammu and Kashmir

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Keywords: Agroforestry; Horticultural trees; Intermediate zone; Multipurpose trees

1. Introduction

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals in some form of spatial or temporal arrangement. In agroforestry systems, there are both ecological and economical interactions between different components (Lundgren and Raintree, 1982). Agroforestry plays a vital role in the development of the Indian economy through tangible and intangible benefits. The trees on the bunds of the agricultural field are farmer friendly and compatible. The selection of intercrops depends mainly on climatic conditions of the area, resource availability, and farmers' need (Saroj and Dadhwal, 1997).

2. Materials and methods

The study was conducted in the Reasi district of Jammu and Kashmir (J&K). The district lies between 33°09'N and 74°84'E, having a geographical area of 1719 km^2. The area has been divided into three main agroclimatic zones, that is, subtropical zone (300–1200 m), intermediate zone (1200–2000 m), and temperate zone (2000–2800 m), depending on the topography, altitude, and temperature condition. A total of six villages, namely, Kanjali, Bhabbar, Salal, Arnas, Mala, and Mahore, were included in the present study. They are situated in four developmental blocks: Katra, Reasi, Arnas, and Mahore. For the altitudinal study, two villages in each agroclimatic zones were selected to collect the data. Field surveys were conducted in Kanjali, Bhabbar, Salal, Arnas, Mala, and Mahore in February 2022. The desired details such as the name of the village, altitude, existing agroforestry system, tree species, and crops were also recorded. In each village, 10 sample plots of 10 × 10 m^2 were marked randomly for detailed study in the agroforestry field.

3. Results and discussion

Results of the study indicate that the proportion of forest trees, fruit trees, and crops was found to be 41.86%, 30.23%, and 27.90%, respectively. A total of 18 forest tree species, 13 fruit tree species, and 12 field crops were recorded in the study area. At lower Himalayan altitude, forest tree species such as babul (*Acacia nilotica*), siris (*Albizia lebbeck*), dhaman (*Grewia optiva*), kalal (*Bauhinia variegata*), beri (*Ziziphus mauritiana*), taali (*Dalbergia sissoo*), bamboo (*Dendrocalamus strictus*), dhrenk (*Melia azedarach*), toot (*Morus alba*), tunu (*Toona ciliata*), and lasinia (*Leucaena leucocephala*) were common along 300–1200 m. Willow (*Salix alba*), black locust (*Robinia pseudoacacia*), Himalayan alder (*Alnus nepalensis*), honeyberry (*Celtis australis*), siri (*A. lebbeck*), dhaman (*G. optiva*), kalal (*B. variegata*), beri (*Z. mauritiana*), toot (*M. alba*), and fagori (*Ficus palmata*) were common in mid-Himalayan altitude along 1200–2000 m. In the high Himalayan range (2000–2800 m), species such as white willow (*S. alba)*, black locust (*R. pseudoacacia*), Himalayan alder (*A. nepalensis*), banj oak (*Quercus leucotrichophora*), and Himalayan elm (*Ulmus wallichiana*) were common.

Fruit trees species such as pomegranate (*Punica granatum*), peach (*Prunus persica*), pear (*Pyrus pyrifolia*), orange (*Citrus sinensis),* mango (*Mangifera indica*), lemon (*C. limon)*, and loquat (*Eriobotrya japonica)* were common at lower Himalayan altitude along 300–1200 m. In mid-Himalayan range, orange (*C. sinensis),* mango (*M. indica*), pomegranate (*P. granatum*), peach (*P. persica*), pear (*P. pyrifolia*), loquat (*E. japonica),* and lemon (*C. limon)* were common along 1200–2000 m. Species such as walnut (*Juglans regia*), apricot (*P. armeniaca*), apple (*Malus pumila*), and plum (*P. domestica*) dominated the high Himalayan altitudes along 2000–2800 m.

Among field crops, paddy (*Oryza sativa*), mustard (*Brassica nigra*), black gram (*Vigna mungo*), chickpea (*Cicer arietinum*)*,* oat (*Avena sativa*), wheat (*Triticum aestivum*), maize (*Zea mays*), bajra (*Pennisetum glaucum*), and potato (*Solanum tuberosum*) were common crops, which were cultivated in the field of farmers along diverse altitudinal range.

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6.7 Diversity and Foraging Behavior of Pollinators on *Sesamum indicum* L. Flowers

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Keywords: Bombus; Diversity; Foraging; Megachilid; Sesamum

1. Introduction

Sesame (*S. indicum* L.) is a popular oilseed crop that has successfully signified its irreplaceable role in human nutrition. It contains zygomorphic flowers with pendulous tubular corolla which attracts many entomo-foragers to facilitate cross-pollination. It is evident from the studies conducted by Rakesh and Lenin (2000) that the rate of cross-pollination ranges between 0.5% and 65% and depends mainly on insect activity, environmental conditions, and the availability of other vegetation. In this context, the diversity of native foragers visiting the sesame flowers and their foraging behavior were recorded which may become instrumental in cross-pollination.

2. Materials and methods

In different farmers' fields across various landscapes such as plain areas (Dhiansar in Samba district), steep rainfed landscapes (Sunderbani area of Rajouri), and elevated rainfed areas (Bajalta area of Jammu), the present experiment was conducted from July to mid-September (2017 and 2018). Selected patches of *S. indicum* were monitored regularly during the peak flowering period (August–September) during the daytime at hourly intervals. Different insect foragers visiting sesame were collected with aerial nets and stored in insect vials. For visual observation, crops with a large number of freshly opened flowers were selected for recording foraging behavior and bouts of bees. The line transect method of sampling was administered wherein each line transect was approximately 30 m long. Three different pockets were selected for visual observation with a linear distance of 3 m within a field. Pollinator activity was monitored from morning to evening at an hourly interval based on snapshot observation of 5 minutes in each hour. Moreover, Shannon-Wiener diversity (*H*) and Simpson Index (*D*) were worked out to study the magnitude of pollinator diversity and species richness in the field. The data generated over 2 years were pooled for statistical analysis using SPSS 20.0 to compare differences in frequency of occurrence and the most dominant insect pollinator of this crop.

3. Results and discussion

A total of 17 pollinator species from three families (Apidae, Megachilidae, Halictidae) visiting *S. indicum* flowers were recorded. In all study areas, two bumblebee species (*Bombus haemorrhoidalis* and *B. trifasciatus*) were recorded as prominent pollinators along with six megachilid bee species, three honey bee species, and two Halictidae species (Table 1). Diurnal visitation pattern of insect foragers revealed peak activity time during forenoon between 10.00 and 12.00 noon (Figure 1). Spatial distribution among various solitary bee foragers of sesame revealed that megachilid and halictid bees visited sesame flowers in high altitude subtemperate areas of Sunderbani, in the elevated landscape of Bazalta, and plains of Jammu district. *Amegilla* spp. and *Bombus* spp. were found visiting these flowers in almost all landscapes, whereas *Xylocopa* spp. was mostly found in plain areas of Jammu. Moreover, large-bodied megachilid bees were found to enter the flower and use their mandible to hold petals after they landed on the flower to collect nectar and pollen. However, large- to medium-bodied *Apis* spp. (*Xylocopa* spp., *Amegilla* spp., etc.) were found to spend less time, but they also showed a peculiar behavior of nectar robbing by puncturing at the base without entering flowers. Species diversity as per Shannon-Wiener Diversity and Simpson Index was calculated as H = 2.74 and D = 1.42, respectively, indicating high species richness among various pollinator families. The abundance of foragers showed a polynomial distribution pattern indicating an almost even distribution of insects among various solitary bee groups with the domination of a few groups in terms of flower visitation. The average length of foraging bout was found higher in megachilids and bumblebees, whereas in other cases moderate foraging bouts were recorded. Apart from these, the maximum diversity was recorded from the elevated landscape (Bazalta), which was a relatively less disturbed habitat than the Dhiansar plain area (disturbed habitat). Moreover, sesame is mainly propagated by the broadcasting method on elevated and intermediate landscapes wherein proper line sowing can be advocated to optimize the plant population exposed for cross-pollination mediated by native pollinators. Further, many new species of native pollinators foraging on sesame flowers were recorded for the first time from the Jammu region which may be conserved by providing the different stem cuttings for the provision of nesting sites to the native pollinators.

Table 1 List of insect visitors recorded from sesame flowers from various landscapes in Jammu

Insect morphospecies	Family	Landscape type		
		High altitude subtemperate zone	Elevated land	Plain
		+	+	+
A. confusa Smith	Apidae	–	+	+
X. fenestrata Drury	-do-	–	+	+
X. pubescens Spinola	-do-	–	+	+
B. haemorrhoidalis Smith	-do-	+	+	+
B. trifasciatus Smith	-do-	+	+	-
A. dorsata Fab.	-do-	–	+	+
A. mellifera	-do-	–	+	+
A. indica	-do-	–	+	+
Nomia iridiscens Smith	Halictidae	+	+	+
N. curvipes Fab.	-do-	+	+	+
Megachile bicolour Fab.	Megachilidae	+	+	+
M. hera Bing.	-do-	+	+	+
M. lanata Fab.	-do-	+	+	+
M. disjuncta Fab.	- do -	+	+	+
M. carbonaria Smith	-do-	+	+	-
M. anthracina Smith	- do -	+	+	-

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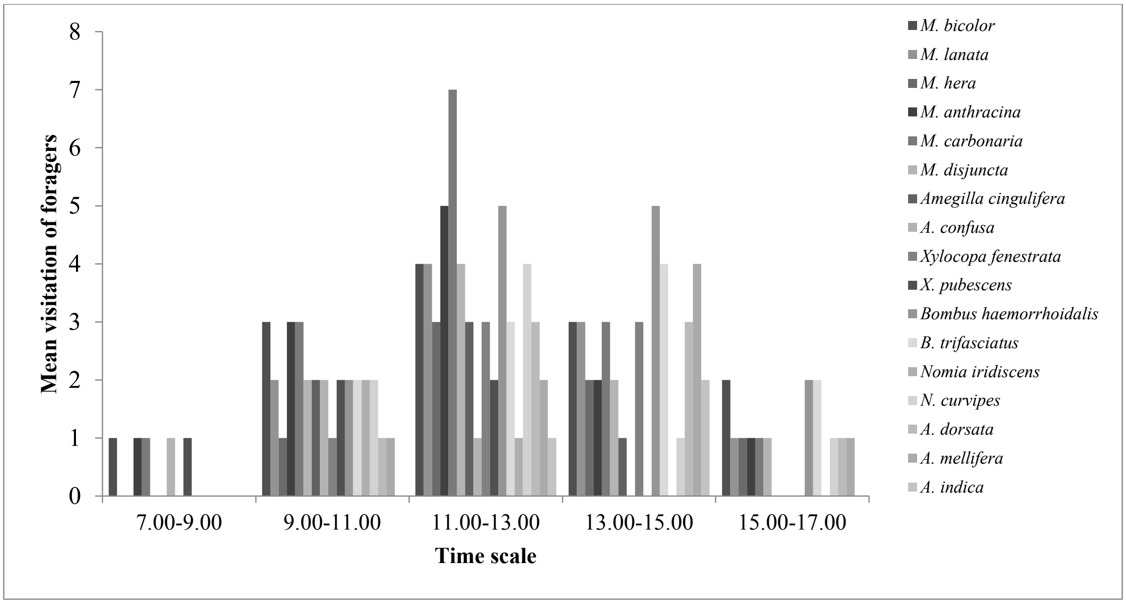

Figure 1 Diurnal flower visitation pattern of various solitary bees on sesame in Jammu

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6.8 Enhancement of Germination in *Berberis lycium* Royle by Different Pre-sowing Seed Treatments

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Keywords: *B. lycium*; Dormancy; Growth regulators; Stratification

1. Introduction

According to IUCN, *B. lycium* Royle (Kashmal) is having a vulnerable status of conservation (Waseem *et al.*, 2006). Fruits of this plant are very nutritious and a rich source of vitamins, minerals, antioxidants, anthocyanins, and so on. Further, the seeds have cancer-suppressing properties (Sood *et al.*, 2013). It is utilized as fuelwood species due to its high calorific value. Berberine present in rhizomes has marked antibacterial effects. The natural regeneration in this species through seeds gives little success as the seeds show around 34.00% germination. The main reason for the lower germination is seed dormancy. Considering the importance of this vulnerable shrub species with poor propagation by sexual approaches, the present study was undertaken to evaluate the effect of different stratified temperatures, periods of stratification, and growth regulators on seed germination of *B. lycium* Royle.

2. Materials and methods

The present investigation was conducted in the laboratory at the Department of Silviculture and Agroforestry, Dr YSP UHF, Nauni, Solan (HP) during the year 2017-18. The freshly harvested seeds of *B. lycium* Royle were collected from the vicinity of Nauni in district Solan during the month of June 2017. The seeds were stratified with sand as a stratifying media. Stratification of seeds was done in perforated polythene bags in order to allow seed respiration. The seeds were kept moist during the entire stratification period. During November to December 2017, three seed lots were kept for stratification for 15 (P_1), 30 (P_2), and 45 (P_3) days. Stratification of seeds was carried out at four different temperatures, namely, T_1 (11–22°C), T_2 (+5°C), T_3 (0±1°C), and T_4 (–5°C). After stratification, the seeds were further treated with gibberellic acid at three different concentrations, that is, GA_3 (100, 200, 300 ppm), prior to sowing, and the untreated seed lot was used as control (G_1). The observation of germination percent (as per ISTA rules) recorded and data generated from the investigation were subjected to statistical analysis in accordance with the procedure suggested by Panse and Sukhatme (2000).

3. Results and discussion

The seed germination percent (70.00%) in *B. lycium* Royle was observed at maximum when the seeds were stratified at 0±1°C for 30 days combined with the application of 200 ppm gibberellin ($T_3P_2G_3$). Treatment of seeds with GA_3 enhanced the performance and germination because GA_3-treated seeds reduced the germination time, which could be due to the more rapid uptake of water in seeds treated with GA_3 than in the control. Seeds treated with GA_3 showed an increase in the germination rate due to the initiation of the early metabolic process in many plant species. GA_3 increases the growth potential of the embryo. During seed germination, embryonic GA_3 is released that triggers the weakness of the seed coat by stimulation of expression of many genes involved in cell expansion as reported in *Arabidopsis thaliana*. GA_3 has been reported to increase the percentage of seed germination. The enhanced seed germination in *B. lycium* observed under GA_3 seed treatment might be due to increased cell elongation and cell division activities along with a better supply of nutrients under the low temperature. Similar results about the effect of GA_3 have been reported in *Terminalia bellirica* and *Santalum album* seeds in which 200 ppm treatment with GA_3 was found to be more effective for enhanced seed germination.

Table 1 Effect of stratification temperature, stratification period, and gibberellic acid (T × P × G) on germination percent (%) of *B. lycium*

Gibberellic acid (conc. in ppm)	Interaction between T × P × G															
	T_1 (11–22°C)				T_2 (+5°C)				T_3 (0±1°C)				T_4 (–5°C)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Control	30.00 (33.15)	43.33 (41.15)	36.67 (37.21)	36.67 (37.17)	26.67 (31.06)	35.00 (36.36)	38.33 (38.23)	33.33 (35.18)	33.33 (35.20)	36.67 (37.24)	38.33 (38.21)	36.11 (36.89)	30.00 (33.15)	36.67 (37.21)	33.33 (35.10)	33.33 (35.15)
GA_3 100 ppm	36.67 (37.24)	33.33 (35.24)	45.00 (42.10)	38.33 (38.19)	46.67 (43.07)	38.33 (38.19)	36.67 (37.19)	36.67 (37.08)	36.11 (36.84)	30.00 (33.15)	43.33 (41.05)	33.33 (35.09)	36.67 (37.19)	33.33 (35.15)	38.33 (38.18)	36.11 (36.84)
GA_3 200 ppm	41.67 (40.18)	31.67 (34.17)	41.67 (40.18)	38.33 (38.18)	56.67 (48.82)	46.67 (43.06)	50.00 (44.98)	51.11 (45.62)	65.00 (53.74)	70.00 (56.82)	63.33 (52.72)	66.11 (54.43)	50.00 (44.98)	41.67 (40.18)	66.67 (54.81)	52.78 (46.66)
GA_3 300 ppm	31.67 (34.22)	33.33 (35.20)	38.33 (38.23)	34.44 (35.88)	48.33 (44.03)	43.33 (41.14)	46.67 (43.03)	46.11 (42.73)	51.67 (45.95)	55.00 (47.86)	65.00 (53.74)	57.22 (49.18)	30.00 (33.15)	33.33 (35.20)	55.00 (47.86)	39.44 (38.74)
Mean	35.00 (36.20)	35.42 (36.44)	40.42 (39.43)		44.58 (41.74)	37.92 (37.86)	42.92 (40.86)		44.17 (41.49)	47.92 (43.77)	52.50 (46.43)		36.67 (37.12)	36.25 (36.94)	48.33 (43.99)	

Note: The values in parenthesis are transformed values (angular transformation).

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6.9 Understanding Climate Change Perception of Local Communities in Fozal Valley of Kullu District, Himachal Himalayas

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Keywords: Adaptation and mitigation; Climate change; Community Perception; Fozal valley

1. Introduction

The Himalayas and the people inhabiting Himalayas are perceived to be the most vulnerable to the impacts of global and regional climate change. Thus, assessing the local community's perception of climate change is critically important for designing adaptation and mitigation strategies. Climate change perception is determined by the social, cultural, economic, and institutional setup of the surrounding environment (Carr, 2008). Also, men and women perceive climate change challenges differently. In the Indian Himalayan Region, women are more dependent on natural resources and are firsthand affected by climate change challenges (Nellemann *et al*., 2011). Adzawla *et al*. (2019) also highlighted that climate change severely impacts women due to their low adaptive capacity. In the eastern Himalayas, women have admitted that climate change has negatively impacted the collection of forest foods, crop harvesting, fermenting, and food storage (Bhadwal *et al*., 2019). To understand this issue, this study aims to present the varied intergroup response of local communities with a focus on how women's response differs from men's response toward climate change and the various adaptation strategies suggested by the local communities.

2. Materials and methods

Household survey

We conducted household surveys in three different villages of Fozal valley, Kullu district – Himbari, Dhara, Runga, and Beasar. We collected information from 127 participants, 86 men and 89 women, using semi-structured questionnaires. According to the census 2011, 30% of total households were surveyed in each village. Different indicators were used for collecting information on socioeconomic status such as age, gender, education, income source, and perception of local communities; however, only 22 indicators through three responses, that is, Yes, No, Can't say, are discussed in this paper.

Analysis of socioeconomic data and response to climate change

The collected data were analyzed by calculating the percentage for each indicator. A mixed effect model was used to explore the possible impact of socioeconomic factors on climate change perception. A mixed effect model was used to identify the factors influencing the difference in perception of men and women toward climate change. A mixed effect model is a statistical model containing both fixed effects and random effects.

3. Results and discussion

The analysis reveals that a significant proportion of respondents are aware of biodiversity (74.2%) and forest types (54.85%) of their area and half of the respondents are experiencing climate change (56.57%) in the form of early flowering in agricultural and horticultural crops (65.14%), soil erosion or landslides (84%), and change in species richness of plants and animals (64%). More than half of the respondents have adopted new crops (66.28%). Although a few respondents admitted to commercially exploiting forest resources on smaller scales, a large portion of them expressed their willingness to participate in the conservation initiatives (80.57%). A significant difference is noted between men's and women's perceptions of climate change (Figure 1). More than 50% of the women population have perception scores in the range of 0 to –4 indicating a comparatively negative perception of climate change impacts. 40.38% of the total variance of the random effects is attributed to the nested effects (chi-square, X-squared = 47.005, p value = 9.422e-07). The communities reported that mainly developmental activities are responsible for climate change in their localities and there is also a decrease in agricultural and horticulture productivity due to climate change. The communities are experiencing changes in temperature and precipitation patterns at the local scale. It is also found that farmers are shifting toward high-yielding varieties and cash crops from traditionally grown crops. The observations are indicative of the changing local climate conditions in the mountains and highlight the importance of designing a better adaptive mechanism for mountain ecosystems to cope with climate change.

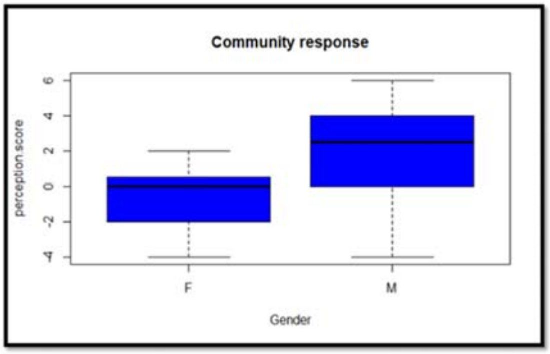

Figure 1 Perception of climate change from a gender perspective

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6.10 Response of 25 Economic Tree Species to Extremely Severe Cyclonic Storm *Fani* in Selected Coastal Districts of Odisha

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Keywords: Cyclone; Fani; Pole; Sapling; Seedling; Storm; Tree

1. Introduction

As a result of global warming and climate change in recent years, the frequency and intensity of tropical cyclones are increasing in some areas. The east coast of India is one of the six most cyclone-prone areas in the world. In the last century, the Indian subcontinent has experienced 1019 cyclonic disturbances, of which 890 were along the eastern coast and 129 were along the western coast and 260 cyclonic disturbances had their landfall, especially along the Odisha coast. On the Odisha coast, the revisit or recurrence time of a severe storm is around 4 years and the revisit time of cyclones is nearly 2 years, which is much shorter than that of the other states indicating that Odisha is the most frequently cyclone affected coastal state in India (Govt of Odisha, 2019). The Extremely Severe Cyclonic Storm 'Fani' made its landfall on 3rd May near Puri (Odisha) at about 8.30 a.m. and passed over Puri, Khordha, Cuttack, Jagatsinghpur, Kendrapara, Jajpur, Bhadrak, Balasore, and Mayurbhanj districts of Odisha and then moved into West Bengal by the early morning of 4th May.

2. Materials and methods

An investigation was carried out to assess the response of 25 economic tree species to Extremely Severe Cyclonic Storm *Fani* with a maximum sustained surface wind speed of 170–180 kmph gusting to 250 kmph. The study was carried out in the four most affected districts of Odisha, namely, Puri, Khordha, Cuttack, and Jagatsinghpur, which cover about 11,983 km^2 geographical area. Each species was assessed in its four stages of growth, that is, tree, pole, sapling, and seedling stage. The mean of the total score of damage was compared both stage-wise and species-wise by using ANOVA for split plot design considering four stages of growth as main plot units, 25 tree species as subplot units, and four districts as four replications. The study area experiences a tropical hot and humid climate with an annual rainfall of about 1500 mm. The plants uprooted, trunk snapped, branch broken, bent, and leaf stripped/dried were scored as 100, 80, 60, 40, and 20 points, respectively, and the damage score was calculated by the formula: percent of plant damaged × respective score (Bhol and Sinha, 2006).

3. Results and discussion

There was a significant difference in the response of trees to the Extremely Severe Cyclonic Storm *Fani* with regard to damage. *Borassus flabellifer* (palmyra palm) resisted the most exhibiting the least damage with a damage score of 18.2 in the tree stage and 2.4 in the pole stage only. Its average damage score of four stages of growth (tree, pole, sapling, and seedling) was 5.15 (Table 1). On the other hand, *Moringa oleifera* (drumstick) recorded the highest score of damage (81.2 in tree, 70.8 in pole, 32.0 in sapling, and 10.8 in seedling stage) with an average score of 48.72 in the four stages of growth. The total score of damage was highest in the tree stage (53.01), followed by the pole stage (33.61), sapling stage (12.67), and seedling stage (2.54).

Table 1 Total score of damage of different economic tree species by *Fani* at different stages of plant growth

Tree species	Common name	Total score of damage (points) at different stages of growth				
		Tree	Pole	Sapling	Seedling	Mean
Acacia auriculiformis	Australian wattle	59.20	38.80	12.80	1.20	28.00
A. mangium	Mangium	76.00	57.00	17.20	2.40	38.15
Aegle marmelos	Bael	34.80	19.40	7.20	2.80	16.05
Anacardium occidentale	Cashew nut	65.60	44.80	25.20	3.20	34.70
Anogeissus acuminata	Button tree	54.00	39.20	22.80	2.40	29.60
Anthocephalus cadamba	Kadam	78.40	57.80	7.20	3.60	36.75
Areca catechu	Areca nut	29.20	5.40	0.00	0.00	8.65
Artocarpus heterophyllus	Jack tree	42.80	25.20	7.80	3.20	19.75
Azadirachta indica	Neem	27.00	13.40	9.40	2.40	13.05
B. flabellifer	Palmyra palm	18.20	2.40	0.00	0.00	5.15
Calophyllum inophyllum	Alexandrian laurel	51.80	27.60	12.40	1.60	23.35
Casuarina equisetifolia	Casuarina	72.40	54.40	10.00	3.60	35.10
Cocos nucifera	Coconut	27.00	4.80	0.00	0.00	7.95
Eucalyptus tereticornis	Blue gum	75.60	57.40	14.00	2.80	37.45
Leucaena leucocephala	Subabul	76.40	57.20	15.00	3.00	37.90
Mangifera indica	Mango	56.00	35.80	28.80	2.80	30.85
M. oleifera	Drumstick	81.30	70.80	32.00	10.80	48.72
Phoenix sylvestris	Sugar palm	21.60	3.20	0.00	0.00	6.20
Pongamia pinnata	Pongam tree	27.00	14.60	9.60	2.40	13.40
Psidium guajava	Guava	56.40	24.80	18.00	2.40	25.40
Samanea saman	Rain tree	71.00	50.40	11.20	2.80	33.85
Syzygium cumini	Jamun	56.80	39.60	27.40	2.80	31.65
Tamarindus indica	Tamarind	36.80	13.20	3.60	1.60	13.80
Tectona grandis	Teak	76.20	53.40	13.20	4.00	36.70
Terminalia arjuna	Arjun	53.80	29.60	12.00	1.60	24.25
Mean		53.01	33.61	12.67	2.54	25.46

$CD_{(0.05)}$ for species = 0.69; $CD_{(0.05)}$ for stages of growth=1.24; $CD_{(0.05)}$ for species × stages of growth= 1.39

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6.11 Effect of Pollarding on Branchwood Biomass and Fine Root Dynamics of *Melia composita*

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Keywords: Agroforestry; Branch wood biomass; *M. composita*; Root dynamics; Pollarding

1. Introduction

Shortage of wood due to a multitude of reasons has led to the introduction of trees on the farm. Trees on the farm (agroforestry) have played an important role in meeting the demand for wood during the last couple of decades mainly due to large-scale plantations of short rotation tree species such as eucalyptus and poplar. Recently, *M. composita* has become one of the popular agroforestry tree species among farmers in India due to its multiple uses. In order to integrate this species into farmer's fields, exhaustive research is required, especially regarding its management. Reliable information on the effect of tree management options like pollarding in *M. composita* on its vigor and biomass productivity is lacking. A study was therefore carried out to study the effect of pollarding on the production of small wood, leaf biomass, and the behavior of fine root dynamics of *M. composita*.

2. Materials and methods

An investigation was carried out in the experimental farm of the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha during the year 2021 with the objective of evaluating the effect of pollarding on branch wood biomass and fine root dynamics in *M. composita.* The experiment was laid out in a randomized block design with four treatments (T_0, T_1, T_2, and T_3) and seven replications. Four treatments included T_0 (unpollarded), T_1 (pollarded at age of 3 years), T_2 (repeat pollarding of T_1 trees after 2 years), and T_3 (pollarded at age of 5 years) and were carried out on *M. composita* planted at a spacing of 6 m × 4 m. Observations were recorded for diameter at breast height (DBH), tree height, number of shoots/sprouts per stump, fresh leaf biomass, fresh branch wood biomass, and root mass density. For measuring root mass density, tree roots were sampled with the help of cores at two soil depths, that is, 0–15 cm and 16–30 cm. The fine roots were extracted after passing the core through a sieve. Roots less than 2.0 mm were separated and oven dried at 70°C for 48 h. Root mass density was calculated by dividing the mass of dried roots in the core by the volume of the core.

3. Results and discussion

Different pollarding treatments showed a significant effect on diameter at breast height of *M. composita* (Table 1). A maximum diameter of 28.02 cm was found in T_0 (control). A decrease in DBH was recorded in all the pollarded trees as compared to the control (unpollarded). Similar results have been reported for various tree species such as *Leucaena*, *Populus*, *Platanus*, and *Prunus* following pollarding treatments (Lang *et al*., 2015). Tree height was maximum (18.22 m) in treatment T_0 (unpollarded) since it was not pollarded and as such had the maximum height compared to the rest of the treatments, which is obvious as heading back the main trunk at 1.5 m height restricted the tree height in all other treatments. Maximum (35.79) numbers of shoots were recorded again in the T_0 treatment (control), followed by T_1, T_3, and T_2 treatments. Maximum (367.40 kg) fresh branch wood biomass was recorded in T_0 (control), whereas maximum (154.25 kg) fresh leaf biomass was recorded in T_1. Branch wood biomass was higher in T_0 (unpollarded) since the tree canopy was not altered compared to all other treatments while higher leaf biomass was observed in T_1 (pollarded at age of 3 years) since it was pollarded once and had well-developed young branches. Lower root mass density was observed in pollarded treatments compared to control, indicating that altering the aboveground portion of the tree affects the fine roots in the top layer of soil. Similar results have been reported by many workers (Mclvor *et al*., 2020). Among all the pollarded treatments, T_1, T_2, and T_3 higher values for all the growth parameters were observed in T_1 because it was pollarded once and had a growth period of 2 years after pollarding.

Table 1 Effect of different pollarding treatments on growth parameters of *M. composita*

Treatments	DBH (cm)	Height	No. of shoots	Branch wood biomass (kg)	Leaf biomass (kg)	Root mass density (kg/m^3)
T_0	28.02	18.22	35.79	367.40	125.02	2.71
T_1	24.27	14.08	34.89	237.70	154.25	2.65
T_2	22.51	7.00	30.93	33.59	14.44	2.45
T_3	23.04	9.17	32.52	34.74	19.27	2.57
C.D.$_{(0.05)}$	1.97	0.45	2.87	4.67	2.71	0.17

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6.12 Variability Estimates for Growth Performance in *Salix* Clones Under Salt Stress

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Keywords: Biomass; Growth; Physiology; Salix; Salinity; Variability

1. Introduction

Salinity is one of the major abiotic stresses posing a serious challenge to modern agriculture. In India, about 6.73 million ha area is affected by salinity, which has been estimated to reach 20 million ha by 2050. In Punjab, about 6.4% of the total geographical area is affected by salinity. *Salix* spp. are of multiple utilities and hold immense potential for phytoremediation of sewage and polluted water. In genus *Salix*, species as well as clonal variation in response to salt tolerance has been reported to range from sensitive to highly tolerant. Therefore, the evaluation of genetic variability for various morpho-physiological traits among *Salix* clones in response to salinity stress is highly desirable for the selection of a suitable clone/genotype for salt tolerance.

2. Materials and methods

The experiment was carried out in the teaching area, Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, Punjab during the year, 2021. The experimental material included five selected clones of the genus *Salix* (PN 731, UHFS 141, UHFS 119, UHFS 85, and UHFS 111) developed in the Department of Tree Improvement and Genetic Resources, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Stem cuttings of selected *Salix* clones were established in a pot experiment in the month of February, arranged in factorial completely randomized design (CRD) using three replications, and were irrigated with 0, 20, 40, 60, 80 mM NaCl treatments for the active growth period. The observations on growth and physiological characteristics of clones were recorded at an interval of two months after initiation of salinity treatments, that is, May, July, and October. However, the biomass parameters were recorded at the end of experiment. The data obtained on growth, biomass, and physiological characters were subjected to statistical analysis as per the factorial completely randomized design (CRD) using R software developed by R Core Team (2020).

3. Results and discussion

All the growth and biomass parameters showed a broad range of values with significant reduction with an increase in salinity treatments. Among physiological traits, significant reductions were observed in total chlorophyll, carotenoids, total starch, and relative water content, while salinity stress raised the content of proline, total soluble sugar, total soluble protein, total phenol, electrolyte leakage, and Na^+/K^+ ratio in all the clones.

Table 1 Variability estimates and genetic parameters for growth and physiological traits of *Salix* clones

Parameter	Mean	Range	Coefficient of variation (%)		h^2_{bs} (%)	Genetic advance	Genetic gain (%)
			Genotypic	Phenotypic			
Plant height (cm)	80.78	43.75-115.0	17.31	26.71	42.02	18.67	23.11
Collar diameter (mm)	6.83	5.72–7.94	6.868	10.38	43.73	0.638	9.34
No. of leaves per plant	96.26	41.25–149.0	20.53	32.63	39.57	25.61	26.60
No. of branches per plant	2.91	1.75–3.50	15.24	32.82	21.57	0.424	14.57
Root length(cm)	56.23	30.50–108.5	11.13	16.70	44.40	8.590	15.28
Fresh shoot weight (g)	62.90	19.85–114.4	17.92	25.07	51.13	16.61	26.41
Fresh root weight (g)	40.21	15.02–71.15	24.36	30.39	64.28	16.18	40.24
Dry shoot weight (g)	33.08	10.00–62.05	16.39	24.96	43.13	7.33	22.16
Dry root weight (g)	20.42	8.25–36.25	22.82	28.39	64.61	7.71	37.76
Total chlorophyll (mg/g FW)	1.38	0.71–2.74	18.35	31.51	33.90	0.305	22.10
Carotenoid (mg/g FW)	0.07	0.04–0.12	10.92	23.53	21.56	0.007	10.01
Total phenol (mg/g DW)	19.73	5.55–40.62	1.084	14.51	13.21	0.779	3.95
Proline (µmol/g FW)	0.93	0.24–2.01	41.33	53.67	59.30	0.611	65.70
Total soluble sugar (mg/g DW)	23.53	13.80–27.62	5.505	10.97	25.16	1.338	5.69
Total soluble protein (mg/g DW)	2.16	1.72–2.48	4.082	5.428	56.57	0.136	6.30
Relative water content (%)	35.58	18.10–60.05	18.53	19.32	91.95	13.03	36.62
Electrolyte leakage (%)	23.39	12.42–35.26	8.450	12.67	44.42	2.713	11.60
Total Starch (mg/g DW)	19.04	9.87–31.64	10.21	12.83	63.32	3.187	16.74
Na^+/K^+	0.81	0.23–1.98	16.76	30.88	29.47	0.151	18.64
POD	5.42	1.97–9.10	19.16	20.61	86.40	1.98	36.53
SOD	9.67	4.91–15.34	14.87	19.80	56.39	2.22	22.96

The mean values of 80.78 cm (plant height), 6.83 mm (collar diameter), 96.26 (number of leaves per plant), 2.91 (number of branches per plant), 56.23 cm (root length), 62.90 g (fresh shoot weight), 40.21 g (fresh root weight), 33.08 g (dry shoot weight), and 20.42 g (dry root weight) were recorded for growth and biomass parameters. Similarly, mean values of 1.38 mg/g FW (total chlorophyll), 0.07 mg/g FW (carotenoid), 19.73 mg/g DW (total phenol), 0.93 µmol/g FW (proline), 23.53 mg/g DW (total soluble sugar), 2.16 mg/g DW (total soluble protein), 35.58% (relative water

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content), 23.39% (electrolyte leakage), 19.04 mg/g DW (total starch), 0.81 (Na^+/K^+ ratio), 5.42 min^{-1} mg^{-1} protein (POD), and 9.67 min^{-1} mg^{-1} protein (SOD) were recorded for various physiological traits.

The highest value for GCV and PCV were observed in proline (41.33%, 53.67%, respectively) followed by fresh root weight (24.36%, 30.39%, respectively), dry root weight (22.82%, 28.39%, respectively), and the number of leaves per plant (20.53%, 32.63%, respectively). High heritability (broad sense) and genetic gain were recorded in relative water content (91.95, 36.62, respectively), POD (86.40, 36.53, respectively), dry root weight (64.61, 37.76, respectively), fresh shoot weight (64.28%, 40.24%, respectively), and proline (59.30, 65.70, respectively), and thus these traits must be given due importance while making the selection for salt tolerance in *Salix* species.

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6.13 Impact of Mulch on Growth, Yield, and Quality of Summer Squash under Climatic Conditions of Gurez Valley

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Keywords: Growth; Impact; Mulch; Squash; Yield

1. Introduction

Summer squash (*Cucurbita pepo* L.) locally known as 'chappankaddoo or valyatikaddoo' and belongs to the family Cucurbitaceae is a native of Mexico and the United States. In India, Uttar Pradesh, Punjab, and Haryana are the states where summer squash is considered among the most commonly consumed vegetable crops with cultivation limits extending to Himachal Pradesh, Jammu and Kashmir, and West Bengal. It is a tender, annual, warm-season vegetable crop that is harvested when fruits are immature and contains carbohydrates, fiber, potassium, vitamin B, and vitamin C, which make it higher in food value. India shares 14.78% production of squashes, pumpkins, and gourds in the world's total production and stands in the second position after China (22.83%) (Anonymous, 2016).

2. Materials and methods

A field experiment was conducted to study the 'Effect of mulch on growth, yield and quality of Summer Squash (*C. pepo* L.)'. The experimental trial was conducted during Kharif 2021-22 at the experimental farm of MAR&ES, Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir (SKUAST-K), Izmarg Gurez. The experiment consisted of six mulch treatments, namely, T_1 (control), T_2 (black mulch), T_3 (yellow mulch), T_4 (blue mulch), T_5 (transparent mulch), and T_6 (forest litter), with three replications, thus making the total of 18 treatment combinations. The experiment was conducted in a completely randomized block design. The experiment was laid in plots of 3 × 3 m during the first week of June. The seeds of summer squash were sown during the first week of May 2021 and plants were transplanted after one month of sowing (2–4-leaf stage). The seeds were procured from the Division of Vegetable Science, SKUAST-K. The land was prepared during mid-May and only organic manures (FYM) were given @25 t/ha at the time of land preparation. The data were recorded during the edible stage of squash (immature stage). A mulch of different colors was applied before transplanting the crop. All the parameters were taken using standard procedures. No chemical fertilizer was applied.

Table 1 Impact of mulch on growth attributes and yield-related parameters of summer squash

Treatment details	Plant height (cm)	No. of branches per plant	Plant spread (cm)	No. of fruits per plant	Fruit yield per plant (kg)	Fruit yield per hectare (q/ha)	Average fruit weight (kg)
T_1: Control (no mulch)	62.31	15.67	91.11	8.09	4.13	97.72	0.54
T_2: Black mulch	76.51	25.07	106.06	11.55	6.75	121.35	0.78
T_3: Yellow polythene	73.04	23.04	102.48	10.73	5.90	112.31	0.68
T_4: Blue polythene	74.38	22.18	100.22	9.77	5.70	107.97	0.64
T_5: White mulch	70.06	20.02	97.70	8.98	5.39	103.74	0.62
T_6: Forest litter	66.54	18.41	95.29	8.06	5.01	100.47	0.56
C.D ≤ 0.5	4.14	1.93	3.48	0.92	0.82	4.71	0.059

3. Results and discussion

From Table 1, it was observed during Kharif 2021 that treatment T_2 (black mulch) recorded maximum values of plant height (76.51 cm), number of branches/plant (25.07), plant spread (106.06 cm), average fruit weight (0.784 kg), number of fruits per plant (11.55), fruit yield per plant (6.75 kg), fruit yield per hectare (121.35 q/ha), among growth and yield parameters, whereas the values were statistically significant in case of the number of branches per plant, fruit yield per plant, fruit yield per hectare, and at par with treatments T_3 and T_4 in case of plant height and treatment T_3 in case of the number of fruits per plant. Similar results have been reported by other scientists (Kumar and Sharma, 2018).

Black plastic mulch is effective in increasing soil temperature (Mahadeen, 2014) and thereby improved the yield of summer squash by 74% over control and transparent mulch helps in soil solarization by increasing soil temperature that led to a yield gain of 25–28% in melon crop over control (Patil *et al*., 2013). Sunlight can pass through the transparent mulch, and so weeds can grow under them and need to be controlled by spraying suitable herbicides before applying mulching. It was found that the treatment T_2 (black mulch) showed maximum values with respect to vegetative and yield parameters. Thus it should be considered for further research because of its potential to increase sustainability and because it provides a critical and conceptually sophisticated understanding of biodiversity science within which management and policy decisions can be made.

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6.14 Effect of Canopy Management Practices on Growth Characteristics of *Melia composita*

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Keywords: Canopy management; Debranching; *M. composita*; Pollarding

1. Introduction

Owing to the increase in population, the demand for tree products is increasing rapidly in India. The forest-based industries in India have been hindered by a lack of long-term sustained wood supply, necessitating imports of timber, paper, pulp, and wood products from other countries. In order to produce more wood, many tree species, such as Poplar, Eucalyptus, Casuarina, and Bamboos, have been integrated into the agro-ecosystem. Of late, *M. composita* has also become one of the preferred tree species for plantations and agroforestry arrangements in the states of Punjab, Haryana, and Uttar Pradesh (Luna and Kumar, 2006). In order to make full use of this species in agroforestry, it is important to understand the tree growth characteristics as well as its ability to withstand canopy management practices. There have been scanty studies on the effect of management practices like pruning, lopping, and pollarding on the growth and development of *M. composita* under subtropical climates of north India.

2. Materials and methods

The research was conducted at the experimental farm, Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, located at 32^0-40′ N latitude and 74^0-58′ E longitude at 332 m above the mean sea level. The experimental field was divided into two blocks. Planting of *M. composita* was done in two blocks in July 2015 at a spacing of 6 m × 4 m in a randomized block design (RBD). Up to 6 months of planting, no tree management practice was imposed in the first block (BI). Unpollarded trees in the first block are referred to as control (T_0), whereas in the second block (BII), debranching was done by removing all the branches except the top four in all the saplings and is referred to as T_2. After a gap of 2 years in December 2017, marked trees were pollarded by cutting off the main stem at 3.50 m in height in both blocks. Treatment T_3 refers to the pollarded (T_1) trees in BI, whereas treatment T_4 refers to the pollarded (T_2) trees in BII. The objective was to quantify the effect of early debranching and pollarding on the growth characteristics of *M. composita*. The data were collected on various growth parameters, such as tree height, diameter at breast height (dbh), crown spread, number of branches per tree, and crown spread. Aboveground biomass of trees was estimated using a non-destructive method in July 2018 and 2019. The light transmission ratio (LTR) was recorded with a digital illuminance meter (Model: TES-1332A). Leaf chlorophyll was determined using a SPAD-502 plus chlorophyll meter. The data so obtained was statistically analyzed using the technique of analysis of variance (ANOVA) for randomized block design (RBD).

3. Results and discussion

Tree height was maximum (8.08 m) in T_1 in 2018, which was statistically at par with T_2 (7.98 m) but significantly different from T_3 (4.20 m) and T_4 (3.36 m). The tree height in T_3 (4.20 m) was higher than in T_4 (3.36 m) (Table 1). In the year 2019, the tree height in T_1 was maximum (11.80 m), which was statistically superior to T_2 (9.94 m), T3 (5.24 m), and T4 (4.28 m). The height in T_3 was statistically superior to T_4 in 2019 (Table 1). There was no significant effect of canopy management practices (pollarding) on dbh during both years. Crown spread was maximum (6.21 m) in T_1, which was statistically higher than that of T_2 (4.60 m), T_3 (0.87 m), and T_4 (0.68 m), respectively, in the year 2018 (Table 1). The crown spread in T_3 and T_4 was statistically at par in 2018. A similar trend was observed in 2019 (Table 1) where the maximum crown spread was recorded in T_1 (7.12 m), which was statistically higher than the remaining treatments. The crown spread in T_3 and T_4 was also statistically at par in 2019. The number of branches per tree also varied significantly with management practices (treatments) both in 2018 and 2019. In 2018, maximum (96.04 kg) aboveground biomass was recorded in treatment T_1 which was statistically at par (94.72 kg) with treatment T_2. In treatment T_3 (32.77 kg), aboveground biomass was recorded which was statistically at par (32.68 kg) with treatment T_4. During 2019, maximum (111.64 kg) aboveground biomass was recorded in treatment T_1 which was statistically at par (110.34 kg) with treatment T_2. In treatment T_3 (36.43 kg), aboveground biomass was statistically at par (35.33 kg) with treatment T_4 (Table 1). Comparatively higher aboveground biomass was recorded in T_0 and T_1 compared to T_2 and T_3 because a large portion of the tree trunk was removed in treatments T_2 and T_3 due to pollarding. The light transmission ratio of *M. composita* was significantly affected by different treatments during both years. The light transmission ratio was maximum (64.07 %) for treatment T_4 followed by treatment T_3 and T_2 with a mean value of 61.70% and 42.95%, respectively, and the minimum (29.37%) light transmission ratio was recorded in treatment T_1 (Table 1). In 2019, the light transmission ratio was maximum (76.73%) for treatment T_3, which was followed by treatment T_4 (55.36 %). The light transmission ratio in treatment T_2 (40.19 %) was statistically at par (26.82 %) with treatment T_1 (Table 1). Since the canopy was unaltered in T_0 and T_1, it did not allow the light to pass through it, resulting in lower values of LTR compared to pollarded treatments T_2 and T_3. The effect of different treatments on the leaf area of *M. composita* was statistically non-significant. Data in Table 1 show that in 2018 the maximum (60.80%) chlorophyll content was recorded in treatment T_1 followed by treatment T_2 and T_3 with a mean value of 57.94% and 56.71%, respectively, and the minimum (55.10%) chlorophyll content was recorded in treatment T_4. However, during 2019, no particular trend was observed (Table 1). The findings of the present investigations indicate that the effects of various treatments on physiological parameters like chlorophyll content and leaf area were found to be non-significant. However, debranched trees showed a minor decline in few of the growth characteristics. Thus, the current findings provide scope for new management options in *M. composita*.

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Table 1 Effect of canopy management on growth characteristics of *M. composita*

Treatments	Year 2018								Year 2019							
	Tree height (m)	Diameter at breast height (cm)	Crown spread (m)	Number of branches per tree	Aboveground biomass (kg tree^{-1})	Light transmission ratio (%)	Leaf area(cm^2)	Leaf chlorophyll content (%)	Tree height (m)	Diameter at breast height (cm)	Crown spread (m)	Number of branches per tree	Aboveground biomass (kg per tree)	Light transmission ratio (%)	Leaf area(cm^2)	Leaf chlorophyll content (%)
T_0	8.08	21.58	6.21	33.40	96.04	29.37	6.34	60.66	11.80	22.76	7.12	36.20	111.64	26.82	6.56	63.98
T_1	7.98	19.46	4.60	19.76	94.72	41.20	6.27	57.80	9.94	20.64	5.55	27.44	110.34	40.19	6.78	62.91
T_2	4.20	19.11	0.87	4.60	32.77	61.7	6.13	56.60	5.24	20.40	2.91	25.40	36.43	76.73	6.50	64.73
T_3	3.36	18.68	0.68	4.48	32.68	64.07	7.04	55.00	4.28	20.36	2.46	24.60	35.33	55.36	7.38	56.71
$CD_{0.05}$	0.74	N.S	0.34	13.98	4.47		NS	NS	0.51	N.S	0.44	5.49	6.18		NS	NS

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6.15 Constraints Faced by the Farmers in Kitchen Gardening in Jalandhar District, Punjab

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Keywords: Kitchen gardening; Problem; Vegetable growers

1. Introduction

Home gardens are broadly advanced in many countries as a mechanism to turn away neediness and as a source of income for subsistence families in developing countries, kitchen garden plays an important role for rural families to provide vegetables, fruits, and pulses in their daily diet. India is the second largest producer of fruits and vegetables in the world (Tuteja, 2011) but the intake of vegetables in our daily diet is low. At present, the per capita availability of vegetables in India is about 375 g, which is quite less compared to that prescribed by dieticians. The dietary requirement of the vegetable can be easily fulfilled through the concept of kitchen gardening as a vegetable can be easily raised on a small piece of land. Kitchen gardening provides fresh and organic vegetables and fruits that are more nutritious and have the presence of higher amounts of antioxidants. These antioxidants neutralize free radicals present in the body system and minimize the chances of the occurrence of degenerative diseases like cancer, arthritis, memory loss, and paralysis (Dhaliwal, 2017).Nutrient cycling is another ecological benefit of home gardens. The abundance of plant and animal litter and the continuous recycling of organic soil matter contributeto a highly efficient nutrient cycling system.

2. Materials and methods

The study was conducted in rural Punjab by taking just one district,that is, Jalandhar. A list of 348 trained respondents on kitchen gardening during the time of 2011–2015 was acquired from KVK, Jalandhar because Jalandhar provided trainings to the farmers formany years, so the farmers from the last five years (2011–2015) were selected for the study. Out of the obtained list, a sample of 200 respondents was selected using proportionate random sampling technique. The information was gathered with the assistance of individual meetings intended for the reason. A list of major constraints was prepared in consultation with extension scientists, available literature, field functionaries, and progressive vegetable growers. The information gathered during the time of inquiry was through open-ended questions asked by the trainers. The response of the respondents was analyzed with the help of appropriate statistical tools such as frequency, percentage, mean score, range method, and linear regression.

The majority of the respondents faced the problems of vegetables not growing properly during summer because of infestation by insect pests, diseases in the summer season due to high temperatures. The problem of frequent inundation of the kitchen garden during the rainy season was reported by 61.50 per cent and the problem of proper protection against grazing of local animals due to high cost for purchasing equipment for protection was reported by 62.50 per cent of the respondents. Almost half of the respondents (49.00%) faced insect pest problems, and around 20 % of them faced labour shortage frequently due to labor engaged in other field activities. More than one-third of the respondents (38.50%) lacked knowledge about the major pest and disease identification and their management. The study revealed that age, education, and experience of farmers contributed significantly at a 0.01 level of probability.

3. Results and discussion

The results of the study revealed that the respondents perceived a lot of constraints in practicing kitchen gardening.

Table 1 Distribution of the respondents according to the constraints faced by the farmers

(*n*=200)

Constraint	MPS
Lack of knowledge about the major insect pests and diseases identification and their management	38.50
Labor problem	20.00
Insect pest problem	49.00
Disease problem	27.00
Frequent inundation of kitchen garden during the rainy season	61.50
Vegetables don't grow properly during summer	73.50
Lack of knowledge about seed multiplication	1.00
The problem of protection against grazing of local animals	62.50
Seed availability	2.00
Costly seed	1.00
Fruit drop after fully developed	2.00
Investment is more but the output is less	1.00

Various suggestions for effective kitchen gardening in the study area were offered by the respondents. To make the kitchen garden more effective, the majority of the respondents suggested that vegetable seedlings should be provided by PAU/KVK because the seedlings purchased from private seed shops were at higher prices. Another suggestion of the respondents was to provide practical training. Along with creating awareness among farmers about kitchen gardening, seed kit should be provided at a nominal price.

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6.16 Diversity Assessment and Selection of Superior Walnut (*Juglans regia* L.) Genotypes from Seedling Origin Trees of North-Western Himalayas

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Keywords: Diversity; Frequency; Promising selection; Walnut

1. Introduction

The Persian walnut is one of the most important horticultural crops grown in India. In the current study, walnut germplasm from 10 different locations of the district Poonch, located in the northern part of India, was evaluated to determine the variability and identify promising types. The region has rich morphological, phenological, and carpological walnut diversity because of the large variability of native walnut, resulting from cross-pollination and seedling propagation. A total of 75 walnut genotypes were evaluated using phenological and pomological characteristics. Studying the growth, leaf, phenological, inflorescence, and fruit characteristics revealed high variability. Nut weight (NW) ranged from 8.20 to 25.60 g, whereas kernel weight (KW) varied from 4.80 to 14.50 g. In this study, we recorded kernel percentage in a broader range from 35.20% to 68.45% and shell thickness (ST) from 0.97 to 1.90 mm. The principal component analysis revealed that traits related to kernel weight, kernel percentage, nut weight, nut length, kernel length, and kernel width accounted for a large proportion of phenotypic variability. We identified one promising genotype, that is, SJPW-01, after considering the important traits in a selection index. The promising genotype will be further used in a breeding programme for the development of superior quality walnut varieties. Based on the observed variation, it is concluded that the magnitude of phenotypic variation in the population under study is high, and the implication of the results will play a vital role in future walnut breeding programmes.

2. Materials and methods

Germplasm collection was undertaken from 2015 to 2020 on 70 walnut genotypes. The areas of walnut germplasm collection included Mandi, Azmabad, Chakrada, Adai, Loran, Sabjian, Chella, Surankote, Buffliaz, and Lassana of the district Poonch of Jammu division of Jammu and Kashmir between an altitude of 33.38°N and longitude of 74.3°E. Topography is mostly hilly terrain along with gently undulating plains. The surveyed area is typically temperate and receives winter rains and snow and normal rainfall in monsoon. The highest day temperature in these areas during summer remains 7–27°C. The winters are very cool with an average temperature of –2°C to 1°C. The sampling method under natural variability was determined by germplasm collection through exploration. Trees were selected after evaluation based on regular fruit production according to interviews with walnut tree owners and observed phenotypic diversity. The selected trees were healthy, mature, and had a full crop. After a thorough screening, 70 walnut genotypes were identified and geo-referenced for a detailed study. Each tree was coded and assigned with SJPW (standing for SKUAST Jammu Poonch walnut). Sufficient nut samples of *J. regia* were collected and walnut trees were marked with white paint in order to acquire the bud/graft sticks for further multiplication. One-way analysis of variance (ANOVA) was conducted to detect significant differences in the mean morphological traits between the studied accessions by SPSS.

3. Results and discussion

Phenotypic traits are greatly important during the domestication and introduction of fruit species. Yield capacity is an important trait for economic walnut production. Productivity of walnut depends on flowering time and habit, fruit number on lateral and terminal shoots, lateral fruitfulness, nut and kernel weights, and kernel percentage (Hendricks *et al*., 1998). The data about the extent of variation among the selected walnut accessions for morphological characters are given in Table 1. There were significant differences for leafing and flowering dates among the studied accessions. Late leafing is an ideal character in walnut to escape the spring frost injury. The date of flowering ranged from 29 March to 6 April. The dichogamy was not all the same in the selected trees. But protandry was most common among the studied trees. Yield capacity is an important trait for economic walnut production. Among the 75 seedling accessions studied, yield varied from 35 to 150 kg per tree. Nut size was the determining factor for the market. Nut characters (Table 1) revealed a significant variation in nut length which varied from 25 to 47.63 mm, while the nut diameter varied from 23 to 48.50 mm, nut weight varied from 8.20 to 25.60 g, and shell thickness ranged from 0.97 to 1.90 mm. Kernel characteristics are a feature of great importance in superior walnut selections. Kernel characteristics (Table 1) also showed a significant variation among the selected walnut genotypes for a breeding programme. Breeding of new walnut cultivars is characterized by earlier fruiting, higher yield, lateral bearing, high adaptability to different ecological conditions, and high fruit quality (Akca and Ozongun, 2004).

Table 1 Characterization of nut and kernel characters during 2015–2022

Years	Nut weight (g)	Nut length (mm)	Nut diameter (mm)	Shell thickness (mm)	Yield (kg/tree)	Kernel %
2015	23.80	47.20	42.30	1.91	5.15	51.27
2016	23.35	47.10	42.15	1.92	12.25	51.40
2017	23.48	46.85	42.25	1.90	17.45	52.20
2018	24.10	47.25	42.45	1.91	27.13	52.15
2019	23.62	47.13	42.11	1.93	33.10	51.45
2020	23.38	46.98	42.17	1.90	40.35	51.55
CD (0.05%)	0.12	0.11	0.10	0.09	2.15	0.12

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6.17 Distribution of Termites and Their Associated Termitophiles in Himachal Pradesh

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Keywords: Distribution patterns; Himachal Pradesh; Termites; Termitophiles

1. Introduction

Termites are the most predominant and prevalent group of eusocial insects comprising about 3000 species under 330 genera (living as well as fossil) throughout the world (Krishna *et al*., 2013). However, in India, there are around 300 species under 52 genera known so far (Rajmohana and Rituparna, 2018). Termites are of immense ecological importance as silent soil engineers. The crucial role of improving soil fertility, enhancing soil water-holding capacity, and natural decomposers are a few of their attributes (Govorushko, 2019). In spite of their ecological services, around 12.4% of species of termites are among major pests in different crops and urban ecosystems causing an estimated loss of more than 40 billion USD annually to the global economy (Ahmad *et al*., 2021). Keeping in view the ecological and economic importance of termites, an extensive survey was conducted to determine their distribution pattern in Himachal Pradesh.

2. Materials and methods

To determine the distribution pattern of termites in Himachal Pradesh, an extensive survey was conducted at various habitats of termites in different agro-climatic zones of Himachal Pradesh from June 2020 to July 2022. The soldier and worker castes of different species of termites were collected and preserved in 80% ethanol. The termitophiles were collected from the mounds of *Odontotermes* sp. and preserved in the same way. The specimens of termites were identified based on soldier morphology according to the identification keys provided by Roonwal and Chhotani (1989) and Chhotani (1997). The generic identification of termitophiles was done with the help of Dr. Taisuke Kanao, Assistant Professor, Yamagata University, Japan. The distribution pattern of termites and termitophiles at the generic level was determined based on the identified specimens.

3. Results and discussion

A total of 10 genera, namely, *Archotermopsis*, *Neotermes*, *Stylotermes*, *Coptotermes*, *Heterotermes*, *Speculitermes*, *Amitermes*, *Angulitermes*, *Odontotermes*, and *Microtermes* belonging to five families were recorded during the present investigation (Table 1). Maximum diversity was recorded in Zone II, where all 10 genera were present. In Zone I, seven genera were present and *Archotermopsis*, *Neotermes*, and *Stylotermes* were found to be absent. In Zone III and Zone IV, only one genus, that is, *Archotermopsis*, was recorded. Maximum diversity was recorded in the family Termitidae (five genera), followed by Rhinotermitidae (two genera). The family Archotermopsidae, Kalotermitidae, and Stylotermitidae were represented by a single genus each. *Archotermopsis*, *Neotermes*, and *Stylotermes* are one-piece feeders and confined to wood hosts with no soil association. The mounds of termites were found up to altitudes of 1300 m AMSL and most of the mounds belong to the genus *Odontotermes* sp. When mounds of *Odontotermes* sp. were opened for termitophile collection, these were identified as Cerylonid beetles, *Termitopisthes* sp. *Odontoxenus* sp., and Termitoxeniinae fly and were recorded from Zone I and II. The present record of different genera of termites is in conformity with those of previous reports (Sharma *et al*., 2020). However, no records on termitophiles are available from Himachal Pradesh.

Table 1 Distribution of termites in agro-climatic zones of Himachal Pradesh

S.No.	Genus	Family	Host recorded	Distribution
Termites				
1.	*Archotermopsis*	Archotermopsidae	Decomposed wood of *Cedrus deodara* and *Pinus wallichiana*	Zone II, III, IV
2.	*Neotermes*	Kalotermitidae	*Albizia chinensis*	Zone II
3.	*Stylotermes*	Stylotermitidae	*Alnus nitida*	Zone II
4.	*Coptotermes*	Rhinotermitidae	Deadwood (polyphagous),	Zone I, II
5.	*Heterotermes*		Deadwood (polyphagous), household structures	Zone I, II
6.	*Speculitermes*	Termitidae	Soil	Zone I, II
7.	*Amitermes*		Grass roots, deadwood	Zone I, II
8.	*Angulitermes*		Soil	Zone I, II
9.	*Odontotermes*		Deadwood (polyphagous), household structures	Zone I, II
10.	*Microtermes*		Deadwood (polyphagous)	Zone I, II
Termitophiles in mounds of *Odontotermes* sp.				
1.	Cerylonid beetles	*Cerylonidae*		Zone I, II
2.	*Termitopisthes*	Scarabaeidae		Zone I, II
3.	*Odontoxenus*	Staphylinidae		Zone I, II
4.	Termitoxeniinae fly	Phoridae: Termitoxeniinae		Zone I, II

Zone I: up to 914 m AMSL, Zone II: 915–1523 m AMSL, Zone III: 1524–2472 m AMSL, and Zone IV: above 2472 m AMSL.

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6.18 Status and Problems of Paddy Straw Management in Punjab

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Keywords: Machinery; Management; Paddy straw; Techniques; Wages

1. Introduction

In Punjab, about 220 lakh tons of paddy straw are produced annually and a large portion of the straw is burnt by the farmers. The straw contains a significant amount of essential plant nutrients. One ton of paddy burning causes a loss of 400 kg of organic carbon, 5.5 kg of N, 2.3 kg of P, 25 kg of K, and 1.2 kg of S. Nitrogen and sulfur are completely destroyed through the burning of leftover (Anonymous, 2022). A big challenge is how to dispose of such a large volume of residues. More agricultural biomass will be produced as a result of the need to increase agricultural production due to the growing population. Crop residue is a significant renewable resource and a crucial part of the stability of the global agricultural landscape's ecosystem (Jain *et al*., 2014).

2. Materials and methods

Paddy straw management is a big problem for Punjab farmers. The adoption of the alternatives available for the burning of paddy straw management is at a slow rate. This study will analyze the problems faced by paddy growers of Punjab while adopting different alternatives to paddy straw management. This will further help the researchers and policy makers to know what kind of efforts are still needed to overcome these problems.

The present study was conducted in the Pathankot and Gurdaspur districts of Punjab. Two blocks from each district were selected randomly. From each block, 25 respondents were selected to make a sample size of 100 respondents for the study. A simple random technique was used for the selection of respondents (paddy growers). For the collection of primary data, interview schedule was prepared and the information regarding the status of farmers was collected. Also, the information concerning the problems faced by farmers regarding paddy straw management was collected from farmers using structured pre-tested interview schedule. The mean percent score method was used to analyze the problems faced by the respondents in paddy straw management.

Mean percent score (MPS)= Observed score÷Total score × 100

3. Results and discussion

Problems were analyzed by mean percent score (MPS) and on the basis of MPS ranks were assigned to the problems faced by the respondents in paddy straw management (Table 1). The transportation cost, labor wages, lack of machinery, and lack of agencies were ranked at the top by the respondents, followed by high volume, nonavailability of labor, less time period, lack of awareness, storage facilities, the problem of long stubble, and nematode problem. It was suggested by the paddy growers that to overcome these problems, more training programmes and awareness camps should be conducted by the concerned departments. The results for constraints of paddy straw management were previously reported by Jain and Sukhmani (2020) and Kaur (2017).

Data revealed that 70% of the respondents prefer to burn paddy straw and 35% of the respondents incorporate paddy straw into the field. The reason behind the task is the high cost involved in removing the straw from the field after harvesting. Secondly, the shortage of labor and the unavailability of machinery for the straw management compel the respondents for disposing it. About 57% of the respondents never used happy seeder due to the lack of knowledge and the expensive cost of the machinery. It was found that 80% of the farmers sell half or some portion of paddy straw from their field and in the other category 20% of the farmers do not sell paddy straw due to the lack of buyers around them.

Table 1 Problems faced by the respondent in paddy straw management

Problems	Level of seriousness			Total score	Mean score	MPS	Rank
	MS	NS	S				
Problem of long stubble	40	10	50	190	1.9	63.33	VII
Lack of awareness	62	8	30	232	2.32	77.33	V
Transportation cost	100	0	0	300	3	100	I
Labor wages	100	0	0	300	3	100	I
High volume	92	2	6	286	2.86	95.33	II
Lack of machinery	100	0	0	300	3	100	1
Nonavailability of labor	88	4	8	280	2.8	93.33	III
Lack of agencies	100	0	0	300	3	100	I
Less time period	80	8	12	268	2.68	89.33	IV
Nematode problem	24	10	66	158	1.58	52.66	VIII
Storage facility	54	12	34	220	2.2	73.33	VI
Non-affordability of machinery by small farmers	100	0	0	300	3	100	I

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6.19 Economic and Rural Prosperity of Jammu and Kashmir Through Cultivation of Aromatic Crops

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Keywords: Aroma; Biodiversity; Herbal; Medicinal plant; Purple Revolution; Traditional

1. Introduction

India is blessed with varied agroclimatic conditions ranging from subtropical to tropical and alpine/mild temperate to cold arid zones combined with abundant rains and sunshine making it an ideal place for the luxuriant growth of diverse flora. The country is endowed with incredible natural plant resources that have great pharmaceutical value. Union Territory of Jammu and Kashmir harbors a diversity of medicinal and aromatic plants that have been used in traditional health care systems for thousands of years. This knowledge of traditional health care is transmitted from generation to generation. The indigenous communities of the region have been experimenting and exploiting many medicinal plant species for treating different human ailments for centuries. Several studies have aimed to elucidate the varied pharmacological potential of some of the important medicinal plants present in this region. The UT of Jammu and Kashmir is also endowed with a wide range of useful plants. Owing to the varied climatic variations, Kashmir Himalaya harbors a rich diversity of medicinal plants. Since times immemorial, people in the region have learned and practiced the medicinal usage of plants. Through the ages, this ancient prized wisdom has been transmitted from generation to generation as part of oral traditions. Cultivation and propagation of these high-value crops at large scales will help in conservation efforts of plant natural resources without putting much pressure on forest biodiversity and ecology. Secondly, by promoting the cultivation and propagation of these crops, humanity will be benefited from the availability of raw materials of natural herbals and creation of income generation opportunities for farmers, growers, and entrepreneurs. Also, these crops don't need too many inputs like the application of fertilizers, pesticides, and other chemical agents for their growth which will preserve our environment.

2. Materials and methods

The medicinal and aromatic plants constitute an important part of the rich flora present in the forests. It contains a wide variety of trees, medicinal plants, and herbs. The region is believed to have more than 5000 medicinal and aromatic plants. Of these, about 4000 are found to be in the Kashmir valley alone. Over 700 medicinal plants have been found to yield high-quality chemicals and other ingredients used in life-saving medicaments and aromatherapy and in cosmetics. Kashmir lavender is called the crown in the world of aroma. The Kashmir valley often referred to as a 'Terrestrial Paradise' is well known around the globe for its rich plant biodiversity. Being phytogeographically located at the intersection of the Holarctic and Paleotropical Floristic Realms and falling within the North-Western Himalaya, the region is endowed with teeming diversity of medicinal and aromatic plant species (Dar and Khuroo, 2013). The world's best aroma products and herbal material is produced in the valley. The rose of Tangmarg (*Rosa damascena*) is one of the best roses cultivated around the world in terms of its quality. Similarly, highly important medicinal plant varieties like Vanwangan (*Podophyllum hexandrum*) are found growing all over Kashmir forests at an altitude ranging from 3000 to 8000 m asl, especially in fir forests of Gulmarg, Afarvat, Sonamarg, Naranag, Pir Panchal mountain range, and Gurez valley. The roots of the plant yield *Podophyllum* resin used as a precursor for the synthesis of etoposide and teniposide, which are known anticancer drugs approved by US FDA. In recent years, the government has given a lot of interest in cultivation and promotion of MAPs cultivation and many mission projects were launched to boost the aroma sector through the cultivation of these high-value crops on large-scale Jammu and Kashmir Arogya Gram Yojana (JAAG) and CSIR Aroma Mission. Under these projects, thrust is given to popularize the cultivation of crops such as *Lavender*, *Rose*, *Salvia*, *Tagetes*, *Mentha sp.*, and *Rose geranium* for increasing farmers' income manyfold. CSIR's Aroma Mission is generating new avenues of self-livelihood and entrepreneurship opportunities in the aroma sector. India is a vast country with diverse plant resources available, which should be used for the benefit of mankind. The primary motive of this advantageous mission is to promote the cultivation of aromatic crops for essential oil and bring additional 10,000–20,000 ha of land under cultivation of some high-value aromatic crops. The Aroma Mission of the CSIR has generated rural employment of farmers, spurred entrepreneurship in aromatic oils and other aromatic products manufacturing, and lowered the import of essential and aromatic oils. Through CSIR's Aroma Mission, important medicinal and aromatic plants are being cultivated on around 6000 ha of land. At an estimate, the Mission has generated 10–12 lakh man-days of rural employment, and more than 500 tons of essential oil worth Rs 60 crore was produced during the last 2 years. Aroma Mission is very valuable because it helps increase the income of the growers and farmers through the cultivation of high-demanding aromatic crops. Not only do farmers of India benefit from this mission, but the aroma industry and future entrepreneurs can also avail the benefits of this scheme to become global leaders in the production and export of aromatic oil. Approximately 10,000 ha of the additional area would be brought under cultivation of various aromatic and medicinal crops generating employment among rural youth and and creating trained and skilled manpower leading to an estimated income enhancement of farmers in the range of Rs 150,000 to 250,000 per hectare depending upon the crop they would grow.

3. Results and discussion

The mission projects like the CSIR Aroma mission have really changed the lives of many farmers and growers in

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many parts of the country by increasing their income manyfolds and it is spreading and emerging as a big industry toward sustainable agriculture. CSIR IIIM Jammu and branch laboratory Srinagar are actively promoting this mission in areas of Bhaderwah, Doda, Kishtwar, Bandipora, Budgam, Baramulla, Anantnag, Kupwara regions of the UT of Jammu and Kashmir. The mission has already created many farming clusters cultivating these crops at a large scale and as a result of this production has also increased, thereby changing the lives of many farmers. The mission projects are helping these farmers with technological know-how, supply of quality planting material, and establishment of market linkages and has led to many success stories of successful farming and brought a new revolution and kranti in the region which is now famously known as Purple Revolution. Jammu and Kashmir has all the potential to become a potential supplier of raw medicinal herbs and aromatic herbs for the emerging nations as well as the global market. By doing this, the drugs worth millions of rupees that are imported every year to meet the national requirements can be met internally without putting any pressure on our natural resources of forests and develop well-organized cultivation practice packages in all regions and areas where such crops can be cultivated and grown. Many of these plants have been reported to have anticancer, anti-bacterial, anti-angiogenic, hepatoprotective, antioxidant, anti-inflammatory, and antiviral activities generating the possibility of designing drugs of economic importance. Traditionally, wormwood (*Artemisia absinthium*) is regarded as a useful remedy for liver and gallbladder problems. Aromatherapists use lavender in inhalation therapy to treat headaches, nervous disorders, and exhaustion. Herbalists treat skin ailments, such as fungal infections (like candidiasis), wounds, eczema, and acne, with lavender oil. It is also used in a healing bath for joint and muscle pain. Studies have shown that the carnosic and rosmarinic acids in rosemary have powerful antibacterial, antiviral, and antifungal properties. Consuming rosemary regularly can potentially help lower the risk of infection and help the immune system fight any infections that do occur. The cultivation of lavender has changed the fortunes of farmers in Jammu and Kashmir under the 'Aroma Mission or Purple Revolution', an initiative of the Central Government toward transforming the lives of the farming community in the UT. In J&K, the Indian Institute of Integrative Medicine is the leading organization responsible for the successful implementation of the Aroma Mission. The CSIR Aroma Mission is envisaged to bring transformative change in the aroma sector through desired interventions in the areas of agriculture, processing, and product development and value addition for fuelling the growth of the aroma industry and rural employment generation. It is expected to enable the Indian farming community and all stakeholders of the aroma industry to become global leaders in the production and export of high-value essential oils needed by global players.

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6.20 Elicitation Studies in Cell Suspension Cultures of *Gloriosa superba* L.

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Keywords: Callus; Colchicines; Elicitors; *G. superba*; Suspension cultures

1. Introduction

G. superba L. belonging to the family Colchicaceae is a climbing herb widely distributed in tropical and subtropical parts of India. It is an important medicinal plant due to the presence of the alkaloid colchicine which is present in almost all parts of the plant with the maximum content in tubers and seeds. The germplasm of this plant is rare and due to diverse applications of colchicine, the plants have been overexploited for their use in herbal industries. The plant produces a diverse array of secondary metabolites and various elicitors trigger the formation of such metabolites that helps a plant to adapt to its surroundings (Abdul Malik *et al*., 2020). *In vitro* plant cell suspension cultures facilitate the large-scale production of such important metabolites.

2. Materials and methods

A sustainable supply of plant products without posing any threat to the environment is the current demand of our society, so for mass propagation of the plants, fresh tubers of *G. superba* L. were collected from the botanical garden, University of Jammu. The explants after surface sterilization were inoculated on an MS medium containing different concentrations of BAP (6-benzylaminopurine) and Kn (kinetin). The leaves from *in vitro* grown shoots were used as explants for callus induction on a 2,4-D supplemented MS medium. Cell suspension cultures were established after cutting the friable calli into small pieces and then inoculating them in liquid MS medium supplemented with 4 mg/L 2,4-D. Three fungal cultures, namely, *Alternaria alternata*, *Aspergillus niger*, and *Curvularia lunata* were used for the elicitation experiment. Further, the effect of concentration of the elicitors and their exposure time to the cell suspension was studied and the amount of colchicine was quantified using HPLC (high-performance liquid chromatography).

3. Results and discussion

In the present study, maximum callus was induced from *in vitro* regenerated leaf explants on an MS medium containing 4 mg/L 2,4-D. In non-elicited cultures, the maximum concentration of colchicine in cells and the medium was observed after 28 days of culturing and it was 13.33±0.02 µg/g and 59.30±0.54 µg/L, respectively (Billowria *et al*., 2018). After 12 days of elicitation with *A. alternata*, the colchicine content in cells was observed to be maximum (13.461±0.013 µg/g) at 10% culture filtrate, while for *A. niger* it was 13.59±0.012 µg/g and with *C. lunata* it was 14.27±0.028 µg/g (Figure 1). Similarly, in the medium the content of colchicine was recorded to be more as compared to the cells. The present study suggests that the fungal elicitors have played a potential role in enhancing the concentration of colchicine in *G. superba*. All the cultures showed a different response to the studied elicitors which was reflected in the variations observed in the colchicine accumulation both in cells and in the medium. Thus *in vitro* culture approaches are the potential source of synthesizing bioactive compounds at low cost and less time which can identify the rate-limiting steps present in the complex biosynthetic pathways.

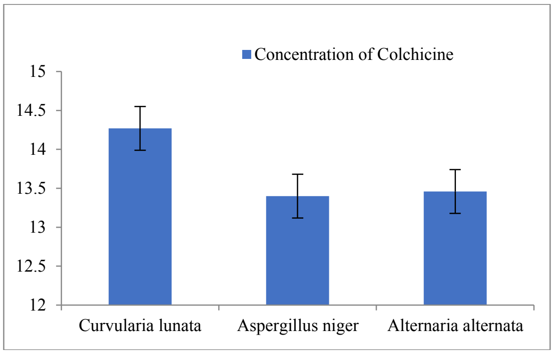

Figure 1 The concentration of colchicine after 12 days of elicitation with fungal cultures

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6.21 Survey and Documentation of Native Stingless Bees from Western Maharashtra and Their Role in Onion Pollination

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Keywords: Onion; Pollination; Stingless bee; Survey

1. Introduction

The rapid decline of managed and wild bees is a global concern for sustainable pollination services and crop productivity. Among the various insect pollinators, honey bees are documented as primary pollinating agents for about 1500 crop species. Onion is one such crop that entirely relies upon insects, particularly bees, for its reproductive success. It is a highly cross-pollinated crop with protandrous flowers. Therefore, a good number of pollinating insect visits is essential for adequate pollination, higher seed productivity, and quality. The managed pollination in onions is primarily through the placement of hives of the domesticated *Apis* spp. However, the use of native non-*Apis* spp. for onion pollination is less explored. In this context, exploring native stingless bee species and their diversity in the onion ecosystem is vital, and little information is available (Makkar *et al*., 2016). Therefore, the present study has been conducted to document the native stingless bees visiting onion, their diversity, and their possible use in managed pollination. It will be an alternative to overcome the loss of *the Apis* species. Also, this will help formulate a conservative strategy and stingless beekeeping for additional income generation for the farmers (Slaa *et al*., 2006; Giannini *et al*. 2015).

2. Materials and methods

A random field survey was conducted in February and March 2022 during the onion peak bloom period in Maharashtra's Pune and Ahmednagar districts to document stingless bee species associated with onion. A total of 16 locations were surveyed. The workers stingless bee species visiting in onion were collected and kept in 70% ethanol for further species characterization using DNA barcoding. The pollination potential of stingless bees *Tetragonula iridipennis* Smith was assessed using hives obtained from a private beekeeping agency (Nashik). The bee hives were relocated to the onion seed production plot (open field) when the flowering approached 25% blooming. The parameters of foraging behavior were studied, including foraging time, visits per unit of time, and working behavior. The whole setup was laid under nylon cages (5 × 5 m cages) with four treatment regimes, including T_1–European been (*A. mellifera Linnaeus*), T_2–Native stingless bee (*T. iridipennis*), T_3–Hand pollination, and T_4–Pollination exclusion (no pollinators activity). The desired layout for each regime was covered with nylon before umbel initiation to avoid the forage visitation of non-targeted bee species. The seed yield in each regime was recorded.

3. Results and discussion

A total of nine locations in the Pune district and seven locations in the Ahmednagar district of Maharashtra were surveyed for stingless bee activity in seed onion. The survey was conducted at farmers' fields. Among the 16 locations surveyed, the prevalence of stingless bees was documented in 15 locations. Stingless species were predominant in six locations (Figure 1), that is, Pimpalwadi, Aliphata, Otur, Tikekarwadi, Manchar, and Kurkundi; this suggests that stingless bee species are one of the important non-*Apis* bee species contributing to onion pollination, and they almost contribute about 39% of forage visitation in onion (Figure 2).

Location-wise, the stingless bees that visited onion umbels were collected and further taken into DNA barcoding for species identification. The genomic DNA isolation protocol and PCR protocol for amplification of cytochrome *c* oxidase I (*COI*) were standardized. The 650 bp of *COI* gene was amplified and sequenced. Cytochrome *c* oxidase I DNA barcode sequence of the species was established. The sequences revealed the prevalence of different stingless bee species including *Tetragonula* spp, *Trigona* spp, *Oxytrigona* spp, *Scaura* spp, and *Melipona* spp with a similarity range between 83% and 90% with the available nucleotide sequences. However, further characterization using morphometry studies is required for further confirmation of these species.

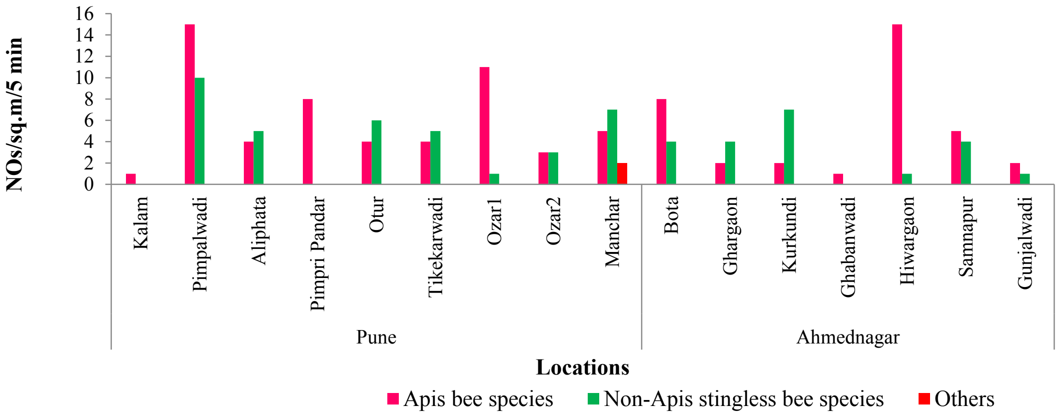

Figure 1 *Apis* and non-*Apis* stingless bee foraging trend in onion

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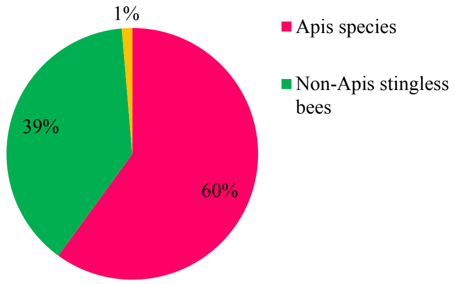

Figure 2 Abundance of non-*Apis* stingless bees and *Apis* species in the onion

The experiment on the pollination potential of the stingless bee *T. iridipenis* revealed that placement of stingless bee hives at 25% blooming of onion recorded the maximum seed yield of 236 kg/ha. It was a better regime than hand pollination and pollinators excluded regimes. The placement of the European bee produced the highest yield of 260 kg/ha. This suggests that non-*Apis* stingless bees can contribute significantly to onion pollination and seed production.

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6.22 Profit Derived Through Protected Cultivation in Tomato Crop

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Keywords: Income; Profit; Protected; Vegetables; Yield

1. Introduction

Owing to the shortage of processing industry and storage infrastructure, off-season cultivation is a viable option to enhance the income and quality of produce. During off-season, vegetables can be cultivated under protected structures such as a net house, poly house, greenhouse, low tunnel, shade house, and row cover (Sirohi and Bahera, 2000). Tomato, capsicum, brinjal, and cucumber are the major vegetable crops that can be grown under protected conditions in Punjab with high productivity and yield as compared to open field conditions. Throughout the year, cultivation of these vegetables is possible through these structures. To ascertain the yield and net profit obtained by the farmers in the cultivation of the tomato crop under protected vegetable cultivation technologies, this study has been planned.

2. Materials and methods

The present study was conducted in six districts, that is, Amritsar, Gurdaspur, Sangrur, Moga, Jalandhar, and Kapurthala, of Punjab state. A list of total vegetable growers in selected districts was prepared with the help of the Department of Horticulture. From this list, 150 farmers who had adopted protected vegetable cultivation were selected according to the probability proportion of the number of farmers involved in protected vegetable cultivation in different districts. An interview schedule was designed. It dealt with the statements to know the yield and net profit obtained by the farmers in the adoption of protected vegetable cultivation. For receiving the response of respondents, the investigator contacted them personally in their villages.

3. Results and discussion

Data from Table 1 reveal that a maximum number of respondents (61.11%) obtained the tomato yield between 80–88.47 quintals per hectare. Data in Table 2 further revealed that a maximum number of respondents (44.44%) had earned a net income of Rs 3.70 to 5.60 million from tomato cultivation in poly house. In the net house technology, 63.16% of the respondents were cultivating tomato crop under the net house, out of these 66.67% of the respondents obtained the tomato yield between 76.76 and 77.97 quintals per hectare (Table 1). Data in Table 2 further indicated that the majority of the respondents (66.67%) had gained net income between Rs 3.08 and 3.63 million per hectare of tomato cultivation in net house technology. In low tunnel technology, 15.79% of respondents were cultivating tomato crop, and out of them 66.67% of the respondents obtained a yield of 64.64 quintals per hectare (Table 1) and the other 33.33% of the respondents obtained the tomato yield of 80.8 quintals per hectare. Data in Table 2 showed that 33.33% of the respondents earned a net profit of Rs 6.025 million per hectare. It can be concluded that under protected cultivation, the yield and net profit of tomato crop were higher as compared to open field conditions, and the yield and net profit of tomato crop in poly house structure were significantly higher than net house and low tunnel structure. Results are similar to Shende and Meshram (2015) who reported that the income of tomato from poly house was higher as compared to open field conditions.

Table 1 Distribution of respondents according to tomato yield under different structures of protected cultivation of vegetables

Crop	Structure	Yield (q/ha)	Frequency	Percentage
Tomato		80.0–88.47	11	61.11
	Poly house (n = 18)	88.47–137.36	5	27.78
		137.36–161.60	2	11.11
		76.76–77.97	8	66.67
	Net house (n = 12)	77.97–81.204	4	33.33
		Above 81.204	–	–
	Low tunnel (n = 3)	64.64	2	66.67
		80.8	1	33.33

Table 2 Distribution of respondents according to net profit from tomato crop under protected cultivation of vegetables

Crop	Structure	Net profit (Million Rs. per ha)	Frequency	Percentage
Tomato	Poly house (n = 18)	3.70–5.60	8	44.44
		5.60–8.32	6	33.33
		8.32–11.12	4	22.22
	Net house (n = 12)	3.08–3.63	8	66.67
		3.63–4.47	2	16.67
		4.47–4.94	2	16.67
	Low tunnel (n = 3)	5.56	1	33.33
		6.025	1	33.33
		6.79	1	33.33

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6.23 Lac Cultivation: An Emerging Enterprise for Economic Sustainability in Karnataka

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Keywords: Ber; Lac cultivation; Economic sustainability

1. Introduction

Lac is a natural resinous secretion by a tiny insect known as lac insect, *Kerria lacca* (Kerr), which is of commercial importance with regard to resin, dye, and wax. Lac cultivation is a source of livelihood and subsidiary income for forest and sub-forest dwellers in many lac-growing areas of the country. Though Karnataka state contributed significantly to national lac production during 1950s, now the share is almost negligible due to varied reasons. Survey studies conducted under the network project on the Conservation of Lac Insect Genetic Resources indicated the presence of lac insects and host plants in Karnataka which are unexploited (Patil *et al*., 2021). There is a great scope for lac cultivation as one of the subsidiary occupations in Karnataka for the benefit of the farming community.

2. Materials and methods

Under the network project on lac, the commercial cultivation of Kusmi lac on *Ziziphus mauritiana* Lam. (Ber) was initiated during 2021-22 in both summer and winter seasons at Bannikuppe (latitude: 12.32783, longitude: 76.355029, elevation: 776.2 $\pm$ 16 m), Mysore district, Karnataka. Naturally grown low fruit yielding type of ber trees of approximately 4 to 5 years were pruned to get the tender shoots for lac inoculation. 10 kg of Kusmi broodlac procured from ICAR-IINRG Ranchi was inoculated uniformly on 12 ber trees following all packages of practices on February 18, 2021. The winter lac crop on Ber was inoculated @ 1 kg per tree on August 10, 2021 with 22 kg of Kusmi broodlac. The tree-wise data on the yield of brood lac was recorded in both the seasons along with farmers' experiences. The productivity was calculated as the ratio of yield and quantity of broodlac inoculated.

3. Results and discussion

The Kusmi lac productivity on ber trees as presented in Table 1 indicates that during summer crop productivity levels are high at 2.20 as compared to winter crop at 1.32. Though regular plant protection measures were taken up, owing to uncertain rains received in October–November 2021 and predation by *Eublemma amabilis* Moore, the growth and quality of brood lac were not good in winter. Farmers have identified a good market linkage for scraped lac, which was sold at Rs 450–500 per kg. Bannikuppe farmers expressed that the presence of thorns affected some operations and that they are interested in lac cultivation on other hosts like *Flemingia* too. The Mysore Paints and Varnish Ltd. (MYLAC) Company, which is manufacturing sealing wax, and artisans involved in making famous wooden toys and lacquerware in Channapatna are procuring lac from northern states. The rationale behind the establishment of the MYLAC factory by the Mysore Maharajas in 1937 was to provide employment opportunities to the localities and effective utilization of natural resources, that is, lac from the forests. Later on, due to unknown reasons or habitat destruction, lac collection must have been stopped. Promoting and encouraging lac cultivation will not only provide economic sustainability for the small and marginal farmers but also conserve lac-associated fauna and flora.

Table 1 Performance of Kusmi lac strain on Ber

Season	Lac crop yield (yield ratio of input/output)	Percent infestation by *E. amabilis*
Summer	1:2.2	3.34
Winter	1:1.32	10.56

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6.24 Evaluating the Effect of Salinity on Photosynthetic Pigments of Cyanobacteria Isolated from Hypersaline-Alkaline Lake

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Keywords: *Chlorophyll; Cyanobacteria; Photopigments; Salinization*

1. Introduction

Cyanobacteria is commonly known as blue-green algae. The application of cyanobacteria in agricultural saline soil remediation can ensure a sustainable supply of food and energy without posing any environmental threat. Direct desalinization by cyanobacteria coupled with pigment formation is an example of sustainably using existing natural resources with long-term higher productivity and farm incomes under climate variability. Algae under stress, including nutritional and physical stress, tends to affect metabolic pathways and the production of its pigments. Pigments are light absorbing compounds and fluorescent at different wavelengths. The main aim of this study was to determine the effect of salinity on photosynthetic pigments like chlorophyll 'a' and carotenoids. Different NaCl concentrations have also been reported to change the lipid content and fatty acid saturation in the case of cyanobacteria. The present research focuses on NaCl concentrations for the most efficient generation of photopigments in the *Cyanospira* sp. (SL09) and *Euhalothece* sp. (SL04B).

2. Materials and methods

The cyanobacterial strains *Cyanospira* sp. (SL09) and *Euhalothece* sp. (SL04B) samples were procured by Microbial Diversity Cyano Tech Cyano Tox, Laboratory of Microbiology Department, School of Life Science, Central University of Rajasthan, Bandar Sindri, Kishangarh (Ajmer).

Media used: Spirulina (SP) medium

Stock solution-1 (g/L): $NaHCO_3$ (27.22 g), Na_2CO_3 (8.06 g), K_2HPO_4 (1.0 g) (pH 9.0–9.2). Stock solution-2 (g/l): $NaNO_3$ (5.0 g), K_2SO_4 (2.0 g), NaCl (2.0 g), $MgSO_4{\cdot}7H_2O$ (0.40 g), $CaCl_2{\cdot}2H_2O$ (0.02 g), $FeSO_4{\cdot}7H_2O$ (0.02 g), EDTA-Na_2 (0.16 g), micronutrient solution (10.0 mL), and vitamin solution (5.0 mL) (pH 3.8–4.0). For growth studies and determination of pigment (chlorophyll a, carotenoid) content, the effect of NaCl concentrations (0%, 2%, 4%, 6%, 8%, 10%, 15%, 20%) on pigment formation (chlorophyll a and carotenoid) was determined using IBM SPSS v23 statistical tool for both *Cyanospira* sp. (SL09) and *Euhalothece* sp. (SL04B). The methanolic extract was prepared. O.D. readings were taken at 665 and 653 nm for chlorophyll a, and a range of light emission was studied from 453 to 470 nm for carotenoids using UV spectrophotometer (Systronics Type-166). Calculations were carried out using the following equations (Schmid *et al*., 2022; Tang *et al*., 2022).

$$\text{Chlorophyll 'a'} = 15.65 \times A665 - 7.34 \times A653$$

$$\text{Carotenoid} = \frac{1000 \times A470 - 2.86\ \text{Chl 'a'}}{221}$$

3. Results and discussion

The maximum biomass 1 g/L was obtained for both the strains and the effect of NaCl concentrations was negligible on growth. An increase in chlorophyll 'a' content at 2% NaCl in the case of *Euhalothece* sp. (SL04B) and a maximum carotenoid content at 4% NaCl showed that the strain had a positive response to high salt concentrations. The results with *Cyanospira* (SL09) have shown maximum carotenoid and chlorophyll 'a' pigment production at 0% NaCl concentration, which shows the strain did not respond to high salt concentrations (Figure 1). In our studies, we conclude that cyanobacterial strain *Cyanospira* (SL09) can serve as a potential strain for pigment formation at zero percent salt concentration. Utilizing cyanobacterial photopigments will increase the production of food, biofertilizers, and secondary metabolites meeting a sustainable supply of food and energy without affecting the environment, due to the ongoing growth in the world population and the depletion of energy resources found in nature.

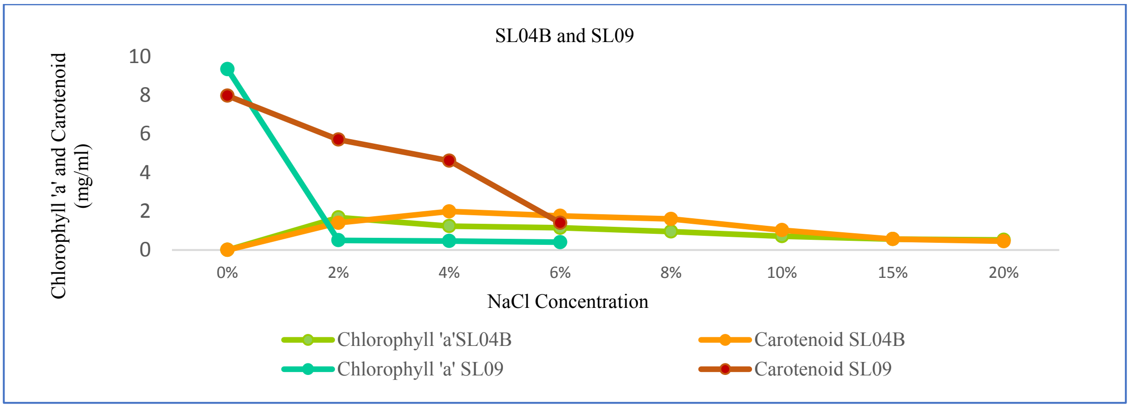

Figure 1 Chlorophyll a and carotenoid content at different NaCl concentrations. The values are mean of triplicates.

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6.25 Estimation of Genetic Diversity in Progenies of Selected Seed Sources of *Ulmus villosa* Under Field Conditions

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Keywords: Growth; Seed source; Short rotation; Variability

1. Introduction

Short-rotation forestry is a promising component of agroforestry with lucrative remunerative benefits that could serve as an alternate source of income generation for the farmers. More than 90% of the industrial round wood in India comes from short-rotation species growing outside conventional forests. Exotic tree species such as *Populus* spp. and *Eucalyptus* spp. have gained considerable acceptance among the farming community in the northwestern states of Punjab, Haryana, and Uttar Pradesh. However, there is a need to broaden the choice of species for diversified uses in the farming community. *U. villosa* is one of the promising short-rotation tree species whose potential remains unexplored. It is a fast-growing multipurpose agroforestry tree species belonging to the family Ulmaceae and finds greater favor on the account of multifarious end uses, that is, a good source of timber for construction purposes, agricultural implements, and fuelwood. Owing to its relatively short rotation period, it has tremendous potential for exploitation under farm forestry and plantation systems. Therefore, evaluation of genetic variability for various growth traits among different seed sources of *U. villosa* is highly desirable and has been undertaken in the present study.

2. Materials and methods

An extensive survey was conducted in Himachal Pradesh and well-matured seeds were collected separately from five different seed sources located in Mandi, Kullu, and Solan districts of Himachal Pradesh in the month of February-March 2019. A detailed description of these seed sources is presented in Table 1. The progenies were raised under nursery conditions and the seedlings of selected superior progenies were transplanted under field conditions in the month of August 2019 in randomized block design at a spacing of 4 m × 2 m in the east-west direction and the observations on growth parameters were recorded at the end of the growing season in 2020.

Table 1 Seed sources descriptions of the present study

Seed source	Name	District	Latitude	Longitude
S1	Suket	Mandi	31°51´N	76°88´E
S2	Jhidi	Mandi	31°82´N	77°17´E
S3	Kumi	Mandi	31°60´N	76°94´E
S4	Kullu	Kullu	32°02´N	77°12´E
S5	Nauni	Solan	31°29´N	76°77´E

3. Results and discussion

On the basis of overall performance for growth characters, seed sources S1 (Suket) and S5 (Nauni) were found outstanding for trait plant height (181.11 and 173.53 cm), collar diameter (13.51, 14.13 mm), the number of branches per plant (58.64 and 58.13), petiole length (4.17 and 3.75 mm), internodal length (28.90 and 30.56 mm), and leaf area (16.97 and 14.68 cm^2). Variability with respect to different growth traits among different seed sources ranged between 137.54 and 197.66 cm for plant height, 5.84 and 17.55 mm for collar diameter, 34.67 and 69.62 for the number of branches per plant, 2.47 and 4.54 mm for petiole length, 20.62 and 36.74 mm for internodal length, and 8.04 and 18.24 cm^2 for leaf area. The highest value in terms of the genotypic coefficient of variation (16.18) was recorded for the leaf area, whereas the highest value for the phenotypic coefficient of variation was noted in collar diameter (25.28). Maximum heritability and genetic gain were recorded for petiole length (69.04%; 22.97%) followed by leaf area (51.05%; 23.81%), and thus it is hereby suggested that these traits must be given due weightage during selection.

Table 2 Variability estimates and genetic parameters for growth traits of *U. villosa* seed sources under field conditions

Characters/ parameters	Mean	Range	CV (%)	Coefficient of variance		Heritability (%)	Genetic advance	Genetic gain (%)
				Genotypic	Phenotypic			
Plant height	163.98	137.54–197.66	8.02	6.81	10.52	41.92	14.90	9.09
Collar diameter	12.48	5.84–17.55	19.70	15.84	25.28	39.25	2.55	20.44
Number of branches	50.50	34.67–69.62	14.76	12.21	19.16	40.64	8.10	16.04
Petiole length	3.51	2.47–4.54	8.99	13.42	16.15	69.04	0.81	22.97
Internodal length	26.32	20.62–36.74	11.73	11.28	16.27	48.05	4.24	16.10
Leaf area	13.47	8.04–18.24	15.85	16.18	22.64	51.05	3.21	23.81

Reference

Sodhi R. 2020. Evaluation of Ulmus villosa Brandis seed sources under nursery conditions in Punjab. M.Sc thesis, Punjab Agricultural University, Ludhiana, India.

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6.26 Changes in Micronutrients, Organic Matter of Soil, and Their Correlation Through Integrated Nutrient Management in Maize-Mustard Crop Rotation Under Rainfed Agriculture in Foothills of Himalayas

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Keywords: INM; Micronutrients; Organic matter, Rainfed agriculture; Soil fertility

1. Introduction

Maize (*Zea mays L.*) is one of the most adaptable developing crops, able to thrive in a wide range of agroclimatic conditions. After rice and wheat, it is the third most significant cereal in India. On the other hand, Indian mustard is the country's most important oilseed crop. Both crops are highly nutrient requiring and heavily deplete soil nutrients and moisture. Multiple nutritional deficits arise as a result of poor recycling of organic sources (Kumar, 2008). In the past, fertilizer research in our country was mostly focused on the nutritional needs of specific crops, but there has recently been a shift in research priorities from individual crops to cropping systems that incorporate residual effects. The addition of inorganic with organic materials speeds up the mineralization process by lowering the C:N ratio. In light of this, the overall goal of this research was to find the best integrated nutrient management strategies for the rainfed area of Jammu in maize-mustard crop rotation.

2. Materials and methods

The field experiment was conducted at Advance Centre for Rainfed Agriculture (ACRA), Rakh Dhiansar of Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST), Jammu in the foothills of the Himalayas. The soils in the experimental region are alluvial with a sandy loam texture. The experiment was laid out by taking 10 treatments in a plot size of 5 × 3 m with three replications in a randomized block design (Table 1). After the completion of the rotation of maize and mustard crops, soil samples were taken at two depths of 0–15 cm and 15–30 cm. These samples were then analyzed in a laboratory for micronutrients by atomic absorption spectrophotometer method after extraction by DTPA (Lindsay and Norvell, 1978) and soil organic matter by Walkley and Black (1934) method.

3. Results and discussion

The various treatments of INM had made significant changes in the status of micronutrients and soil organic matter in the surface layer (0–15 cm) of soil after harvest of the mustard crop as shown in Tables 1 and 2. The highest value of available iron and copper (20.73 µg/g) was recorded with the application of 50% RDF of N, P, and K through chemicals + 50% RD of N through FYM (T7). The conjoint application of organic and inorganic sources of nutrients increased available iron and copper. This may be attributed to the reason that the organic acids that are released during the mineralization of FYM make organic chelates leading to the prevention of adsorption, fixation, and precipitation of iron and solubilization of the already precipitated iron in the soil (Selvi *et al*., 2003). In the surface layer (0–15 cm) of soil, the treatment T9 (100% RDF of N, P, K through chemicals + zinc sulphate @ 20 kg/ha) recorded the greatest value of available zinc (1.37 µg/g) among all the treatments. The treatment T8 with the application of FYM @ 10 tons/ha recorded the highest content of available manganese (23.37 µg/g) and soil organic matter (0.81%) in surface soil. In the subsurface layer (15–30 cm) of soil, lower micronutrients and organic matter were recorded than that in the surface layer (0–15 cm), but the trend was found to be the same among all the treatments in both the layers of the soil. The correlation was found to be significant and positive between the micronutrients Fe, Zn, Cu, Mn, and soil organic matter. Bhat *et al*. (2017) also reported the same findings in their study.

Table 1 Effect of INM on available iron and zinc in soil

Treatments	Available Fe (µg/g)		Available Zn (µg/g)	
	0–15 cm	15–30 cm	0–15 cm	15–30 cm
T_1 Control	13.43	12.07	0.90	0.46
T_2 100% RDF of N, P, K through chemicals	16.03	14.27	0.97	0.57
T_3 50% RDF of N, P, K through chemicals	15.70	12.63	0.94	0.53
T_4 50% RD of N through crop residue	17.73	14.87	1.16	0.72
T_5 50% RD of N through FYM	18.50	16.20	1.04	0.67
T_6 50% RDF of N, P, K through chemicals + 50% RD of N through crop residues	20.33	16.93	1.24	0.89
T_7 50% RDF of N, P, K through chemicals + 50% RD of N through FYM	20.73	18.43	1.21	0.87
T_8 FYM @ 10 tons/ha	19.50	16.70	1.25	0.94
T_9 100% RDF of N, P, K through chemicals + zinc sulphate @ 20 kg/ha	16.20	15.27	1.37	0.94
T_{10} Farmer practice (FYM @ 4 tons/ha + 40 kg urea/ha)	16.05	14.15	1.02	0.65

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Table 2 Effects of INM on available copper, manganese, and organic matter in the soil

Treatments	Available Cu (µg/g)		Available Mn (µg/g)		Soil organic matter %	
	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
T_1 Control	0.66	0.39	12.57	6.90	0.23	0.16
T_2 100% RDF of N, P, K through chemicals	0.73	0.44	17.33	10.37	0.37	0.32
T_3 50% RDF of N, P, K through chemicals	0.73	0.41	15.97	8.67	0.34	0.28
T_4 50% RD of N through crop residue	0.83	0.52	20.20	13.30	0.50	0.35
T_5 50% RD of N through FYM	0.84	0.59	19.76	11.23	0.41	0.34
T_6 50% RDF of N, P, K through chemicals + 50% RD of N through crop residues	0.84	0.62	22.17	13.73	0.62	0.43
T_7 50% DF of N, P, K through chemicals + 50% RD of N through FYM	0.87	0.78	22.40	15.73	0.72	0.46
T_8 FYM @ 10 tons/ha	0.84	0.73	23.37	16.93	0.81	0.51
T_9 100% RDF of N, P, K through chemicals + zinc sulphate @ 20 kg/ha	0.77	0.48	19.10	10.70	0.38	0.33
T_{10} farmer practice (FYM @ 4 tons/ha + 40 kg urea/ha)	0.80	0.50	15.30	8.27	0.32	0.25

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6.27 Effects of Seed Priming on Germination and growth of *Quercus leucotrichophora* A. Camus

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Keywords: Germination; KNO_3; PEG "6000"; *Q. leucotrichophora*; Seed priming

1. Introduction

Acorns of *Q. leucotrichophora* have a germination barrier due to the hard seed coat leading to its slow and low germination. The high-quality oaklings are essential for the rapid, successful, and sustainable regeneration of *Quercus* forests. Their production in a forest nursery should be preceded by the sowing of high-quality acorns via giving suitable presowing treatments such as seed priming. Seed priming involves soaking the seed to the point where germination is unavoidable prior to sowing to enhance germination efficiency under stress conditions. In view of this, the silvicultural approach of modulating seed characteristics via seed priming treatment has been profoundly decided which involves soaking of seeds in a solution of PEG and KNO_3.

2. Materials and methods

The research included a laboratory study on the effect of seed priming on germination and vigour of *Q. leucotrichophora* by using the top of the paper method with two priming agents, namely, KNO_3 and PEG "6000". The design of the experiment adopted was CRD with four replications. The study comprised 19 treatments, namely, T_1 (1% KNO_3 for 24 h), T_2 (1% KNO_3 for 48 h), T_3 (1% KNO_3 for 72 h), T_4 (1.5% KNO_3 for 24 h), T_5 (1.5% KNO_3 for 48 h), T_6 (1.5% KNO_3 for 72 h), T_7 (3% KNO_3 for 24 h), T_8 (3% KNO_3 for 48 h), T_9 (3% KNO_3 for 72 h), T_{10} (control), T_{11} (PEG "6000"-0.5 MPa for 24 h), T_{12} (PEG "6000"-0.5 MPa for 48 h), T_{13} (PEG "6000"-0.5 MPa for 72 h), T_{14} (PEG "6000"-0.75 MPa for 24 h), T_{15} (PEG "6000"-0.75 MPa for 48 h), T_{16} (PEG "6000"-0.75 MPa for 72 h), T_{17} (PEG "6000"-1 MPa for 24 h), T_{18} (PEG "6000"-1 MPa for 48 h), and T_{19} (PEG "6000"-1 MPa for 72 h). Initially, only those seeds were selected that are free from weevils and fungus infestation. After that, ethanol sterilized Petri dishes were covered with Whatman no. 1 filter paper. Different priming treatments discussed above were given to seeds for three durations, that is, 24, 48, and 72 h. Subsequently, seeds were removed from the solution, rinsed with tap water three or four times, and then shade dried at room temperature. Unprimed seeds served as control. Then primed and unprimed seeds were placed in a seed germinator at 28±2ºC and 96% RH for germination as well as a vigour test of the oaklings.

3. Results and discussion

Under laboratory conditions, the results on seed germination, seedling length, seedling dry weight, and seedling vigour index I and II of ban oak seeds after applying treatment T_{11} were statistically significant over all other priming treatments. The T_{11} resulted in the highest (73.75%) germination percentage, highest (23.21 cm) seedling length, maximum (29.75 mg) seedling dry weight, and maximum (1724.37) seedling vigour index I and II (11,460.7). Minimum (15.82%) germination percentage, lowest (4.75 cm) seedling length, minimum (29.75 mg) seedling dry weight, and minimum seedling vigour index I (122) and II (2160) were recorded in T_{16}, T_2, T_{17}, T_2, and T_{17}, respectively. Evidence from various findings also reported that PEG at –0.5 MPa proved best and germination percentage was inversely proportional to PEG concentration (Rosa *et al*., 2005). This is apparent in the present work on ban oak as priming at a high concentration of PEG "6000", that is, –0.75 and –1 MPa did not benefit seed germination. The effect of KNO_3 on germination was not at par as compared to PEG at T_{11}, plausibly due to the low molecular weight of KNO_3 that allowed it to penetrate the seed tissues causing toxicity (Bonome *et al*., 2006). The controlled hydration pattern was maintained by very large molecules of PEG "6000" reducing damage to the embryonic cell walls by the abrupt entry of water into the seed (Missio *et al*., 2018).

Table 1 Effect of seed priming on germination and vigour of ban oak under lab conditions

Treatments	Germination (%)	Seedling length (cm)	Seedling dry weight (mg)	Seedling vigour index I	Seedling vigour index II
			Mean		
T_1	36.25 (36.97)*	11.57	233.50	417.50	8083.75
T_2	25.82 (30.50)*	4.75	29.75	122.02	2386.75
T_3	54.57 (47.62)*	15.32	226.00	837.62	8568.27
T_4	35.00 (36.20)*	14.37	214.75	500.00	5215.00
T_5	28.30 (32.11)*	10.57	213.65	299.74	4754.40
T_6	53.32 (50.66)*	14.15	317.00	742.88	7977.42
T_7	42.50 (40.65)*	16.77	95.00	708.50	4292.50
T_8	29.15 (32.65)*	23.00	149.75	670.45	3614.60
T_9	36.65 (37.17)	13.27	236.65	486.44	4892.77
T_{10}	27.47 (31.57)*	12.87	194.75	360.97	3750.33
T_{11}	73.75 (62.86)*	23.21	370.50	1,724.37	11460.75
T_{12}	48.75 (44.52)*	17.67	242.32	864.50	5606.25
T_{13}	47.05 (43.28)*	19.90	342.32	932.65	6692.86
T_{14}	22.50 (27.83)*	10.62	88.50	241.25	4950.00
T_{15}	35.82 (36.71)*	12.02	194.32	435.90	4263.17
T_{16}	15.82 (23.37)*	7.75	140.50	123.27	5333.02
T_{17}	22.50 (28.21)*	12.75	26.500	288.75	2160.00
T_{18}	46.65 (43.58)*	6.75	134.00	327.80	6087.82
T_{19}	17.15 (24.38)*	9.87	85.90	171.85	2178.05
$C.D._{(0.05)}$	18.87	3.53	86.94	301.35	2735.15
SE(m)	6.64	1.24	30.62	106.13	963.30
SE(d)	9.40	1.75	43.30	150.09	1362.32
C.V.	36.13	18.36	32.91	39.32	35.79

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6.28 Nest Architecture and Foraging Behavior of Small Carpenter Bee, *Ceratina viridissima* (Dalla Torre), on Different Host Plants

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Keywords: *C. viridissima*; foraging activity; Saccharum spontaneum

1. Introduction

C. viridissima or small carpenter bees are a widespread bee fauna in the subfamily Xylocopinae. They are bright metallic blue to green bees that actively forage on a wide variety of crop plants. They make linear burrows in dead woods and pruned pithy stems to build their nests. The nests contain eggs, larvae, prepupae, pupae, and adult stages. The bee's life cycle takes 41.67±3.12 days to complete. Experiments were conducted at University Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST) Jammu, J&K (UT), India during 2021-22 to study the nest architecture, biology, and foraging behavior of *C. viridissima.* Thirty nests each of *Rosa* spp*., S. spontaneum* (Sarkanda), and *S. bengalense* (Kae) were selected. The nesting parameters, namely, length of the nest, width of nest entrance, length of the chamber, breadth of the chamber, number of chambers, number of adult bees, number of larva, and number of pupa were studied using digital vernier caliper. The studies revealed significant differences among host preferences by *C. viridissima. S. spontaneum* was observed as the most preferred nesting material over the *Rosa* spp. and *S. bengalense.* The length of the nest, width of the nest entrance, length of the chamber, and breadth of the chamber in *S. spontaneum* were 20.77±0.78 mm, 2.60±0.07 mm, 16.8±2 1.00 mm, and 3.06±0.22 mm, respectively. The observations on foraging behavior indicated that *C. viridissima* starts its foraging activity in the morning hours (9:00 am) and returns to its nests in the evening hours (5:30 pm). The correlation studies indicated the strong association of foraging activity of *C. viridissima* with sunshine hours (h) and temperature (^{o}C) while relative humidity and evaporation have a non-significant association with foraging behavior.

2. Materials and methods

The study was carried out in the experimental farm of SKUAST-Jammu. The stems of different host plants, namely, *Rosa* spp., *S. spontaneum* (Sarkanda), and *Saccharum bengalense* (Kae), were collected from different locations on the campus. The entrance holes were plugged with cotton during evening hours ensuring that adult bees were inside the nest. For nest architectural studies, nests were cut longitudinally with the help of a sharp knife preventing injury to immature stages of the nest. Digital vernier caliper was used for recording the observations, namely, length of the nest, width of nest entrance, length of the chamber, breadth of the chamber, number of the chamber, number of adult bees, number of larva, and number of the pupa. The foraging activity pattern of *C. viridissima* was observed by marking nests for recording bee activity during the study period with the help of a camera fitted at the nesting site. The crops selected were *Ocimum sanctum* (Linn.) and *Trifolium alexandrinum* L. Five plants were randomly selected and tagged for recording foraging activity at different hours of the day. The data were analyzed statistically using SPSS-16 software.

3. Results and discussion

According to the findings of this study, the most preferred nest by the small carpenter bee *C. viridissima* was *S. spontaneum* (Sarkanda) (Figure 1) whose average nest length observed was 20.77±0.78 mm, width of the nest entrance was 2.60±0.07 mm, the average length of the chamber was 16.82±1.00 mm, the average breadth of the chamber was 3.06±0.22 mm, the average number of adult bees was 2.80±0.48, the average number of the larva was 3.40±0.52, and the average number of pupa was 1.80±0.02 (Ali *et.al*., 2016). These bees help in the pollination of various crops and enhance the productivity of the crops. The foraging activity was observed to increase with increasing maximum temperature and daily sunshine hours and it shows a positive correlation between the foraging activity and weather parameters (Sharma and Abrol, 2015). The present study concluded that *C. viridissima* preferred pithy stems of three different host plants for nestings, namely, *S. spontaneum* (Sarkanda), *S. bengalense* (Kae), and *Rosa* spp. The current findings will aid in understanding nest preference and nest infrastructure, which could be used to develop artificial nests to save bees. This information may also be useful for providing artificial nesting sites in order to conserve native bees and increase pollination.

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6.29 Physicochemical Profile of Indus River System Tributary – Sutlej Along its Course of Flow in Punjab, India

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Keywords: Buddha Nallah; Pollution; Punjab; Sutlej; Water quality

1. Introduction

Growing industrialization/urbanization has increased water pollution alarmingly, with 70% of Indian rivers presumed to be polluted. The majority of the riverine resources of the country are heavily polluted and have turned into open sewers (Anand *et al*., 2007). The largest tributary of the Indus River system in Punjab, that is, Sutlej, is among the severely polluted rivers, particularly its stretches passing through Ludhiana town due to direct discharge of partially treated/untreated domestic sewage, agricultural run-off, and industrial effluents into it. The river Sutlej sustains diverse fish species, besides supporting the livelihood of fishermen/riparian populations. Moreover, fish harvested from Sutlej is being directly used for human consumption. Due to the immense importance of Sutlej in terms of its rich floral-faunal biodiversity, the major source of capture fisheries of Northern India, and livelihood generation for fishermen, it becomes imperative to assess the ecological health of Sutlej to form suitable strategies to control and prevent the menace of pollution, biodiversity conservation, and restoring its pristine purity.

2. Materials and methods

Water samples (N = approx. 100) were collected (in triplicate) at two-monthly intervals during the study period from February 2018 to June 2019 from four designated sites spots, that is, S-1 (river Sutlej at Ropar Headwork), S-2 (river Sutlej before the confluence of Buddha Nallah at Phillaur), S-3 (river Sutlej after the confluence of Buddha Nallah near village Wallipur), and S-4 (Harike-Pattan where river Sutlej meets with Beas). The samples were collected in clean and dry plastic bottles in the early morning hours of the day and brought to the laboratory under iced conditions in insulated boxes for further analysis. The physiochemical parameters of water, namely, total alkalinity (TA), total hardness (TH), chloride, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD), were analyzed according to the standard methods of APHA (2005). In contrast, ammonia, nitrate, and phosphate were estimated using the DR-900 calorimeter (Hach, make). Water temperature and pH were estimated on the spot using a mercury thermometer and digital pH meter, respectively. One-way ANOVA and Duncan Multiple Range Test (DMRT) were applied to find the significant differences in water quality parameters at the different sampling sites of the river. Bivariate correlation analysis was performed to find out the associations among the different water quality parameters.

3. Results and discussion

The impairment of water quality due to the introduction of pollutants is a problem faced by most industrial cities worldwide. During the present study, comparatively, elevated levels of temperature (27.77°C), TA (170.51 mg $CaCO_3$/L), TH (253.40 mg $CaCO_3$/L), chloride (167.82 mg/L), ammonia (1.85 mg/L), phosphate (1.81 mg/L), BOD (48.44 mg/L), and COD (143.18 mg/L) were recorded at S-3 indicating a higher degree of pollution at this site which is mainly due to direct discharge of industrial effluents, run-off from the catchment area, and domestic sewage waste. The pH (8.33, 7.75, and 8.15) and DO (9.09, 7.93, and 7.34 mg/L) values were recorded within desirable limits at S-1, S-2, and S-4 indicating good ecological health. In contrast, nitrate values were higher at S-2 (5.66 mg/L) due to the direct discharge of Phillaur sewage into river Sutlej at S-2. An inverse relationship was found between the values of DO and BOD (r=–0.972), confirming the heavy load of pollutants being received by river Sutlej along its course of flow in Punjab.

Table 1 Comparative variation in water quality parameters at selected sites during the study period

Parameter	Site-1	Site-2	Site-3	Site-4
Temperature (°C)	21.08^d±0.03	24.45^b±0.05	27.77^a±0.02	23.03^c±0.03
pH	8.33^a±0.01	7.75^c±0.04	7.05^d±0.51	8.15^b±0.02
Total alkalinity (mg $CaCO_3/L^-$)	109.29^c±0.55	132.89^b±0.56	170.51^a±0.64	108.74^c±0.57
Total hardness (mg $CaCO_3$/L)	134.66^c±1.25	156.00^b±1.36	253.40^a±1.75	117.63^d±0.68
Chloride (mg/L)	31.58^d±0.35	52.76^b±0.34	167.82^a±0.67	46.40^c±0.33
Ammonia (mg/L)	0.02^c±0.006	0.74^b±0.04	1.85^a±0.31	0.05^c±0.001
Nitrate (mg/L)	1.91^b±0.27	5.66^a±0.43	1.63^d±0.24	1.78^c±0.25
Phosphate (mg/L)	0.51^c±0.07	1.32^b±0.09	1.81^a±0.08	0.53^c±0.07
Dissolved oxygen (mg/L)	9.09^a±0.69	7.93^b±0.63	2.43^c±0.49	7.34^b±0.55
Biological oxygen demand (mg/L)	2.29^d±0.02	4.21^c±0.11	48.44^a±1.14	11.82^b±1.03
Chemical oxygen demand (mg/L)	14.24^d±1.24	45.78^b±1.41	143.18^a±1.39	23.47^c±1.25

The results of the present study revealed that river Sutlej is under pronounced pressure from pollution after the influx of Buddha Nallah, which is greatly threatening the aquatic biodiversity and livelihood of hundreds of dependent fishermen population. Additionally, higher levels of pollutants present in water might be interfering with fish physiology coupled with endocrine disruption, and the accumulating level of pollutants above maximum permissible limits is also life-threatening to the fish-consuming human population. Therefore, our findings warrant continuous monitoring, devising of suitable pollution control strategies, and their strict implementation to restore, conserve, and sustain the biodiversity of river Sutlej before these changes become irreversible.

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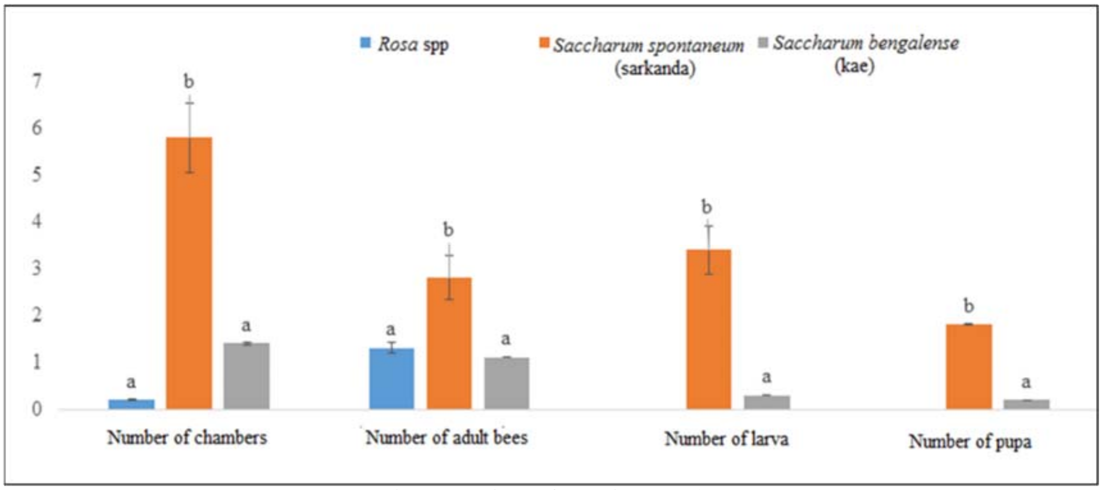

Figure 1 Nesting preference by *C. viridissima*

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6.30 Screening of Efficient Arbuscular Mycorrhizal Fungal Isolates for *Piper mullesua* Under Nursery Condition

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Keywords: Efficiency test; inoculum test; mycorrhiza; *P. mullesua*

1. Introduction

Arbuscular mycorrhizal fungi (AMF), a group of obligate biotrophic fungi belonging to the phylum Glomeromycota, are among the oldest fungi in terrestrial systems on earth. Most AMF can form associations with susceptible plants regardless of the genetic diversity or geographical distribution of the two symbionts (Banerjee *et al*., 2013) and the plants with roots colonized by mycorrhizal fungi are more effective at nutrient and water acquisition, less susceptible to disease, and can be more productive under certain stressful environmental growing conditions such as acidity, salinity, drought, extreme temperature, and heavy metal. Considering the beneficial role, AMF has the potential to become the best kind of biofertilizer for agronomic and medicinally important crops.

P. mullesua is an important medicinal plant belonging to the family Piperaceae predominantly found in the adjoining areas of forests in North East India. But the plant population has been gradually decreasing due to heavy deforestation in the entire North East. This plant species can be conserved by mass multiplication using AMF as a biofertilizer. Medicinal plant seedlings are poorly studied in relation to their physiological responses to AMF applications and there is no report on a study of AMF with *P. mullesua*. Screening and standardization of AMF species are necessary for the conservation of these medicinal plants for their greater importance in human health. The present study has been formulated to assess the impact of the inoculation potential of selected AMF on the growth and quality of cuttings of *P. mullesua*.

2. Materials and methods

Plantlets of piper were raised through stem cuttings. The plantlets were raised in sterilized sand and soil mixture (3:1). Soil samples were collected from different locations in Arunachal Pradesh for the isolation of AMF fungal spores. Samples were taken from depths of 0–15 cm under various land use systems such as forest areas, jhum fields, home gardens, and the natural habitat of piper plants. The experiment inoculum potential test was conducted to check the potentiality of the AMF pure culture to infect any plant species. In view of that, maize, which is very susceptible to mycorrhizal infection, was selected as the host plant. Another experiment "Efficiency test of mycorrhizal isolates" was conducted to evaluate the efficiency of potential mycorrhizal isolates influencing *P. Mullesua* plantlets. Laboratory analyses were done to investigate various growth parameters. The MEI (mycorrhizal efficiency index) was calculated by taking the total dry weight of the plant and using the formula given below

$$\mathrm{MEI} = \frac{100\ \times (1 - \text{Non mycorrhizal plant weight})}{\text{Mycorrhizal plant weight}}$$

The data were subjected to one-way analysis of variance (ANOVA) to determine the effect of treatments. The correlation coefficient was calculated to evaluate the strength of the relationship of total plant biomass with the other parameters considered in the study.

3. Results and discussion

In this experiment, the potentiality of mycorrhizal inoculum was tested by inoculum potential test using maize as the host plant. Mycorrhizal fungal species such as *Glomus mosseae*, *G. etinucatum, G. aggregatum*, *G. fasciculatum, G. hoi, G. macrocarpum*, *G. albidum*, *G. claroidium*, *G. occultum*, *G. aurantium*, *G. microcarpus*, *G. etunicatum*, *G. rubiforme*, and *G. versiforme* have the potentiality to infect all the five replicates of the maize plant at the 10^{-1} spore dilution as compared to the other isolates.

Inoculated plantlets exhibited a significant increase in plant biomass with respect to untreated plantlets. Among the 25 fungal species, *G. versiforme* (0.937 g), *G. etinucatum* (0.902 g), *G. aggregatum* (0.892 g), *G. fasciculatum* (0.786 g), *G. hoi* (0.814 g), *G. macrocarpum* (0.808 g), *G. albidum* (0.843 g), *G. claroidium* (0.911 g), *G. occultum* (0.784 g), and *G. aurantium* (0.735 g) were found to increase in biomass of plantlets significantly (F = 160.56, df = 26, p < 0.001) compared to the non-mycorrhizal *P. mullesua* plantlets. The maximum increase in shoot length was observed for plantlets inoculated with *G. versiforme* (8.57 cm). The performance of *G. claroidium* and *G. etinucatum* were similar to the former.

AMF inoculation in piper seedlings exhibited a significant influence on the uptake of phosphorous. Plants inoculated with *G. versiforme* (34.42 µg/g), *G. claroidium* (33.62 µg/g), and *G. etinucatum* (32.57 µg/g) showed significantly higher P concentration (F=12.55, df=26, p<0.001) in leaves than non-inoculated control. Minimum P concentration in leaves was observed for *Gigaspora candida*. A high correlation (r=0.94) was observed between shoot length and plant biomass. However, shoot length (r=0.84) and MEI% (r=0.89) were highly correlated with the percent mycorrhizal infection of the plantlets. Phosphorus showed closely correlated with % infection (r=0.58) and MEI% (r=0.51).

From the above experiment, it can be summarized that out of 25 mycorrhizal fungal species isolated from the different land use systems of Arunachal Pardesh, 14 mycorrhizal isolates, predominantly genus *Glomus*, were found more potent for establishing infection in maize plants. Out of these 14 potential mycorrhizal fungal isolates, 10 were found effective in terms of mycorrhizal efficiency index in establishing mycorrhizal infection and improving nutrient uptake in *P. mullesua* plants. As the *P. mullesua* plants are gradually vanishing due to high deforestation in the foothills of Himalayas, selected mycorrhizal fungal isolates can surely boost the survivability of the plants in nursery conditions. This approach will surely help in increasing the growing area of the medicinally important *P. mullesua* plants.

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6.31 Impact of Informative Videos on Gain in Knowledge of the Farmers

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Keywords: Gain in knowledge; Paddy straw; Straw management

1. Introduction

Crop residues in general are the parts of plants left in the field after crop is harvested and threshed. These materials at times have been regarded as waste materials that require disposal, but it has been increasingly realized that they are important natural resources and not the wastes. About 40% of the nitrogen (N), 30–35% of the phosphorus (P), 80–85% of the potassium (K), and 40–50% of the sulfur (S) taken up by the rice remains in vegetative plant parts at crop maturity. Thus, there is need to reorient the behavior of farmers so that these residues could be properly utilized. This can be achieved through the quick dissemination of information through efficient media of communication. Timely and appropriate information is considered as an important factor that leads to change in behavior of receivers. Although there are number of communication technologies available, video is the most effective medium to convey information in an attractive way and also effectively supports educational efforts (Rani and Rao, 2014). The study was on the impact of informative videos on gain in knowledge of the farmers related to crop residue management and to test the gain in knowledge after watching informative videos.

2. Materials and methods

The study was conducted in the Ferozepur, Sangrur, and Ludhiana district of Punjab. A total of one hundred eighty (180) respondents were selected, that is, 120 respondents were selected as experimental and 60 respondents as control group were randomly selected. Three stages contact was made, that is, before treatment, at the time of treatment (video exposure) and after treatment to know the impact on gain in knowledge. In order to assess gain in knowledge, four knowledge tests covering the important aspects of informative videos, namely, basic crop residue management techniques, in-situ residue management, ex situ residue management, and fertilizer application were prepared. Thus, for each informative video, a total knowledge score was worked out and gain in knowledge was made on the basis of mean score and t-test was used to test the significance and 0.05 was the level of significance.

3. Results and discussions

The finding reveals that before exposure to informative videos, 48.33% of the respondents were having medium level of knowledge followed by low (37.50%) and high (14.17%), while after exposure to the informative videos, 50% of the respondents had medium level of knowledge followed by high (32.50 %) and low (17.50 %). About 18.33% increased in proportion of respondents knowledge level was observed in high knowledge level category, whereas 20.00% decrease was observed in low knowledge level category. In the case of control group in posttest evaluation, it was observed that just 7% increase was observed by the respondents of high knowledge level category.

After exposure to informative videos, a significant difference was observed in mean knowledge score between of experimental and control groups. The impact of informative videos on knowledge score was also calculated as effect of treatment that was found to be 7.00. Thus, it could be concluded that there was a positive and significant difference between experimental and control groups in respect to the knowledge levels of respondents after exposure to informative videos. It could be concluded that selected informative videos had enhanced the knowledge level of the respondents.

Table 1 Distribution of experiment and control groups according to the level of knowledge at and before exposure to informative videos

Type of informative content in video	Level of knowledge	Experimental group (n = 120)			Control group (n = 60)		
		Before f (%)	After f (%)	% Shift	Before f (%)	After f (%)	% Shift
Overall	Low (≤29)	45(37.50)	21(17.50)	–20.00	23(38.33)	21(35.00)	–3.33
	Medium (30–46)	58(48.33)	60(50.00)	+1.67	29(48.34)	27(45.00)	–3.34
	High (≥47)	17(14.17)	39(32.50)	+18.33	8(13.33)	12(20.00)	+6.67
Effect of treatment (Y – X) – (Z – A) = 7.00							

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6.32 Effect of Phosphorus and Zinc Levels on Production, Productivity, and Economics of Cluster Bean (*Cyamopsis tetragonoloba* L.)

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Keywords: Cluster bean; Phosphorus; Zinc

1. Introduction

Cluster bean, an annual legume known as *Cyamopsis tetragonoloba*, is mostly grown in arid and semiarid regions where resources are scarce (Kumar, 2005). It is a Leguminosae (Fabaceae) family crop that self-pollinates and is well known for its extraordinary resistance to heat and drought (Kumar and Rodge, 2012). It is a healthy food source, and the soft green pods are an inexpensive way to get nutrients. In addition, high protein cow feed is made from cluster bean meal and seed (Rai and Dharmatti, 2013). The endosperm of the crop's seeds contains high-quality gum (28–33%), so it has recently been given significant importance in the industrial sector. Zinc is necessary for plant growth and serves as an enzyme activator for a number of other enzymes. Phosphorus is a key component of nucleic acids (RNA and DNA), nucleoproteins, amino acids, phosphatides, phytin, and a number of coenzymes and it plays an important part in the assessment of energy-rich phosphate bonds such ADP and ATP, nuclear protein, and phospholipid.

2. Materials and methods

At the research farm, Krishi Vigyan Kendra, Sangaria, Hanumangarh (Rajasthan), which is situated at geographical coordinates 29° 51' 39.14" N latitude, 74° 20' 51.96" E longitude, and 192.81 m altitude above the mean sea level, the experiment was carried out during the *Kharif* season of 2020. The experiment was triple-replicated and set up using a randomized block design. The treatments included combinations of the basal application of three different phosphorus levels—P_1 (20 kg/ha), P_2 (40 kg/ha), and P_3 (60 kg/ha)—as well as three different zinc levels—Z_1 (05 kg/ha), Z_2 (10 kg/ha), and Z_3 (15 kg/ha). The mean weekly maximum and lowest temperatures, relative humidity, and rainfall throughout the growth season were 40.13°C, 21°C, 80.84%, 53.48%, and 4.72 mm, respectively. One day prior to planting on each of the treatment combinations, the field was equally watered.

3. Results and discussion

Table 1 shows that the quantity of pods per plant, seed yield, and stover yield were significantly influenced by phosphorus and zinc. The treatment combination of Phosphorus (60 kg) and zinc (10 kg) produced a significantly higher number of pods per plant (47.40), grain yield (1270.00), and stover yield (3810.30), whereas treatment combinations of phosphorus (60 kg) and zinc (15 kg), phosphorus (40 kg), and zinc 10 kg, phosphorus 60 kg and Zinc 5 kg was found to be statistically at par to phosphorus 60 kg and zinc 10 kg in seed yield and stover yield. Table 2 shows the results regarding gum content that were not influenced due to different levels of phosphorus and Zinc. However, maximum gum content (33.40%) was produced in phosphorus (60 kg) and zinc (10 kg). Minimum gum content (30.78%) recorded under phosphorus (20 kg) and zinc (05 kg). The increase in seed yield due to phosphorus application is attributed to source and sink relationship. At higher use of phosphorus, significantly maximum pod per plant and seeds per pod were obtained, which remained at par with 40 kg phosphorus. At less use of phosphorus, significantly the lowest numbers of seeds per pod were received. This might be due to the greater phosphorus requirements of plants in the field, which facilitated more aeration, greater light interception, and more photosynthetic activity. Phosphorous not only plays an important role in proliferation and growth but also improves nodulation and nitrogen fixation by supplying assimilates to roots in rhizosphere. These findings are in line with the results obtained by Tiwana and Tiwana (1994) and Shivran *et al*. (1996). It appears that greater translocation of photosynthates from source to sink might have increased seed yield (Balai *et al*., 2017).

Table 1 Effect of phosphorus and zinc levels on yield and yield attributes of cluster bean

Treatment combinations	No. of pods/plant	Seed yield	Stover yield
20 kg/ha phosphorus + zinc 05 kg/ha	32.63	870.34	2349.92
40 kg/ha phosphorus + zinc 05 kg/ha	40.23	1020.00	3064.00
60 kg/ha phosphorus + zinc 05 kg/ha	45.00	1180.00	3350.00
20 kg/ha phosphorus + zinc 10 kg/ha	32.20	890.00	2492.56
40 kg/ha phosphorus + zinc 10 kg/ha	45.97	1220.00	3696.26
60 kg/ha phosphorus + zinc 10 kg/ha	47.40	1270.00	3810.30
20 kg/ha phosphorus + zinc 15 kg/ha	34.77	910.00	2548.28
40 kg/ha phosphorus + zinc 15 kg/ha	42.80	1145.00	3104.07
60 kg/ha phosphorus + zinc 15 kg/ha	46.27	1250.00	3759.78
F test	S	S	S
SEm±	1.82	21.89	104.40
CD (p = 0.05)	5.46	65.61	313.16

Table 2 Effect of phosphorus and zinc levels on gum content in cluster bean

Treatment combinations	Seed yield
20 kg/ha phosphorus + zinc 05 kg/ha	31.0
40 kg/ha phosphorus + zinc 05 kg/ha	31.7
60kg/ha phosphorus + zinc 05 kg/ha	31.4
20 kg/ha phosphorus + zinc 10 kg/ha	31.0
40kg/ha phosphorus + zinc 10 kg/ha	32.0

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60kg/ha phosphorus + zinc 10 kg/ha	32.4
20kg/ha phosphorus + zinc 15 kg/ha	31.3
40 kg/ha phosphorus + zinc 15 kg/ha	31.7
60 kg/ha phosphorus + zinc 15 kg/ha	31.6
F test	NS
SEm±	0.39

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6.33 Effect of Integrated Nutrient Management on Growth, Production, and Productivity in Mustard (*Brassica juncea* L.)

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Keywords: *Azospirillum*; *Azotobacter*; Integrated nutrient management; PSB

1. Introduction

India is the largest rapeseed-mustard growing country in the world, occupying the first position in area and second position in production after China (Anonymous, 2019). Mustard occupies a prominent place among oilseed crops next only to soybean in the country. The oil content varies from 37% to 49% and it is considered to be an important constituent of the Indian diet. Mustard oil is used as the main cooking medium, especially in northern India (Srinivasan, 2005). Apart from these, oil is also utilized for the preparation of vegetable ghee, hair oils, medicines, soap making, mixtures with mineral oils for lubrication, and the manufacture of greases. The cake obtained after the oil extraction is mostly used for cattle feed and manure. Among the various constraints attributing to the low productivity of mustard in arid and semiarid regions, the erratic nature of climate, inefficient irrigation water and fertilizer management, and poor soil physical conditions are the most important factors that lead to low crop yield.

2. Materials and methods

A field experiment was conducted to study integrated nutrient management in mustard for growth, productivity, and profitability during *Rabi* 2018-19. The soil of the experimental plot was loamy sand and the experiment was laid out in a randomized block design with eight treatments, that is, T_0: Control, T_1: 50% of RDF (45 kg N + 20 kgP_2O_5 + 10 kg K_2O ha^{-1}), T_2: 75% of RDF (67.5 kg N + 30 kg P_2O_5 + 15 kg K_2O ha^{-1}), T_3: 100% of RDF (90 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1}), T_4: *Azotobacter* + PSB + *Azospirillum*, T_5: 50% of RDF + *Azotobacter* + PSB + *Azospirillum*, T_6: 75% of RDF + *Azotobacter* + PSB + *Azospirillum*, T_7: 100% of RDF + *Azotobacter* + PSB + *Azospirillum*. All these treatment combinations were replicated thrice. Mustard variety Bio-902 (Pusa Jai Kisan) was used for sowing.

3. Results and discussion

The significantly highest mean value of dry matter accumulation (14.7 g at 30 DAS, 81.5 g at 60 DAS, 176.5 g at 90 DAS, and 240.9 g at harvest) per meter row length was recorded with the application of 100% of RDF + *Azotobacter* + PSB + *Azospirillum* (T_8) over all other treatment except treatment T_4 and T_7 that was statistically remained at par with each other. Dry matter accumulation was significantly increased due to application of 100% of RDF + *Azotobacter* + PSB + *Azospirillum* (T_8) as compared to treatment T_1, T_2, T_3, T_5, and T_6 that was in the tune of 56.4%, 28.3%, 19.0%, 29.8%, and 22.4% at 30 DAS, 51%.7, 23.9%, 19.1%, 25.7%, and 21.6% at 60 DAS, 39.0%, 18.3%, 15.4%, 19.2%, and 16.7% at 90 DAS, and 37.6%, 17.9%, 15.1%, 19.0%, and 16.5% at harvest. Better utilization of nitrogen, phosphorous, and potassium in association with micronutrients might be the reason for increased plant height (Maynard and David,1987).

Application of 100% of RDF + *Azotobacter* + PSB + *Azospirillum* (T_8) exhibited significantly highest number of branches per plant at harvest (6.33) in mustard as compared to the treatment T_1, T_2, T_3, T_5, and T_6 but remained at par with the application of 100% of RDF (T_4) and 75% of RDF + *Azotobacter* + PSB + *Azospirillum* (T_7). Treatment T_4 and T_7 also produced a significantly higher number of branches per plant over all other treatments. The improvement in the number of branches per plant at harvest of mustard due to the application of 100% of RDF + *Azotobacter* + PSB + *Azospirillum* (T_8) as compared to T_1, T_2, T_3, T_5, and T_6 was 45.7%, 20.7%, 15.9%, 22.5%, and 16.9%, respectively. The addition of biofertilizers in relation to N and P fertilization is instrumental in increasing the growth attributes in every level of plant growth, that is, the number of branches per plant (Singh and Sinsinwar, 2006).

Table 1 Effect of integrated nutrient management on growth parameters in mustard crop

Treatments	Plantstand		Dry matter accumulation				Number of branches plant^{-1}
	At 20 DAS	At harvest	At 30 DAS	At 60 DAS	At 90 DAS	At harvest	
T_0: Control	9.69	9.17	9.4	53.8	126.9	175.1	4.34
T_1: 50%ofRDF	9.78	9.24	11.5	65.8	149.2	204.3	5.24
T_2: 75%ofRDF	9.85	9.34	12.4	68.4	152.9	209.3	5.46
T_3: 100%ofRDF	10.00	9.44	14.5	80.4	174.9	238.0	6.30
T_4: *Azotobacter +PSB+Azospirillum*	9.73	9.22	11.3	64.9	148.1	202.4	5.17
T_5: 50%ofRDF + *Azotobacter+PSB+Azospirillum*	9.89	9.40	12.0	67.1	151.3	206.8	5.41
T_6: 75%ofRDF+*Azotobacter+PSB+ Azospirillum*	9.94	9.41	14.2	78.3	173.6	236.5	6.26
T_7: 100%ofRDF+ *Azotobacter +PSB+Azospirillum*	10.05	9.48	14.7	81.5	176.5	240.9	6.33
SEm$\pm$	0.41	0.38	0.51	2.83	6.63	8.73	0.23
CD(P =0.05)	NS	NS	1.55	8.58	20.12	26.47	0.69
CV(%)	7.19	7.09	7.07	7.0	7.33	7.06	7.09

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6.34 Relative Efficiency, Competition, and Economic Evaluation of Chickpea-Based Intercropping Systems

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Keywords: Chickpea; Fenugreek; Intercropping; Linseed; Raya; Row ratio

1. Introduction

Chickpea (*Cicer arietinum* L.) is the third most important food legume crop worldwide. In India, chickpea is cultivated on 10.2 million ha with a production of 11.3 million tons and productivity of 1116 kg/ha. Intercropping offers potential benefits relative to monoculture by increasing yield through the effective use of resources including water, nutrients, and sunlight. Intercropping is a way to enhance biodiversity in an agricultural ecosystem. The success of intercrops in comparison with the pure cropping can be determined by an appropriate density, planting date, resource availability, and intercropping models (Hatfield and Karlen, 1993). Intercropping of chickpea with Indian mustard, linseed, and fenugreek is successful because of their diverse morphology, growth rhythm, and similar climatic requirements and such intercropping systems are quite popular in India. However, spatial arrangement and plant population in an intercropping system have important effects on the balance of competition between component crops and their overall productivity. Hence, the present experiment was undertaken.

2. Materials and methods

A field experiment was carried out at the field area of CCS Haryana Agricultural University, Hisar, Haryana, India (29°'10'N latitude, 75°46'E longitude, and 215.2 M altitude) during the *Rabi* seasons of 2020-21 and 2021-22 in randomized block design replicated thrice with 19 treatments to evaluate chickpea (HC 5) based intercropping systems taking fenugreek (MH 57), linseed (K 2), and raya (RH 725) as intercrop with planting patterns of chickpea + intercrop with the row ratio of 4:4, 5:3, 6:2, 3:5, and 2:6. Soil of the field was sandy in texture, slightly alkaline in pH (7.7), low organic carbon, poor in available phosphorus, medium in available nitrogen, and rich in available potassium. Sowing of sole and intercrops was done at 30 cm row to row distance. The gross plot size was 7.2 m × 3.5 m. The crop management practices were followed as per the recommendations of CCS Haryana Agricultural University, Hisar, India. All intercropping indices to evaluate relative competitiveness and economics were calculated using the formula given by Willey (1979) and Jain and Rao (1980).

3. Results and discussion

The two-year field research study demonstrated that raya intercropping in chickpea was uneconomical over sole chickpea. Chickpea + fenugreek intercropping with different row combinations (4:4, 5:3, 6:2, 3:5, and 2:6) was found most successful and economical compared to the sole plant of chickpea. Considering all intercropping indices, chickpea + fenugreek intercropping with a row ratio of 6:2 closely followed by chickpea + linseed (6:2) was found most economical and suitable having higher LER (1.20), CPEY (2396 kg/ha), LUE (119.3), ATER (1.18), aggressivity (0.53), RCC (4.52), SPI (2208), higher net return (Rs 96,170/ha), and BCR (3.79) and hence was concluded as the most economical and suitable intercropping system for chickpea crop. So, to obtain better crop yield, more land use efficiency, and higher economic return, the chickpea growers may go for intercropping of chickpea with fenugreek with a row ratio of 6:2 instead of sole chickpea planting.

Table 1 Competition and economic evaluation indices for different intercropping systems

Treatments	Seed yield (kg/ha)							Aggressivity		Net return (Rs/ha)	BCR	SPI
	CP	CP	LER	LUE	CPEY (kg/ha)	ATER	RCC	CP	IC			
Sole chickpea	1851	–			1851					85,346	3.48	
Sole fenugreek	–	2159			2540					99,511	3.73	
Sole linseed	-	1708			1843					59,608	2.59	
Sole raya	–	3040			2771					94,724	2.62	
CP + Fenugreek (4:4)	946	1011	1.00	98.9	2137	0.97	1.70	0.02	–0.02	80,606	3.34	1824
CP + Fenugreek (5:3)	1282	869	1.13	112.0	2305	1.11	2.03	0.27	–0.27	91,041	3.64	2074
CP + Fenugreek (6:2)	1528	734	1.20	119.3	2396	1.18	4.52	0.53	–0.53	96,170	3.79	2208
CP + Fenugreek (3:5)	694	1375	1.08	106.3	2313	1.05	0.69	–0.28	0.28	89,250	3.60	1979
CP + Fenugreek (2:6)	529	1587	1.10	108.1	2392	1.06	0.77	–0.52	0.51	93,018	3.71	2040
CP + Linseed (4:4)	1080	944	1.13	112.8	2098	1.12	3.66	0.01	–0.01	76,851	3.13	2090
CP + Linseed (5:3)	1327	765	1.14	113.6	2153	1.13	2.60	0.27	–0.27	81,925	3.30	2124
CP + Linseed (6:2)	1600	534	1.16	115.8	2177	1.14	4.32	0.56	–0.56	83,764	3.37	2149
CP + Linseed (3:5)	681	1049	0.98	98.5	1812	0.98	1.09	–0.23	0.23	60,672	2.67	1813
CP + Linseed (2:6)	522	1200	1.00	99.4	1817	0.99	1.00	–0.46	0.46	60,141	2.63	1847
CP + Raya (4:4)	566	1936	0.94	92.7	2331	0.90	1.04	–0.16	0.16	83,055	2.79	1746
CP + Raya (5:3)	588	1613	0.86	85.0	2060	0.83	0.64	–0.00	0.00	70,927	2.63	1555
CP + Raya (6:2)	661	1435	0.83	81.7	1970	0.80	0.53	0.14	–0.14	68,911	2.70	1500
CP + Raya (3:5)	380	2099	0.91	89.4	2294	0.87	0.73	–0.35	0.35	77,441	2.57	1616
CP+ Raya (2:6)	287	2189	0.90	88.1	2283	0.85	0.71	–0.51	0.51	74,212	2.41	1586
CD at 5%	224		0.09	9.5	650	0.11	0.48	0.20	0.21	21,305	0.67	376
SEm+	77		0.02	3.2	225	0.03	0.16	0.07	0.07	7398	0.23	129

CP = Chickpea, IC = Intercrop, LER = Land equivalent ratio, LUE = Land use efficiency, CPEY = Chickpea equivalent yield, ATER = Area time equivalent ratio, RCC = Relative crowding coefficient, BCR = Benefit-cost ratio, SPI = System productivity index.

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6.35 Prevalence of Chickpea Wilt in Jammu Subtropics

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Keywords: *Fusarium oxysporum* f. sp. cicero; Incidence; Pathogenicity; Spore; Survey; Symptom

1. Introduction

Pulse crops are an important source of food proteins, vitamins, lipids, and certain minerals and are generally grown under risk-prone marginal lands. This crop is being extensively grown in more than 50 tropical and sub-tropical countries in the world as a major winter crop (Gaur *et al*., 2014). Fusarium wilt has become a major threat to chickpea productivity and the yield losses range 10–90% depending upon the severity of the disease. India is the largest producer of chickpea in the world covering 79% of the total area and 67% of production. In Jammu and Kashmir, chickpea ranks first among *Rabi* pulses and occupies an area of 4.0 thousand hectares with a productivity of 6.27 q/ha.

2. Materials and methods

The field experiments of the present investigation on the wilt of chickpea were conducted at the Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha situated at 32.43°N latitude, 74.54°E longitude and 327 m above sea level during *Rabi* 2016-17 and 2017-18 cropping seasons. The laboratory experiments were conducted in the Division of Plant Pathology, SKUAST-Jammu. A survey of different chickpea growing areas of Jammu, namely, Jammu, Samba, and Kathua districts, during *Rabi* 2016-17 and 2017-18 at the fortnightly interval was done and percent disease incidence was calculated using the following formula:

$$\text{Percent disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total number of plants examined}} \times 100$$

During field surveys, diseased chickpea plants were collected from different districts, namely, Jammu, Samba, and Kathua of the Jammu Division during the *Rabi* 2016-17 and 2017-18 crop seasons. The colony and morphological characteristics were conducted to identify the pathogen. The 50 isolates were subjected to virulence analysis on chickpea (cultivar C 235) to prove pathogenicity. Pre-sterilized soil was inoculated with a pure culture grown on corn-sand (1:1) medium at the rate of 20 g and 10 seeds per pot of susceptible chickpea variety C-235 were planted.

3. Results and discussion

Extensive fortnightly surveys were conducted and the overall range of disease incidence in the Jammu division was found to be between 8.11–21.67% and 10.98-23.99%, respectively, with an overall mean disease incidence of 15.64 during 2016-17 and 16.86% during 2017-18 (Table 1). Many workers have reported chickpea wilt throughout the crop season with maximum incidence and damage in the chickpea crop at the seedling stage than at maturity and the disease was prevalent in all the chickpea growing areas surveyed. The fungus was identified by the color of the mycelia, the number of micro and macro conidia, and so on under the compound microscope. Colony color in most of the isolates (Foc-1, Foc-18, Foc-28, Foc-34, Foc-37, Foc-38, Foc-41, and Foc-43) was initially white and kept on changing with time and final color, slightly purplish with discrete orange colored pigmentation. The pathogenicity test of *F. oxysporum* f. sp. *ciceri* (Foc) isolates causing chickpea wilt was conducted on susceptible chickpea cultivar (C-235) grown in sterilized pot soil at the seedling stage. The findings are also in consonance with the studies of Patra and Biswas (2017) on cultural, morphological, and pathogenic variability among the 11 isolates of *F. oxysporum* f. sp. *ciceri* causing wilt of chickpea.

Table 1 Prevalence of chickpea wilt in Jammu subtropics during *Rabi* 2016-17 and 2017-18

District	Block	Location	Disease incidence (%)		
			2016-17	2017-18	Pooled
Jammu	Bishnah	Deoli	15.32	16.78	16.04
		Dhabad	20.18	20.97	20.57
		Pataidi	17.98	18.87	18.42
		Mean±S.E.	17.82±1.93	18.87±1.72	18.34±0.05
		Range	15.32–20.18	16.78–20.97	16.04–20.57
	Satwari	Panotra Chak	12.98	14.87	13.92
		Sohanjna	18.89	19.98	19.43
		Chatha	21.67	23.99	22.83
		Mean±S.E.	17.84±2.56	19.61±2.63	18.72± 0.18
		Range	12.98–21.67	14.87–23.99	13.92–22.83
	Akhnoor	Lehar	20.76	21.54	21.15
		Palori	14.87	15.98	15.42
		Pangiari	17.11	18.99	18.04
		Mean±S.E.	17.58±1.72	18.83±1.60	18.20±0.05
		Range	12.98–21.67	14.87–23.99	15.42–21.15
Samba	Vijaypur	Chhanni	17.90	18.94	18.41
		Dhiansar	20.76	21.98	21.36
		Salmeri	15.87	16.10	15.98
		Mean±S.E.	18.17±1.42	19.00±1.70	18.58±0.41
		Range	15.87–20.76	16.10–21.98	15.98–21.36

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	Samba	Nanke	16.98	17.98	17.47
		Sumb	18.77	19.47	19.11
		Rakh	15.54	16.09	15.81
		Mean±S.E.	17.09±0.93	17.84±0.97	17.46±0.02
		Range	15.54 – 18.77	16.09 – 19.47	15.81-19.11
	Ghagwal	Ragu Chak	19.98	20.98	20.35
		Sanoora	11.46	12.89	12.17
		Harsat	15.99	16.67	16.33
		Mean±S.E.	15.81±2.46	16.84±2.33	16.28±0.00
		Range	11.46–20.76	12.89–21.98	12.17–20.35
Kathua	Hiranagar	Kootah	8.11	10.98	9.54
		Jatwal	10.67	12.87	11.76
		Tokal	11.32	12.76	12.03
		Mean±S.E.	10.03±0.98	12.20±0.61	11.11±0.04
		Range	8.11–11.32	10.98–12.87	9.54–12.03
	Barnoti	Budhi	11.87	12.65	12.25
		Sonthal	13.45	14.98	14.21
		ChhannRorian	15.44	16.34	15.88
		Mean±S.E.	13.58±1.03	14.65±1.07	14.11± 0.03
		Range	11.87–15.44	12.65–16.34	12.25–15.88
	Kathua	Rajbagh	14.78	15.54	15.15
		Lagate	12.45	13.67	13.05
		Hatli	11.45	12.67	12.05
		Mean±S.E.	12.89±0.98	13.96±0.84	13.41±0.00
		Range	8.11–15.44	10.98–16.34	12.05–15.15
		Overall mean	15.64	16.86	16.25
		Overall range	8.11–21.67	10.98–23.99	9.54–22.83

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6.36 Production of Broccoli (*Brassica oleracea* var. *italica*) under Organic Management

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Keywords: Biofertilizers; Broccoli; Nutrient Dynamics; Organic Manures; Seed Production

1. Introduction

Broccoli (*B. oleracea* var. *italica*) belongs to the family Brassicaceae. In India, it is mostly cultivated in hilly areas of Himachal Pradesh, Uttar Pradesh, Nilgiri Hills, and the Northern plains of India (Shankar *et al*., 2019). In the Jammu region of J&K UT, this crop is gaining popularity among consumers and farmers are growing it as an exotic vegetable crop. It is generally a high nutrient demanding crop and any kind of nutrient stress during the critical growth and development stages of broccoli affects the entire morphological, yield, and seed-related traits of the crop. Organic farming is one such strategy that not only ensures food and environmental safety but also adds to the biodiversity of the soil. Organic farming, which largely avoids the use of synthetic fertilizers, pesticides, insecticides, other chemicals, and so on, depends largely on the application of biofertilizers, bulk organic manures for nutrition, and biopesticides for managing insect pests and diseases. The application of biofertilizers to the soil increases soil microflora which constitutes all kinds of useful bacteria, fungi, and nitrogen fixers. On the other hand, biopesticides are derivatives that include a wide range of microbial pesticides, biochemicals obtained from microorganisms, and other natural sources to provide pest resistance based on pathogenic microorganisms.

2. Materials and methods

The experiment was carried out at Vegetable Block, Organic Farming Research Centre, SKUAST-J during the winter season 2020-21. The soil was loamy in texture, slightly alkaline in pH (7.79), and medium in organic carbon (1.0%) and available nitrogen (194.7 kg/ha) while the medium in phosphorus (18.68 kg/ha) and potassium (175.4 kg/ha). Jammu Broccoli-07 variety was used for the experimentation. The trial was laid out in randomized block design with three factors, namely, biofertilizers (B_1: *Azotobacter* + Phosphate Solubilizing Bacteria + Potassium Mobilizing Bacteria; B_2: *Azospirillum* + Phosphate Solubilizing Bacteria; and B_3: Organic Liquid consortia-NPK), organic manures (M_1: vermicompost and M_2: FYM), and biopesticides (P_1: Neem oil + *Beauveria bassiana* and P_2-NSKE (5%) + *Bacillus thuringiensis* (Bt)] and their combinations. 30-day-old healthy seedlings of uniform shape and size were transplanted in well-prepared experimental plots size of 3 m × 3 m on ridges at a spacing of 60 × 45 cm.

3. Results and discussion

The individual application of biofertilizers, organic manures, and biopesticides showed a significant influence on morphological and yield parameters like plant height, days to 50% curd initiation, days to 50% curd maturity, weight of lateral shoots/plant, curd weight/plant and yield (Table 1). Among biofertilizers, B_1 (*Azotobacter* + Phosphate Solubilizing Bacteria + Potassium Mobilizing Bacteria) recorded maximum morphological and yield parameters which were statistically highest as compared to B_2 and B_3. Maximum plant height (49.48 cm), minimum days to 50% curd initiation (64.75 days), minimum days to 50% curd maturity (79.75 days), a maximum weight of lateral shoots/plant (152.18 g), maximum curd weight/plant (291.61 g), and maximum yield (97.21 q/ha) were recorded. This might be due to the ability of biofertilizers to help in secretions of growth-promoting substances which may lead to better root development, transportation of water, and proper uptake and decomposition of nutrients. In the case of organic manures, M_2 (FYM) recorded maximum plant height (49.64 cm), minimum days to 50% curd initiation (66.67 days), minimum days to 50% curd maturity (81.67 days), a maximum weight of lateral shoots/plant (148.92 g), maximum curd weight/plant (256.42 g), and maximum yield (99.24 q/ha), which was statistically highest as compared to M_1. Biopesticides, P_1 (Neem oil + *B. bassiana*) recorded maximum plant height (48.21 cm), minimum days to 50% curd initiation (65.83 days), minimum days to 50% curd maturity (80.83 days), a maximum weight of lateral shoots/plant (145.13 g), maximum curd weight/plant (289.85 g), and maximum yield (96.62 q/ha). Among the interaction of biofertilizers and organic manures, $B_1 \times M_2$ [(*Azotobacter* + Phosphate Solubilizing Bacteria + Potassium Mobilizing Bacteria) × (FYM)] showed maximum plant height (52.29 cm), minimum days to 50% curd initiation (64.50 days), minimum days to 50% curd maturity (79.50 days), a maximum weight of lateral shoots/plant (156.86 g), maximum curd weight/plant (313.72 g), and maximum yield (104.57 q/ha), which was statistically highest as compared to other combinations. In case of interaction between biofertilizers and biopesticides, maximum plant height (50.98 cm), minimum days to 50% curd initiation (62.50 days), minimum days to 50% curd maturity (77.50 days), a maximum weight of lateral shoots/plant (152.93 g), maximum curd weight/plant (305.86 g), and maximum yield (101.95 q/ha) were recorded in $B_1 \times P_1$ [(*Azotobacter* + Phosphate Solubilizing Bacteria + Potassium mobilizing Bacteria) × (Neem oil + *B. bassiana*)]. This was statistically highest as compared to all other combinations.

Among the interaction of all the three factors, maximum plant height (54.79 cm), minimum days to 50% curd initiation (62.00 days), minimum days to 50% curd maturity (77.00 days), a maximum weight of lateral shoots/plant (164.36 g), maximum curd weight/plant (328.72g), and maximum yield (109.75 q/ha) were recorded in $B_1 \times M_2 \times P_1$ [(*Azotobacter* + Phosphate Solubilizing Bacteria + Potassium Mobilizing Bacteria) × (FYM) × (Neem oil + *B. bassiana*)], which were statistically highest as compared to all the other combinations.

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Table 1 Effect of biofertilizers, organic manures, and biopesticides on growth and yield of broccoli

Treatments	Plant height (cm)	Days to 50% CI (DAT)	Days to 50% CM (DAT)	Weight of lateral shoots/plant (g)	Curd weight/plant(g)	Curd yield (q/ha)
B1	49.48	64.75	79.75	152.18	291.61	97.20
B2	47.03	68.50	83.50	144.58	277.79	92.60
B3	42.54	71.50	86.50	131.38	250.00	83.33
CD(0.05)	2.20	1.78	1.78	6.60	13.20	4.40
SE(m)±	0.75	0.61	0.61	2.25	4.50	1.50
M1	43.06	69.83	84.83	137.17	284.54	82.85
M2	49.64	66.67	81.67	148.92	297.73	99.24
CD(0.05)	1.79	1.45	1.45	5.39	10.78	3.59
SE(m)±	0.61	0.49	0.49	1.84	3.68	1.23
P1	48.21	65.83	80.83	145.13	289.85	96.62
P2	44.29	70.67	85.67	140.96	256.42	85.47
CD(0.05)	1.80	1.45	1.45	N/S	10.78	6.22
SE(m)±	0.61	0.49	0.49	1.84	3.68	2.12
BXM						
B1XM1	46.67	65.00	80.00	147.50	269.50	89.83
B2XM1	44.93	70.50	85.50	142.78	261.16	87.05
B3XM1	37.58	74.00	89.00	120.23	214.96	71.65
B1XM2	52.29	64.50	79.50	156.86	313.72	104.57
B2XM2	49.13	66.50	81.50	146.38	294.43	98.14
B3XM2	47.51	69.00	84.00	142.52	285.04	95.01
CD(0.05)	3.11	2.51	2.51	9.33	18.67	6.22
SE(m)±	1.06	0.86	0.86	3.18	6.37	2.12
BXP						
B1XP1	50.98	62.50	77.50	152.93	305.86	101.95
B2XP1	46.86	67.00	82.00	142.08	282.93	94.31
B3XP1	46.79	68.00	83.00	140.38	280.75	93.58
B1XP2	47.98	67.00	82.00	151.43	277.36	92.45
B2XP2	47.19	70.00	85.00	149.08	272.66	90.89
B3XP2	38.29	75.00	90.00	122.38	219.25	73.08
CD(0.05)	3.11	2.51	2.51	9.33	18.67	6.22
SE(m)±	1.06	0.86	0.86	3.18	6.37	2.12
MXP						
M1XP1	44.78	68.67	83.67	135.34	270.07	90.02
M2XP1	51.64	63.00	78.00	154.92	309.62	103.21
M1XP2	47.33	71.00	86.00	139.00	227.01	75.67
M2XP2	47.64	70.33	85.33	142.92	285.84	95.28
CD(0.05)	NS	2.05	2.05	7.62	15.25	5.08
SE(m)±	0.86	0.70	0.70	2.60	5.20	1.73
BXMXP						
B1XM1XP1	47.17	63.00	78.00	141.50	283.00	94.33
B2XM1XP1	43.59	70.00	85.00	133.78	265.76	85.59
B3XM1XP1	43.58	73.00	88.00	130.73	261.46	87.15
B1XM2XP1	54.79	62.00	77.00	164.36	328.72	109.57
B2XM2XP1	43.59	64.00	79.00	150.38	300.09	100.03
B3XM2XP1	50.01	63.00	78.00	150.02	300.04	100.01
B1XM1XP2	46.17	67.00	82.00	153.50	256.00	85.33
B2XM1XP2	46.26	71.00	86.00	153.78	256.56	85.52
B3XM1XP2	31.58	75.00	90.00	109.73	168.46	56.15
B1XM2XP2	49.79	67.00	8200	149.36	298.72	99.57
B2XM2XP2	48.13	69.00	84.00	144.38	288.76	96.25
B3XM2XP2	45.01	74.00	89.00	135.02	270.04	90.01
CD(0.05)	4.40	3.55	3.55	13.20	26.41	8.80
SE(m)±	1.5	1.21	1.21	4.50	9.00	3.00

Reference

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6.37 Knowledge and Adoption of the Small Ruminant Breeders of J&K Regarding Improved Small Ruminant Meat Production Practices

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Keywords: Adoption; Chevon; Constraints; Goat; Knowledge; Mutton; Sheep

1. Introduction

All over the world, small ruminants, that is, sheep and goats are reared primarily for meat, wool, milk, and hide. Among the top 20 exported commodities of the world, sheep meat ranks 13th with a value of about $2.5 billion (FAOSTAT, 2014). Small ruminants contribute significantly to the livelihood of a large population in low-input, smallholder production systems. The contribution of livestock to the economy of Jammu and Kashmir is quite significant. Meat consumption is often an indicator of the economic status of a country or an individual. The domestic meat demand is believed to increase with increasing literacy and family income. People with a higher social or economic status demand a greater amount of high-quality meat products (Birthal and Joshi, 2006). However, due to a mismatch in demand and supply of mutton, the import of sheep and goats to Jammu and Kashmir is continuously increasing from the neighboring states.

2. Materials and methods

The study with an exploratory research design was conducted in Jammu and Kashmir union territory to investigate the reasons for this mismatch in demand and supply of mutton and chevon. A pretested interview schedule was developed and data were collected through a personal interview technique by employing a multistage sampling procedure to access the knowledge and adoption of the small ruminant breeders of J&K regarding improved small ruminant production practices. For the purpose of the present study, a standardized knowledge test was developed and the items with difficulty index ranging from 20 to 80 and discrimination index ranging from 0.10 to 0.80 were retained for final selection for inclusion in the knowledge check. A total of 24 items were finally selected for the knowledge test. Knowledge was scored as '1' for correct answer and '0' for wrong answer. The adoption was measured in terms of the percentage of small ruminant farmers of the state adopting a particular practice in the study area.

Jammu division and Kashmir division were selected for the study, as advised by the Sheep Husbandry Department, Jammu and Kashmir. A list of districts from the selected divisions where small ruminant meat production is being done was prepared with the help of the Sheep Husbandry Department of Jammu and Kashmir. Out of this list, two districts from the Jammu division and two districts from the Kashmir division were selected randomly without replacement. Thus, a total of four districts were selected for the study. A list of blocks, where small ruminant meat production is being done, was prepared in consultation with the field functionaries of the selected four districts.

Two blocks, from each of the selected four districts, were selected randomly without replacement from the list. Thus, a total of eight blocks were selected for the study. In each selected block, a list of villages was prepared where small ruminant meat production was being practiced. Two villages were selected randomly without replacement from each selected block and a total of 16 villages were selected for the study. The ultimate unit of the sample (respondents) was selected randomly without replacement. For each selected village, a list of small ruminant farmers was obtained from the flock managers and assistant stock managers (ASMs) of the respective villages. Fifteen respondents were selected from each of these 16 selected villages. Thus, a total of 240 small ruminant farmers belonging to Kathua, Rajouri, Anantnag, and Baramulla districts were selected for the study. A small ruminant farmer with a minimum of 20 sheep or goats was the respondent. The data are presented division wise to know the difference in knowledge and adoption between the respondents of the two divisions of UT.

3. Results and discussion

The overall age of the respondents was about 46 years with an experience of nearly 17 years in sheep husbandry. The majority of the respondents (53.3%) were illiterate and had a migratory lifestyle (97.9%). The majority of the respondents from the Jammu division (81.7%) belonged to the scheduled tribe category, whereas most respondents from the Kashmir division (71.7%) were not from any reserved social category ($\chi^2 = 165.2$, $p = 0.0000$). The overall average knowledge score was 9.47±0.23 and the knowledge index was 39.46% (knowledge gap = 60.54). The majority of the respondents (53.3%) had low knowledge followed by the medium level (35.4%). The respondents were having the least knowledge of breeding practices (30.53%), followed by feeding practices (37.67%). There was a significant difference in the knowledge of the respondents between the divisions as shown in Table 1 ($t = -2.7642$, $p = 0.0031$).

Table 1 Practice wise knowledge index regarding improved small ruminant meat production practices

Practice	Division		Overall knowledge index ($n = 240$)	t value/p value
	Jammu ($n = 120$)	Kashmir ($n = 120$)		
Management	36.66	41.81	39.23	–2.0954/(0.0186)*
Feeding	34.17	41.16	37.67	–2.8904/(0.0021)**
Breeding	26.83	34.33	30.53	–2.7826/(0.0029)**
Health care	45.00	47.60	46.30	–1.1347/(0.1288)NS
Overall	36.88	42.05	39.46	–2.7642/(0.0031)**

*Result is significant at $p < .05$. **Result is significant at $p < .01$. NS = Non-significant.

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None of the respondents were isolating new animals from the flock for at least 30 days nor were giving vitamin A supplements to the pregnant ewes. The least adopted breeding practices were not using the same ram for more than 2 years (14.2%) and not allowing inbreeding within the flock (23.8%). Low adoption was also found for maintaining an antiseptic footbath at the shed entrance (3.3%). None of the respondents were practicing dipping. Age, experience, and family size were negatively and significantly related to the knowledge. Education, extension contact, mass media exposure, risk orientation, and economic motivation were positively and significantly associated with both the knowledge adoption.

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6.38 Mean Performance for Various Traits and Organoleptic Test in Local Cucumber (*Cucumis sativus* L.) Under Subtropical Plains of Jammu

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Keywords: Cucumber; Hedonic scale; Mean performance; Organoleptic test

1. Introduction

Cucumber (*C. sativus* L., 2*n* = 2x = 14), also named 'Khira', belongs to the family Cucurbitaceae and is a warm season vegetable crop grown worldwide in both open and protected conditions. The center of origin of cucumber is India and *C. sativus* L. *var. hardwickii*, a wild relative of cucumber, is its progenitor. It is grown for its tender fruits, which are consumed raw as salad, cooked as a vegetable, or as pickling cucumber in its immature stage. Of late, cucumber production has suffered a lot due to insect pests and diseases during the summer months in the subtropical plains of Jammu. So, there is a great demand for screening local/desi cucumber germplasm to select elite genotypes with improved quality and higher yield for direct selection or use as a parent in the hybridization programme. Since a considerable amount of variability exists in this crop, a germplasm collection is essential for any rational plant breeding programme. Though there is a wide range of genetic variability available in India, not much attention has been given to the genetic improvement of local cucumber. Keeping these points in consideration, the present investigation was formulated to identify good performers with wider acceptability.

2. Materials and methods

The experimental material comprised 21 diverse genotypes of local cucumber collected from different areas of J&K and the study was carried out in Vegetable Experimental Farm-I, Division of Vegetable Science & Floriculture, SKUAST-Jammu during 2018-19. The sowing in the nursery was done in the month of January 2019 in polybags under protected conditions and healthy seedlings were transplanted in randomized complete block design with three replications in March 2019. The observations were recorded on various characters, namely, days to 50% flowering, days to first female flowering, node number at which first female flower appears, days to first harvest, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits/vine, vine length (m), number of seeds/fruit, 1000 seed weight (g), total soluble solids (°brix), fruit yield/vine (kg), and fruit yield/hectare (q/ha). The averaged values of all the four plants of various genotypes were subjected to statistical analysis at the computer laboratory of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu and were analyzed.

3. Results and discussion

The analysis of variance showed significant variations among the genotypes for all the traits under study, indicating the existence of an ample amount of variability among genotypes. Genetic variability is the basic need for a plant breeder to initiate any breeding programme. The mean performance of different traits indicated that genotypes, namely, Cucumber Selection-8 (2.24 kg), Cucumber Selection-3 (1.87 kg), Cucumber Selection-9 (1.87 kg), and Cucumber Selection-11 (1.73 kg), were high yielders with regard to fruit yield per plant. Cucumber Selection-16 (27.33 days) was found to be the earliest for days to 50% flowering and node number at which first female flower appears (4.42) while Cucumber Selection-17 (27.67 days) was found to be earliest for days to first female flowering and Cucumber Selection-7 (46.33 days) was found to be earliest for days to first harvest which determine the earliness of a genotype. Fruit length, fruit diameter, average fruit weight, and the number of fruits per vine are the major yield contributing traits, and wide variations were observed with respect to these traits. The highest total soluble solids was observed in Cucumber Selection-9 (4.00 °brix). This wide range of variations in the genotypes for various characters would help in selecting the best genotypes from existing germplasm. An organoleptic test is used to evaluate the quality of cucumber by a combination of taste (by mouth) and smell (by nose) by taste panels. Organoleptic test by sensory evaluation was done in various local cucumber genotypes based on their color, aroma, texture, taste, flavour, and overall acceptability of cucumber fruits based on the Hedonic scale (1–9) (Peryam and Pilgrim, 1957). In the present study for the organoleptic test, a committee was constituted comprising two Professors, one Associate Professor, two Assistant Professors, one Field Assistant from the Division and two PG students of different Divisions. Based on the scores given by the committee for 21 local cucumber genotypes, Cucumber Selection-5 was found to be the best for color based on sensory evaluation, which secured the highest score (7.67) based on the hedonic scale. In the case of aroma, Cucumber Selection-9 obtained the highest score (7.67) and in the case of texture, Cucumber Selection-5 obtained the highest score (7.67). The highest score for taste was observed in Cucumber Selection-9 (7.67). However, in the case of flavor, Cucumber Selection-9 obtained the highest score (7.67). Cucumber Selection-9 (7.67) got the best overall acceptability. These results are in line with the earlier work of Uthpala *et al*. (2018).

9-Point Hedonic Scale

9	Like Extremely
8	Like Very Much
7	Like Moderately
6	Like Slightly
5	Neither Like nor Dislike
4	Dislike Slightly
3	Dislike Moderately
2	Dislike Very Much
1	Dislike Extremely

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Theme 7

Innovations in Soil Health and Water Management

7.1 Effect of Different Nutrient Management Practices on Soil Properties in Sorghum+ Pearl Millet Cropping System

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Keywords: FYM; Integrated; Jeevamrit; Nitrogen

1. Introduction

Fodder sorghum (*Sorghum bicolor* (L.) Moench) and pearl millet (*Pennisetumglaucum* (L) R. Br.) are key Kharif crops with good herbage quality, palatability, and acceptability to ruminants in rainfed environments. The sole application of inorganic fertilizers impaired soil health. Therefore, if soil fertility and productivity are to be maintained in a sustainable manner, the concept of integrated nutrient management must be adopted. Organic sources help in improving organic matter content in the soil that improves the physical condition of the soil for better performance of microorganisms and physical status of soil by improving soil fertility and physical properties such as soil structure, aeration, porosity, infiltration rate, and water holding capacity, as well as decreasing soil crusting. With this in mind, as well as the higher nutrient requirements, limited availability, and higher cost of inorganic fertilizers for sorghum and pearl millet under rainfed fringes, the current study was framed.

2. Materials and methods

The current study took place in *Kharif*2019 at the Fodder Section, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experiment comprises of nine treatments, namely: 10tons/ha farm yard manure (FYM)+5% *Jeevamrit*, 10tons/ha FYM+10% *Jeevamrit*, 15tons/ha FYM+5% *Jeevamrit*, 15tons/ha FYM+10% *Jeevamrit*, 50% of recommended N+10tons/ha FYM+5% *Jeevamrit*, 50% of recommended N+10tons/ha FYM+10% *Jeevamrit*, 50% of recommended N+15tons/ha FYM+5% *Jeevamrit*, *50% of recommended N+15tons/ha FYM+10% Jeevamrit* and. recommended nitrogen (N), phosphorus (P), and potassium (K) were tested three times in a randomized block design. Organic liquid manure *Jeevamrit* was prepared on the farm. For 2 Lof *Jeevamrit* preparation, 100 g cow dung, 100 mL cow urine, 20 g jaggery, 20 g gram flour, 0.1 kg soil, and 2 L of water were added. The cow dung and cow urine were mixed in water in a bucket. Thereafter, to this liquid mixture jaggery, soil and gram flour were added and stirred well with the help of a stick to ensure complete mixing of all the ingredients. This liquid mixture was allowed to ferment for 48 h. After complete fermentation, two dilutions of 5% and 10% were prepared from this concentrated liquid mixture and applied in each treatment at the recommended rate of 500 L/ha.

3. Results and discussion

No appreciable effect of treatments was observed on soil pH and it remained in the acidic spectrum. A higher value of soil organic carbon than other treatments was recorded with the application of 50% recommended N+15 tons/ha FYM+10%*Jeevamrit*followed by 50%recommended N+15 tons/ha FYM+5%*Jeevamrit*, while the minimum value was recorded with the application of recommended NPK. A careful observation of the data revealed that integrated and sole organic nutrition application resulted in a higher value of organic carbon, microbial biomass carbon, and available N, P, and K in the soil as compared to the treatments that include the sole application of inorganic sources. The beneficial effect of the integrated use of inorganic fertilizers and organic manures was related to the incorporation of organic material in the soil, an increase in the number and activity of microorganisms, and better regulation of organic carbon dynamics in soils. A significant difference was observed between the values of all parameters in all integrated nutrient management practices and organic nutrient management as compared to recommended NPK. The integrated application not only increases the available nutrient status in soil but also helps in the mineralization of non available forms of nutrients already present in the soil. Yaduvanshi *et al.* (2013) also observed a significant increase in soil organic carbon content with the integrated use of FYM and recommended NPK in wheat and rice.

The research findings reveal that the integrated use of both organic and inorganic sources in the field improves the overall soil health status better than the sole application of organic sources and recommended NPK. Organic on-farm preparations such as *Jeevamrit* and *Beejamrit* should be used by farmers because these not only result in decreasing the cost of cultivation but also improve the soil'0s physical, chemical, and biological conditions.

Table 1 Effect of different nutrient management treatments on soil pH, organic carbon content (%), microbial biomass carbon (mg/kg), and soil available NPK (kg/ha)in sorghum+pearl milletcropping system

Treatment	pH	Organic carbon	Microbial biomass carbon	Available N	Available P	Available K
10 tons/ha FYM+5% *Jeevamrit*	5.1	0.90	38.4	201	11.22	129
10 tons/ha FYM+10% *Jeevamrit*	5.2	0.89	36.7	217	12.23	153
15 tons/ha FYM+5% *Jeevamrit*	5.1	0.91	36.4	220	15.67	187
15 tons/ha FYM+10% *Jeevamrit*	5.2	0.92	37.1	228	14.59	227
50% recommended N +10 tons/ha FYM+5% *Jeevamrit*	5.3	0.91	37.5	238	18.46	127
50% recommended N +10 tons/ha FYM+10% *Jeevamrit*	5.4	0.96	38.2	256	19.25	124
50% recommended N +15 tons/ha FYM+5% *Jeevamrit*	5.4	0.98	39.9	252	20.16	217
50% recommended N +15 tons/ha FYM+10% *Jeevamrit*	5.4	0.99	39.4	248	19.12	198
Recommended NPK	5.3	0.88	34.6	246	18.35	118
Initial values	5.2	0.90	33.4	229	16.02	156.70

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7.2 Effect of Foliar Application of Nano Urea on Productivity and Profitability of Fine Rice Under Irrigated Subtropics of Jammu Region

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Keywords: Nano urea; Nanoscale polymers

1. Introduction

Nano urea is a liquid formulation manufactured by Nano Biotechnology Research Center in association with Indian Farmers Fertiliser Cooperative Limited. It contains nanoscale nitrogen particles (55,000 nanoparticles) with a high surface area(10,000 times over 1mm Urea prill). On foliar application, these small particles are delivered directly to the plant cell, thereby releasing nitrogen inside the cells as per the requirement in a phased manner, which ensures low and target efficient release for providing the nutrients to the crop and thus increasing nutrient use efficiency.

2. Materials and methods

The field experiment was conducted during Kharif, 2021 at the Research Farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, main campus Chatha, Jammu. Geographically, the experimental site is located at 320 40' N latitude and 740 58' E longitude with an altitude of 332 m above mean sea level in the Shivalik foothills of North-Western Himalayas. The soils of the experimental field are sandy loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen and potassium, and medium in available phosphorous. The DTPA extractable zinc is below a critical level. The experiment was laid out in a randomized block design with 10 treatment combinations, replicated thrice. Seedlings of Pusa Basmati-1121 were transplanted at a spacing of 20 cm × 10 cm during the second fortnight of July. The application of fertilizers was done in accordance with the treatments as per the technical program of the experiment. Moreover,17.18 kg/ha sulfur(S) was applied to the treatments T1, T5, and T9 to have uniformity in the nutrients applied to the crop.

Table 1 Effects of the foliar application of nanourea on productivity and profitability of fine rice

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Netreturns (Rs./ha)	B:C ratio
T1Recommended PKZn(25:15:4.3:kg/ha)	2673.62	3697.76	37,614.15	0.87
T250% recommended N+recommended PKZn (25:25:15:4.3kg/ha)	3568.01	4322.98	62,080.59	1.39
T3 75% recommended N+recommended PKZn(37.5:25:15:4.3kg/ha)	3797.69	4712.40	68,918.66	1.54
T4 100% recommended NPKZn (50:25:15:4.3kg/ha)	4006.65	5100.12	75,171.84	1.67
T5 Recommended PKZn (0:25:15:4.3kg/ha)+2FSNanoUreaeach@2mL/L of water	3567.99	4320.65	61,806.99	1.38
T650%recommendedN+recommended PKZn (25:25:15:4.3kg/ha)+2FSNanoUrea each@2mL/L of water	4182.12	5163.86	78,724.62	1.69
T775% recommended N +recommended PKZn (37.5:25:15:4.3kg/ha)+2FSNano Urea each @2mL/Lofwater	4207.34	5185.66	79,265.74	1.70
T8 100% recommended NPKZn (50:25:15:4.3kg/ha)+2FSNanoUreaeach@2ml/ litre of water	4215.09	5200.02	79,305.07	1.69
T9 Recommended PKZn(25:15:4.3kg/ha)+FSNanoUrea@4mL/L of water	3588.98	4324.65	63,039.15	1.42
T1050%recommendedN+recommended PKZn(25:25:15:4.3 kg/ha)+FSNanoUrea@4mL/Lofwater	4110.21	5151.63	77,322.45	1.68
Sem±	69.48	129		
CD(5%)	208.44	387.00		

DTPA: Diethylenetriamine pentaacetate

3. Results and discussion

Grain and straw yield (Table 1) of rice was significantly influenced by the foliar application of nano urea. It is inferred that treatment T8 (100% recommended NPKZn +2 foliar sprays of nanourea each @2mL/Lof water) recorded significantly higher grain yield (4215.09 kg/ha) and straw yield (5200.02 kg/ha) and this treatment was statistically at par with treatment T7 (75% recommended N+ recommended PKZn+2 foliar sprays of nanourea each @ 2mL/Lof water), T6 (50% recommended N+ recommended PKZn (25:25:15 kg/ha)+2 foliar sprays of nanourea each @ 2mL/Lof water), T10 (50% recommended N+ recommended PKZn (25:25:15 kg/ha)+foliar sprays of nanourea @4 mL/Lof water),and T4(100% recommended NPKZn). However, with regard to net returns and B:C ratio, 75% recommended N+ recommended PKZn+2 foliar sprays of nanourea each @2mL/Lof water recorded the highest net returns (Rs. 79,265.74/ha) and B:C ratio (1.70), which was followed by 50% recommended N+ recommended PKZn (25:25:15 kg/ha)+2 foliar sprays of nanourea each @2mL/Lof water with net returns of Rs. 78,724.62/ha and B:C ratio of 1.69, 100% recommended NPKZn +2 foliar sprays of nanourea each @2mL/Lof water with net returns of Rs. 79,305.07/ha and B:C ratio of 1.69, and 100% recommended N:P:K:Zn (50:25:15:20 kg/ha) recorded net returns of Rs. 75,171.84/ha and B:C ratio of 1.67.

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7.3 Benefits of Paddy Straw Management Technologies Used by Potato Growers in Jalandhar District of Punjab

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Keywords: Potato; Paddy Straw; Benefits

1. Introduction

Potato (*Solanum tuberosum*) is a major vegetable crop with a total cultivation area of 2.14 million hectares in India. Approximately 20 million tons of paddy straw was produced in Punjab alone which was not relished by animals because of its high silica content, due to which 80% of paddy straw produced was burnt on the fields for its management. It was considered a useful method for the management of paddy straw from the perspective of farmers. But with the burning of paddy straw in the fields, harmful gases were emitted which was one of the reasons for the environmental pollution. In addition to human and animal health hazards due to air pollution, it causes the loss of vital components such as nitrogen, phosphorus, sulfur, and potassium from the top soil layer, making the land less fertile and unviable for agriculture in the long run (Kaur *et al*., 2021). To solve the problem of burning, there are various alternative ways to manage paddy straw which are eco-friendly and also dispose of paddy straw at the proper time without delaying the sowing of the potato crop. Punjab Agricultural University recommended some alternate techniques such as Baler, Mulcher, Paddy straw chopper, Rotavator, and Mould board plough. It is crucial to study the economic and environmental benefits of paddy straw management technology in the sixth largest potato producing state in India, that is, Punjab.

2. Materials and methods

The present study was conducted in the Jalandhar district of Punjab. Jalandhar district was selected purposively for the study as it has the highest area under potato cultivation. A list of potato growers was obtained from the District Horticulture Department, Jalandhar. From that list, five blocks, namely, Nakodar, Adampur, Bhogpur, Jalandhar East, and Jalandhar West, having a maximum area under potato cultivation were selected. From these five blocks, a sample of 200 potato growers was selected by proportionate cum random sampling method. Benefits can be classified as environmental and economic benefits. Paired *t*-test was used to find out whether the differences in cost of production and yield of potato due to the adoption of paddy straw management technologies were significant.

3. Results and discussion

The result as given in Table 1 indicated that the *t*-values for the two-tailed significance levels of difference between sample means for the response was 0.000 cost of production due to the adoption of all the technologies by the potato growers. It showed that the adoption of paddy straw management technologies by potato growers resulted in a significant increase in the cost of production. The results also indicated that for yield, the *t*-values for two-tailed significance level of the difference between sample means for the response was 0.015 for the Baler, 0.327 for Rotavator, and 0.000 for Paddy straw chopper, Mulcher, and Mould board plough. The result showed that there was a significant increase in the yield of potatoes after the adoption of the Paddy straw chopper, Mulcher, and Mould board plough by potato growers. Thus, there were statistically significant differences observed in all five technologies used for paddy straw management in potatoes.

Table 1 Paired *t*-test on change in the cost of production and yield of potato after the adoption of paddy straw management technologies by potato growers

Paddy straw managing technology	n*	Cost of production (Rs/ha)					Yield (t/ha)				
			Mean	Difference	t-test	Sig (two-tailed)		Mean	Difference	t-test	Sig (two-tailed)
Baler	34	Before	2.102	1.502	8.736	.000	Before	5.023	3.683	2.565	.015
		After	3.605				After	8.707			
Paddy straw chopper	24	Before	1.126	8.408	5.119	.000	Before	1.068	1.583	6.612	.000
		After	1.967				After	1.084			
Mulcher	137	Before	6.359	5.015	14.628	.000	Before	1.060	1.005	6.019	.000
		After	1.137				After	1.070			
Rotavator	195	Before	1.00	6.22	9.149	.000	Before	1.083	.074	1.000	.327
		After	1.622				After	1.184			
Mould board plough	163	Before	1.002	1.068	9.914	.000	Before	6.228	5.093	7.323	.000
		After	2.070				After	1.135			

[*]Number of potato growers adopting a particular technology.

The potato growers observed changes in their soil and microclimate after using paddy straw management technologies in potatoes. The change in the soil such as soil becoming fertile was observed by 37% of potato growers. Only 5.5% of respondents found that the soil became leveled after using these technologies, and a decrease in air pollution after the adoption of paddy straw management technologies in the potato field was observed by 26.5% of potato growers. With the non-burning of paddy straw in the potato field, 6% of potato growers observed that the beneficial insects which are important for the soil survived in large amounts as compared to the burning of paddy straw. Eight percent of potato growers observed that after using paddy straw management technologies in the potato field, there was a decrease in irrigation in succeeding crops.

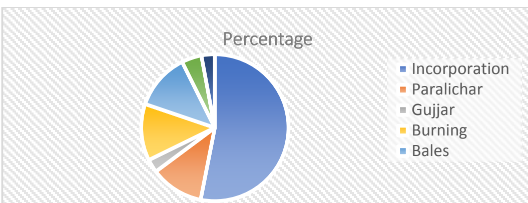

Figure 1 Paddy straw used by potato growers

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7.4 Scientific Rationality and Adoption of Indigenous Soil and Water Conservation in Kolli Hills, Tamil Nadu, India

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Keywords: Adoption; Indigenous Tribal Agricultural Practices; Rationality; Soil and water conservation

1. Introduction

In India, for more than millions of years, primitive tribes are living in forests and hills without having contact with outside world. Likewise, the Kolli Hills of Namakkal district of Tamil Nadu, with the inhabitant *Malayali* tribes, have been contingent on the utilization of various indigenous reserves and resources. This local community is most directly involved in soil and water conservation. There is an infinite need for the researcher to collate and rationalize the available Indigenous Tribal Agricultural Practices (ITAPs) on soil and water conservation before they totally vanish. The use and amalgamation of indigenous knowledge and the latest know-how assure the end user with appropriate need-based technology.

2. Materials and methods

This study was performed at Kolli Hills, situated in the Namakkal district of Tamil Nadu in India, encompassing 14 clusters of villages (population 37,462). Seven clusters of villages (population 20,541 and 3730 ITAP practicing farmers) were sorted out based on agricultural farming systems. The informal interviews facilitated the collection of details on indigenous practices associated with soil and water conservation from 20 aged farmers from each village and arrive at 28 ITAPs for further analysis. In the second phase, a rationality assessment was performed for nine selected ITAPs related to soil and water conservation which were then referred to the 50 agricultural engineering scientists and they were asked to rate them on a four-point continuum ranging from 4 to 1, using the scoring procedure followed by Venkatesan *et al.* (2016). The rationality of the individual ITAPs was computed based on the mean score from the total score specified. Then the ITAPs were categorized as rational and irrational. ITAPs were further analyzed for the extent of adoption from the sample of 30farmers, who were proportionately selected by random sampling from seven clusters of villages in Kolli Hills. The adoption score was arrived at by summing the scores obtained for all the ITAPs, and the adoption quotient, which was calculated by adopting the method followed by Venkatesan *et al.* (2016).

3. Results and discussion

The analysis is depicted in Table1, which does emphasis that out of 9 selected ITAPs on soil and water conservation,7 ITAPs (1,2,4,5,6,7, and 8) and 2 ITAPs (3 and 9) were adopted by >75% and 50–75% of the tribal farmers, respectively. Moreover, all the selected ITAPs on soil and water conservation were found to be scientifically rational. The ITAP 1 was adopted by 93.33% of the farmers to prevent soil erosion and conserve moisture in their own holding. ITAP 2 and ITAP 4 were followed by 86.67% of the farmers, as both do have good scientific rationality. ITAP 5 on *bench terracing* and ITAP 7 on *digging ditches* were having the adoption of 83.33%. Likewise, ITAP 6, on *soil bunds and stone bunds*, and ITAP 8, on *contour ploughing*, were having the adoption of 80% since they are the test verified and scientifically proven soil and water conservation methods followed in sloppy land. The above findings conform with that of Arora *et al*. (2022). The study found that all the ITAPs on soil and water conservation were rationale and were adopted by more than 50% of the tribal farmers. Hence, there should be further research on the validation of those. The rich knowledge of the tribes in soil and water conservation should be amalgamated with scientific knowledge and diffused in areas with similar edaphic and climatic factors. These soil and water conservation aspects can be incorporated into the watershed programs for further enhancement.

Table1 Scientific rationality and adoption pattern of ITAPs on soil and water conservation (*n*=30)

ITAPs on soil and water conservation	Rationality score	Adoption	
		No.	%
The stone bundsareraised along the rough contour lines and ploughingisdone across the slope in the terraced bed	3.54	28	93
Grasses such as*Andropogonsp.* and *Chrysopogonzizanioides* (vetiver) are grown on the bunds	3.70	26	87
Agave sp. and *Euphorbia tirucalli*are planted on the bunds and borders to check erosion and act as windbreaks too	3.56	20	67
Crops such ascoconut, banana, jackfruit, and mango are grown on the bunds of wet and garden lands to serveto conserve soil and water	3.20	26	87
Bench terracing was done by transforming relatively steep land into a series of level strips across the slope of the land	3.53	25	83
Soil bunds and stone bunds are raised to a height of about 1–2 m in red soil areas	3.51	24	80
Ditches are dug in the field for the purpose of holding impounded water. This enriches the groundwater and compensates for the evaporation loss	3.65	25	83
Heaping, minimum tillage, and contour ploughing are practiced for soil and water conservation	3.70	24	80
Agave helps in soil conservation due to soil binding characteristics	3.65	17	57

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7.5 Potential of *Eisenia foetida* for Preparing Vermicompost and its Effect on Yield of Maize

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Keywords: Maize; Vermicompost; Yield

1. Introduction

The rapidly rising population, intensive farming, and industrialization play a significant role in waste generation. According to the World Bank, the total production of waste will reach 3.40 billion metric tons by 2050 (Iqbal *et al*., 2021). Along with the waste generation, on-farming burning and increased use of chemical fertilizers in agriculture lead to deterioration of soil structure, groundwater pollution, environmental pollution, and health hazards. Vermicomposting is a profitable technology that involves the handling of organic leftovers by the process of decomposition in an eco-friendly way to a stage that can be reserved, managed, and utilized in agricultural fields without any negative effects.

2. Materials and methods

The study was conducted at Punjab Agricultural University, Ludhiana, India. The organic residues such as paddy straw (*Oryza sativa*), neem leaves (*Azadirachta indica*), and dhaincha leaves (*Sesbania bispinosa*) were used for the preparation of vermicompost in cemented pits (0.9 × 0.9 × 0.9 m^3) with cow dung in the ratio of 1:1. One kg earthworm (*E. foetida)* was used for the study. The organic residues were used on a dry weight basis. The prepared vermicompost from different residues was tested on maize crops. The different treatments chosen for the study were control, RDF (recommended dose of fertilizer), RDF+FYM, 100% N through vermicompost prepared from paddy straw, 100% N through vermicompost prepared from neem leaves, 100% N through vermicompost prepared from dhaincha leaves and cow dung vermicompost. The maize variety PMH 1 was sown in the first fortnight of July for 2 years (*Kharif* season) with a recommended package of practices of PAU. Statistical analysis of the different parameters was analyzed with the help of the analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) for randomized block design using CPCS1 software (Cheema and Singh, 1991). The data were compared with a significance level of 5%.

3. Results and discussion

The maximum harvest productivity (65.38%) was observed in cow dung vermicompost treatment. The neem leaves vermicompost had taken lesser days (52 days) for preparation. The maximum nutrient content was observed in dhaincha leaves vermicompost. The 2-year maize grain yield data varied from 31.1 to 56.6 q/ha during the first year and from 32.4 to 57.2 q/ha in the second year. Maximum grain yield was found in integrated nutrient management treatment during both years. Paddy straw, neem leaves, dhaincha leaves, and cow dung vermicompost treatments showed a significant difference of 37.6%, 52.5%, 47.5%, and 39.7% from the control treatment. Similarly, increased average stover yield was recorded with integrated nutrient management treatment (95.4 q/ha). Paddy straw (74.7%), neem leaves (85.1%), dhaincha leaves (84.6%), and cow dung (78.3%) vermicompost treatments represented a significant increase over control treatment. The results in terms of improvement in crop growth and yield might be recorded as significantly higher with the continuous application of organic fertilizers to the soil for further several years. The conversion of organic waste through the vermicomposting process is of multifaceted significance, as it is linked to monitoring pollution of the environment by avoiding on-farm burning and waste production as well as generating profit from the farm waste by converting it into nutrient-rich manure, improving soil properties by recycling the nutrients, and enhancing crop yield.

Table 1 Effect of inorganic fertilizer and vermicompost application on maize grain and stover yield

Treatments	Grain yield (q/ha)			Stover yield (q/ha)		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Control	31.1	32.4	31.8	43.2	45.9	44.6
RDF	52.3	54.8	53.5	84.4	87.2	85.8
RDF+FYM	56.6	57.2	56.9	93.3	97.4	95.4
{Paddy straw+Cow dung (1:1)}+1 kg earthworms	41.7	45.7	43.7	74.1	81.6	77.8
{Neem leaves+Cow dung (1:1)}+1 kg earthworms	43.8	52.9	48.4	77.8	87.2	82.5
{Dhaincha leaves+Cow dung (1:1)}+1 kg earthworms	42.7	51.0	46.9	77.6	87.0	82.3
{Cow dung (100%)}+1 kg earthworms	42.4	46.4	44.3	76.2	82.8	79.5
CD (*p*=0.05)	**5.3**	**4.7**	**3.3**	**5.0**	**3.9**	**3.0**

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7.6 Effects of Integrated Nutrient Management on Seed Quality of Field Pea During Ambient Storage

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Keywords: INM; Rhizobium; Seed quality; Vigor

1. Introduction

The quality seed has a major role in agricultural production. In recent years, it is realized that organic nutrient sources as compared to inorganic fertilizers produce higher seed yields with improved quality. Therefore, in order to improve the quality of seeds, nutritional management practices need to be adopted. Integrated nutrient management holds great assurance in meeting the growing nutrient demands of intensive agriculture without deteriorating soil health besides improving seed quality and storability.

2. Materials and methods

The research experiment was performed during 2015–2017 at the Department of Seed Science & Technology, CCS Haryana Agriculture University, Hisar, Haryana. The freshly harvested seeds of the field pea variety 'HFP 529' were kept in plastic containers at ambient room temperature for up to a period of 15 months and evaluated for seed quality parameters in a completely randomized design (CRD) at an interval of 5 months. The biofertilizers (*Rhizobium* and phosphorus solubilizing bacteria (PSB)) were used as seed treatment @50 mL/10 kg of seed while farmyard manure (FYM) and vermicompost were used @20 and 5 t/ha, respectively. The recommended dose of fertilizers (RDF – 20 kg N+40 kg P_2O_5+0 kg K_2O per ha) was applied as per the treatment details. The samples were analyzed for key characteristics, namely, germination per cent, dry weight, seedling length, vigor index I, vigor index II, and electrical conductivity. Treatment details are given below:

T_0: Control, T_1: *Rhizobium*+100% FYM, T_2: *Rhizobium*+75% FYM, T_3: *Rhizobium*+100% Vermicompost, T_4: *Rhizobium*+75% Vermicompost, T_5: *Rhizobium*+100% RDN, T_6: *Rhizobium*+75% RDN, T_7: PSB+100% FYM, T_8: PSB+75% FYM, T_9: PSB+100% Vermicompost, T_{10}: PSB+75% Vermicompost, T_{11}: PSB+100% RDN, T_{12}: PSB+75% RDN, T_{13}: *Rhizobium*+PSB+100% FYM, T_{14}: *Rhizobium*+PSB+75% FYM, T_{15}: *Rhizobium*+PSB+100% Vermicompost, T_{16}: *Rhizobium*+PSB+75% Vermicompost, T_{17}: *Rhizobium*+PSB+75% RDN, and T_{18}: RDF.

3. Results and discussion

In the present study, the standard germination percentage showed a significant decline during ambient storage. The maximum decline was recorded after 15 months of natural storage in all the treatment combinations. However, the maximum germination percentage (88.33) after 15 months of ambient storage of field pea seed was noted in the treatment amalgamation of *Rhizobium*+PSB+75% recommended dose of nitrogen (RDN) (15 kg N per ha) (T_{17}), followed by 87.67 in *Rhizobium*+100% RDN (T_5).

It might be because seed development is assisted by biofertilizers combined with nitrogen, resulting in better food reserves such as protein and carbohydrates. The highest seedling length (26.60 cm) after 15 months of ambient storage was recorded with treatment T_{17}, while the shortest length (13.37 cm) was recorded in control (T_0). Among all the treatments, T_{17} showed the highest dry weight of seeding after 15 months of natural aging in the treatment combination of *Rhizobium*+PSB+75% RDN and *Rhizobium*+100% RDN (0.41 g). A potential reason could be that field pea plants are nourished by *Rhizobium* and PSB alongside inorganic nitrogen and that macromolecules are converted into micromolecules as a result of certain enzymes (Yadav and Khurana, 2005). The vigor index I and II after the 15 months of natural aging was maximum (2350, 36) in (T_{17}) *Rhizobium*+PSB+75% RDN and minimum (909, 15) in (T_0) control, respectively. The minimum (531 µS/cm/g) was recorded in the treatment (T_{17}) *Rhizobium*+PSB+75% RDN. As a result of the incorporation of biofertilizers and inorganic nitrogen, T17 was able to achieve better performance due to a higher cell membrane stability and a decreased leakage of solutes from seeds because more nutrients were available for plant and seed development, resulting in an intact seed coat (Namvar *et al*., 2013).

From the results of present investigations, it is concluded that the conjoint application of *Rhizobium*+PSB at 75% RDN performed best in terms of seed quality parameters, namely, germination%, dry weight, seedling length, vigor index I and II, and electrical conductivity.

Table 1 Effect of integrated nutrient management on standard germination (%) of field pea seeds stored at ambient condition

Treatments	Fresh seeds	5 months	10 months	15 months	Mean
T_0: Control	87.33	81.33	78.33	68.00	78.75
T_1: *Rhizobium*+FYM (100%)	93.00	91.33	87.00	81.33	88.17
T_2: *Rhizobium*+FYM (75%)	92.33	88.67	86.00	79.33	86.58
T_3: *Rhizobium*+Vermicompost (100%)	90.33	86.00	82.00	73.67	83.00
T_4: *Rhizobium*+Vermicompost (75%)	89.67	83.33	80.00	71.00	81.00
T_5: *Rhizobium*+Nitrogen (100%)	97.33	94.67	91.33	87.67	92.75
T_6: *Rhizobium*+Nitrogen (75%)	95.67	94.00	90.33	86.00	91.50
T_7: PSB+FYM (100%)	92.67	90.00	86.67	80.67	87.50
T_8: PSB+FYM (75%)	92.00	88.33	85.00	78.00	85.83
T_9: PSB+Vermicompost (100%)	90.00	85.00	80.33	71.67	81.75
T_{10}: PSB+Vermicompost (75%)	89.00	83.00	79.67	70.33	80.50
T_{11}: PSB+Nitrogen (100%)	96.67	94.33	91.00	87.00	92.25
Treatments	**Fresh seeds**	**5 months**	**10 months**	**15 months**	**Mean**

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T_{12}: PSB+Nitrogen (75%)	94.33	92.33	88.33	83.67	89.67
T_{13}: *Rhizobium*+PSB+100% FYM	95.00	93.33	89.33	85.33	90.75
T_{14}: *Rhizobium* +PSB+75% FYM	94.67	93.00	89.00	84.67	90.33
T_{15}: *Rhizobium*+PSB+100% Vermicompost	91.67	88.00	84.33	77.00	85.25
T_{16}: *Rhizobium*+PSB+75% Vermicompost	91.33	87.33	83.00	75.33	84.25
T_{17}: *Rhizobium*+PSB+75% Nitrogen	97.67	95.33	91.67	88.33	93.25
T_{18}: RDF	93.33	92.00	87.67	82.67	88.92
Mean	92.46	88.87	85.22	78.59	
	CD	**SE(d)**	**SE(m)**		
Treatments	0.536	0.271	0.192		
Storage	0.224	0.113	0.080		
Treatment × Storage	1.072	0.543	0.384		

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7.7 Cost-effectiveness of Sub-surface Drainage Technology for Reclamation of Saline and Waterlogged Soils in Western Maharashtra, India

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Keywords: Cost-effectiveness; Sub-surface drainage

1. Introduction

With the increase in irrigated agriculture in the arid, semiarid, and subhumid regions of India, there has been an increase in the area under twin problems of waterlogging and soil salinity affecting crop productivity adversely. Nearly 11.53 million hectares in India and 1 million hectares in Maharashtra have been damaged due to excess water and salt storage. ICAR-CSSRI (Karnal) has standardized the sub-surface drainage (SSD) technology which has paved the way for large-scale implementation in India. In Maharashtra, some co-operative water user societies and co-operative sugar factories have taken the initiative in the installation of SSD projects. In Western Maharashtra, especially in the Sangli district, soil reclaimed through SSD technology has been majorly used for sugarcane cultivation. This study has been undertaken to evaluate the economic analysis of this technology. An economic evaluation of such programmes is essential to provide justification for the investment of scarce financial resources and to strengthen the hands of decision-makers for future investments.

2. Materials and methods

The Sangli district was purposively selected for the study as a large area is affected by soil salinity and waterlogging. The three villages having more number of SSD installed farmers were selected from Miraj, Palus, and Walwa tehsils of Sangli district. The 'with' and 'without' approaches were adopted for the collection and analysis of data. In all, 60 sample farmers with SSD and 60 sample farmers without SSD consisting of a total of 120 farmers were selected for the research study. In order to assess the information, a specially designed questionnaire was prepared for data collection from sample farmers through personal interviews. Only the sugarcane crop was considered for the impact of SSD technology. The data regarding the cultivation of adsali sugarcane were taken for the year 2019-20.

In order to know the impact of SSD technology on sugarcane production, decomposition analysis was carried out. In order to assess the economic viability of the SSD technology, net present value (NPV), internal rate of return (IRR), and benefit cost ratio BCR were calculated. A well-installed sub-surface drainage system can function properly for a period of 50 years or even longer although economic life is usually taken as 30 years (Bundela *et al*., 2016).

3. Results and discussion

The average per hectare establishment cost of the SSD system was found to be Rs. 138,183. In total per hectare cost of cultivation for adsali sugarcane, the share of total human labor cost was maximum, which was 25.92% and 28.46% for the 'with' and the 'without' SSD system, respectively. The per quintal cost of production for adsali sugarcane for with and without SSD farms was Rs. 219 and Rs. 279, respectively (Table 1). The gross return of adsali sugarcane was observed to be 68.83% more on 'with SSD' farms as compared to the 'without SSD' farms of adsali sugarcane. The per quintal cost reduction for adsali sugarcane was observed to be 21.52% on 'with SSD' farms over the 'without SSD' farms. The contribution of SSD technology to the additional yield gain of adsali sugarcane was 24.53%. The B:C ratio was greater than unity (i.e., 1.39) and IRR was more than the market rate of interest (i.e., 40.69%), indicating the investment made in the SSD system was economically viable. The major constraint faced by SSD technology user farms was the heavy infestation of vegetation on the open drain, high initial cost, and loss of nutrients due to leaching.

Table 1 Cost-effectiveness of SSD technology for adsali sugarcane

Particulars	Without SSD	With SSD
Yield (q/ha)	893.16	1507.91
Added yield (q/ha)		614.75
Increase in yield (%)		68.83
Total cost (Rs/ha)	249,360.99	330,383.29
Added cost (Rs/ha)		81,022.30
Per cent increase in cost		32.49
Per quintal cost (Rs/q)	279.19	219.10
Unit cost reduction (Rs/q)		60.09
Per cent reduction in per quintal cost		21.52
Total returns (Rs/ha)	245,619.15	414,675.25
Added gross returns (Rs/ha)		169,056.10
Added net returns (Rs/ha)		88,033.80
Per cent increase in returns		68.83
IBCR ratio		2.09
Area under SSD in Maharashtra (ha)	6500	
Total net benefit in 2019-20 (Rs.) (Area under SSD × added net returns (Rs/ha))	572,219,710	
IRR=(Lower discount rate)+(Difference between the two discount rates) × (Present worth of cash flow at the lower discount rate/absolute difference between the present worth of the cash flow at the two discount rates) IRR=40+(42 – 40) × 2297.80/(6687.65)	40.69	

IBCR: incremental benefit cost ratio

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7.8 Impact Analysis of Soil and Water Conservation Work on Farmer's Economy in Western Maharashtra: A Case Study of Ghatshiras Village

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Keywords: Farm economy; Impact analysis; Soil and water conservation

1. Introduction

Maharashtra government launched the flagship programme 'Jalyukt Shivar Abhiyan' in 2015-16, which is the consolidation of all soil and water conservation schemes under one umbrella with an aim to make Maharashtra water scarcity free in upcoming years. There are various views on the impact of soil and water conservation based programmes on rural development. Despite this, very rare attention has been paid to such a systematic study regarding the implementation and impact of the 'Jalyukt Shivar Abhiyan'. An economic evaluation of such programmes is essential to provide justification for the investment of scarce financial resources and to strengthen the hands of decision-makers for future investments. Hence, this study was undertaken with specific objectives, namely, the impact of the scheme on the livelihoods of beneficiaries, changes in land use and cropping pattern, employment pattern, and the socioeconomic status of communities in general.

2. Materials and methods

The Ahmednagar district was purposively selected for the study as a representative district of the scarcity zone of Western Maharashtra. Pathardi tahsil was selected on the basis of the highest number of villages selected for *Jalyukt Shivar Abhiyan* in the district. General information regarding tehsil wise, work wise, and agency wise work executed under the *Jalyukt Shivar Abhiyan* in Ahmednagar district was collected from the Office of the District Superintendent of Agriculture Officer, Ahmednagar. Similar information for different villages of Pathardi tehsil was collected from the Office of Taluka Agriculture Officer, Pathardi. Among the total beneficiary villages of the Pathardi tehsil for the year 2015-16, the Ghatshiras village was randomly selected where 100% of the sanctioned work under *Jalyukt Shivar Abhiyan* was completed. Sixty beneficiary farmers were chosen as the sample beneficiary by the simple randomization method. The 'ex-ante' and the 'ex-post' approaches were adopted for the collection and analysis of data. The year 2014-15 was taken as the 'ex-ante' (before) and the period 2017-18 to 2019-20 being the study year represented the 'ex-post' (after) situation. The tabular method of estimation was used in most of the parts of the investigation.

3. Results and discussion

The per hectare total income during the base year was Rs. 92,312/- with Rs. 67,162/- from crop production and Rs. 25,150/- from livestock activities. The per hectare income had gone up by 66.38% and 13.62% in the case of crop production and livestock activities, respectively, during the study years. These two activities had jointly increased the per hectare total income by 52.01% over the base year. The per hectare total expenditure made on both crop production and livestock went up by 33.67% over the base year. The crop production showed a rise of 42.12% in the per hectare expenditure incurred during the base year of study, while such expenditure on livestock activity increased by 7.87% over the ex-ante year. These findings were consistent with the study conducted by Chandra and Raverkar (2016). The overall benefit-cost ratio for the crop production and livestock activities jointly showed an increase from 0.99 to 1.13. Furthermore, the results of the study revealed that the *Jalyukt Shivar Abhiyan* activities have a significant impact on groundwater recharge, access to groundwater, and hence the expansion in irrigated areas. It has been found to alter crop patterns, increase crop yields and crop diversification, and thereby provide enhanced employment and farm income. Local villagers have been at the forefront of the programme, not just in decision-making, but also in actual execution and monetary contributions. In a nutshell, *Jalyukt Shivar Abhiyan* has not only resulted in physical output but given support to the ecological and socioeconomic progress of the beneficiaries. Looking at all the above results, *Jalyukt Shivar Abhiyan* seems to be one of the basic strategies employed for doubling the farmer's income in rainfed and semi-arid regions of Maharashtra.

Table 1 Impact on income and expenditure pattern

Sr. No.	Particulars	Per farm (Rs.)		Per hectare (Rs.)	
		Ex-ante 2014-15	Ex-post 2017-18	Ex-ante 2014-15	Ex-post 2017-18
I	Income				
1	Crop production	202,226	341,088	67,162	111,747
	Percentage change (%)		68.67		66.38
2	Livestock	75,702	87,153	25,150	28,575
	Percentage change (%)		15.13		13.62
	Total income	277,928	428,241	92,312	140,322
	Percentage change (%)		54.08		52.01
II	Expenditure				
1	Crop production	210,645	303,465	69,958	99,421
	Percentage change (%)		44.06		42.12
2	Livestock	68,943	75,362	22,905	24,709
	Percentage change (%)		9.31		7.87
	Total expenditure	279,588	378,827	92,863	124,130
	Percentage change (%)		35.49		33.67
III	B:C ratio				
1	Crop production	0.96	1.12	0.96	1.12
2	Livestock	1.10	1.16	1.10	1.16
3	Overall	0.99	1.13	0.99	1.13

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7.9 Red Seaweed (*Gracilaria tenuistipitata* var. *liui*) Liquid Fertilizer Increase Yield and Seed Protein of Mungbean (*Vigna radiata*)

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Keywords: Fertilizer; *G. tenuistipitata*; Seaweed; Seed quality; Yield

1. Introduction

Seaweed extract (*G. tenuistipitata* var. *liui*) is found in considerable amounts in plant growth stimulators such as auxin, gibberellins, and cytokinin; vitamins; amino acids; and macro and trace nutrients (Fe, Cu, Co, Ni, Zn, and Mn) (Zodape *et al.*, 2010). Liquid extracts obtained from seaweeds have recently gained importance as foliar sprays for many crops including cereals, pulses, and vegetables. The application of seaweed extract as liquid fertilizer may become a worthy effort for an alternative to synthetic fertilizers increasing the yield of mungbean and this may be the most practical means of solving the protein malnutrition problem in Bangladesh in a sustainable way. However, limited study has been conducted so far on the effect of *G. tenuistipitata* var. *liui* (a red seaweed species) on the yield and nutritional quality of mungbean. We assessed the efficacy of foliar application of seaweed extract from *G. tenuistipitata* var. *liui* as liquid fertilizer on yield and nutritional quality of mungbean.

2. Materials and methods

A pot experiment was conducted at the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh from March to May 2021. The experimental site was situated in a subtropical climatic zone (24°5’23 N and 90°15’36 E). The day and night temperatures were 28.5±1.6°C and 13.6±1.3°C, respectively. The seaweed was collected from the Bay of Bengal, Bangladesh. It was thoroughly washed using tap water, dried under the sun, and powdered by grinder at ambient temperature. Subsequently, it was utilized for extraction. Seven treatments were T1 – control (foliar spray with water), T2 – recommended fertilization (RDF) on soil, T3 – foliar spray with 5% seaweed fertilizer, T4 – foliar spray with 10% seaweed fertilizer, T5 – 15% seaweed foliar spray, T6 – 20% seaweed foliar spray, and T7 – 25% seaweed foliar spray for mungbean variety BU mug5 in a completely random design (CRD) with three replications. Foliar spray was given at seedling and flowering stages. After harvesting, the number of pods/plant, number of seeds/pod, 100-seed weight, and yield data were recorded. The protein content of seed was estimated by the Kjeldahl method by using the powder form of mungbean seeds according to the VELP Scientifica (2015).

3. Results and discussion

The highest number of pods was estimated as 19 in 20% seaweed extract application (Table 1). The number of pods/plant of 16.33, 15.67, 15.00, and 13.16 was recorded at 15%, 25%, 10%, and 5% seaweed extract application, respectively. The application of seaweed extract to the mungbean plants caused 4.36% higher number of seeds/pod compared to the control. The highest number of seeds/pod was 10.3 and it was found at 20% seaweed extract application. It was followed by 10.24, 10.13, 10.05, and 10.21 in mungbean plants treated with 15%, 25%, 10%, and 5% seaweed extract, respectively.

Table 1 Effect of seaweed fertilizers on grain yield and protein content of mungbean

Treatments	Number of pod/plant	Number of seed/pod	100-grain weight (g)	Grain yield (g)/plant	Protein in grain (%)
Control	12.67d	9.87b	4.87f	6.04e	18.06c
Recommended fertilizer	18.67ab	10.21ab	5.78b	10.69b	23.83a
5% seaweed extracts	14.00cd	9.96ab	5.06e	7.05de	19.31bc
10% seaweed extracts	15.00cd	10.06ab	5.26d	7.9cd	21.79ab
15% seaweed extracts	16.33bc	10.24a	5.72b	9.63bc	23.56a
20% seaweed extracts	20.00a	10.30a	6.21a	11.66a	24.94a
25% seaweed extracts	15.67c	10.13ab	5.51c	8.76c	22.36ab
SE (±)	0.83	0.12	0.49	0.50	1.08
LSD (5%)	2.51	0.37	0.15	1.52	3.27

The highest 100-grain weight of mungbean was found in 20% seaweed foliar application, which was 6.21 g and it was 27.3% more than the control. The lowest weight of 100-grain was recorded 4.87 g in control (water spray only). The 100-grain weight of mungbean was found as 5.78 g in case of using the recommended fertilizer doses and it was 18.47% more than the control. The maximum yield was 11.66 g/plant and it was found in plants treated with 20% seaweed extract. The plants treated with water only recorded on an average 6.04 g grain/plant. The yield/plant of 9.63, 8.76, 7.90, and 7.05 g was recorded at 15%, 25%, 10%, and 5% seaweed extract application, respectively, whereas the grain yield/plant of 10.69 g was found with the basal application of chemical fertilizer as recommended.

The maximum protein content was recorded at 20% seaweed extract application (24.94%), followed by 23.56%, 22.36%, 21.79%, and 19.31% in mungbean plants treated with 15%, 25%, 10%, and 5% seaweed extract, respectively. The minimum protein percentage found in the control was 18.06%. In the application of fertilizers as recommendation, mungbean showed 23.83% protein in grain, which was less than that found in 20% seaweed application. The 15%, 20%, 25%, 10%, and 5% seaweed extract applications showed 44.49%, 37.03%, 33.46%, 19.9% and 6.92%, respectively, more average protein content than the control.

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7.10 Efficacy of New Generation Herbicides on Yield Attributes and Yield in Direct Seeded Rice (*Oryza sativa* L.)

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Keywords: Direct seeded rice; New generation herbicides; Yield attributes and yield

1. Introduction

Direct seeded rice (DSR) has evolved as a promising alternative to transplanted rice. Exposure of mechanization, easy sowing, reduced labor requirement and drudgery, earlier crop maturity, increased water use efficiency, higher tolerance to water deficit, and lower methane emission are the advantages of DSR over transplanted rice. Weeds in DSR emerge along with rice, increasing the production cost and reducing the economic yields by up to 90% by competing with the rice crop for resources. Thus, effective control of weeds is an essential condition for attaining a better yield of rice in DSR. New generation herbicides are used to provide effective weed control in DSR. An attempt was made to evaluate the efficacy of new generation herbicides in DSR.

2. Materials and methods

The experiment was conducted at Pattathikadu, Tamil Nadu during *Kuruvai* 2020 in RBD and replicated thrice. Eleven treatments consisted of Unweeded check (T_1), Hand weeding (HW) at 20 and 40 DAS (T_2), Penoxsulam+ butachlor (0.97%+38.8% SE) @ 2000 mL/ha (PE) at 7 DAS (T_3), Bispyribac sodium 10% SC @ 200 mL/ha (EPoE) at 15 DAS (T_4), Fenoxaprop-*p*-ethyl 6.9% EC (6.7%) @ 875 mL/ha (PoE) at 30 DAS (T_5), Penoxsulam+butachlor (0.97%+38.8% SE) @ 2000 mL/ha (PE) at 7 DAS fb twice HW at 20 and 40 DAS (T_6), Bispyribac sodium 10% SC @ 200 mL/ha (EPoE) at 15 DAS fb HW at 40 DAS (T_7), HW at 20 DAS fb fenoxaprop-*p*-ethyl 6.9% EC (6.7%) @ 875 mL/ha (PoE) at 30 DAS (T_8), Penoxsulam+ butachlor (0.97%+38.8% SE) @ 2000 mL/ha (PE) at 7 DAS fb Bispyribac sodium 10% SC @ 200 mL/ha (EPoE) at 15 DAS (T_9), Penoxsulam+butachlor (0.97%+38.8% SE) @ 2000 mL/ha (PE) at 7 DAS fb Fenoxaprop-*p*-ethyl 6.9% EC (6.7%) @ 875 mL/ha (PoE) at 30 DAS (T_{10}), and Bispyribac sodium 10% SC @ 200 mL/ha at 15 DAS (EPoE) fb Fenoxaprop-*p*-ethyl 6.9% EC (6.7%) @ 875 mL/ha (PoE) at 30 DAS (T_{11}). Pre-germinated Aduthurai-37 (variety) seeds were sown at 15 cm × 10 cm spacing on puddled and leveled field (wet DSR) with 40 kg seed rate per ha. The crop was fertilized with 120:40:40 kg NPK per ha.

3. Results and discussion

Application of bispyribac sodium followed by one HW (T_7) produced a higher number of panicles per m^2 (434.14), number of filled grains per panicle (94.14), grain yield (6540 kg/ha), straw yield (8522 kg/ha), and BCR (2.82). Timely weed management facilitated the crop to have sufficient space, light, nutrients, and moisture, and thus the number of panicles, filled grains, and yield was increased (Priya *et al*., 2017). The lowest number of yield attributes, yield, and BCR was recorded in the unweeded check. It can be concluded that the highest yield could be achieved by the application of bispyribac sodium at 15 DAS+one HW at 40 DAS.

Table 1 Efficacy of new generation herbicides on yield attributes and yield of DSR

Treatments	Panicles (m^{-2})	Filled grains/panicle	Grain yield (kg/ha)	Straw yield	BCR
T_1 - Unweeded check	236.00	59.63	2412	3805	1.19
T_2 – Hand weeding (HW) at 20 and 40 DAS	371.40	85.89	5633	7661	2.40
T_3 – Penoxsulam+butachlor (0.97%+38.8% SE) @ 2000 mL/ha (PE) at 7 DAS	312.96	72.89	3543	5315	1.64
T_4 – Bispyribac sodium 10% SC @ 200 mL/ha (EPoE) at 15 DAS	327.54	75.89	3965	5715	1.85
T_5 – Fenoxaprop-*p*-ethyl 6.9% EC (6.7%) @ 875 mL/ha (PoE) at 30 DAS	296.66	70.30	3191	4866	1.47
T_6 – Penoxsulam+butachlor (0.97% +38.8% SE) @ 2000 mL/ha (PE) at 7 DAS fb twice HW at 20 and 40 DAS	379.75	87.74	5795	7823	2.33
T_7 – Bispyribac sodium 10% SC @ 200 mL/ha (EPoE) at 15 DAS fb HW at 40 DAS	434.14	94.14	6540	8522	2.82
T_8 – HW on 20 DAS fb fenoxaprop-*p*-ethyl 6.9% EC (6.7%) @ 875 mL/ha (PoE) at 30 DAS	355.98	83.09	5265	7340	2.25
T_9 – Penoxsulam+butachlor (0.97%+38.8% SE) @ 2000 mL/ha (PE) at 7 DAS fb bispyribac sodium 10% SC @ 200 mL/ha (EPoE) at 15 DAS	343.86	79.50	4549	6581	2.00
T_{10} – Penoxsulam+butachlor (0.97%+38.8% SE) @ 2000 mL/ha at 7 DAS (PE) fb fenoxaprop-*p*-ethyl 6.9 % EC (6.7%) @ 875 mL/ha (PoE) at 30 DAS	341.67	78.81	4336	6260	1.86
T_{11} – Bispyribac sodium 10% SC @ 200 mL/ha (EPoE) at 15 DAS fb fenoxaprop-*p*-ethyl 6.9% EC (6.7%) @ 875 mL/ha (PoE) at 30 DAS	416.96	90.51	6190	8201	2.68
SEm±	4.02	0.84	72.30	107.4	--
CD (p=0.05)	11.96	2.51	214.75	319	--

PE, preemergence; EPoE, early postemergence; PoE, postemergence; HW, hand weeding

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7.11 Influence of Recommended Dose of Fertilizer with Foliar Nutrition on Growth and Yield of Green Gram

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Keywords: Cow urine; Fish amino acid; Green gram; Panchagavya; RDF; Vermiwash

1. Introduction

Green gram (*Vigna radiata* L.) holds a major role in the Indian diet because it is rich in protein, amino acid, and mineral nutrients. Green gram is a short-duration crop and improves soil fertility, and fits in mixed/intercropping and crop rotations. It is a leguminous crop and can fix atmospheric nitrogen. The productivity in our country is not decent enough to fulfill the domestic demand. The yield potential is very low. Several ways are initiated to boost productivity. One among them is the foliar application of organic and inorganic sources of nutrients. Foliar application of nutrients at crucial stages of crop growth is the most acceptable and correct technique for correcting nutrient deficiencies and helps to realize the most potential yield. The integrated use of inorganic fertilizers with cow urine, vermiwash, panchakavya, seaweed extract, jeevamruth, fish amino acid, and humic acid helps to maintain optimum crop yield. The present field experiment was planned to develop remunerative, productive, sustainable, and nutrient management practices for irrigated green gram.

2. Materials and methods

The experiment was conducted during February–April 2020 with green gram Co-8 at Experimental Farm. The experiment was laid out in randomized block design (RBD) with three replications and eight treatments, namely, T_1 – Control (100% recommended dose of fertilizer (RDF), 25:50:25 kg/ha), T_2-100% RDF+foliar application of 5% cow urine on 30 and 45 DAS, T_3-100%. RDF+foliar application of 5% vermiwash on 30 and 45 DAS, T_4 – 100% RDF+foliar application of 3% panchakavya on 30 and 45 DAS, T_5-100% RDF+foliar application of 5% seaweed extract on 30 and 45 DAS, T_6-100% RDF+foliar application of 5% jeevamruth on 30 and 45 DAS, T_7 – 100% RDF+foliar application of 0.5% fish amino acid on 30 and 45 DAS, and T_8 – 100% RDF+foliar application of 2% humic acid on 30 and 45 DAS.

3. Results and discussion

The treatment (T_4) 100% RDF+foliar application of 3% panchakavya on 30 and 45 DAS significantly recorded higher plant height (57.19 cm), LAI (3.72), and DMP (3431 kg/ha) at harvest. The minimum plant height, LAI and DMP at harvest was recorded under the control treatment (T_1). Increasing plant height was mainly due to the growth hormones present in panchakavya which promote rapid cell division and elongation (Gunasekar *et al*., 2018). The effect of panchakavya on LAI might be due to the fact that liquid manure is a source of nutrients, vitamins, and growth hormones, which enhance the number of leaves, leaf length, and breadth, thus increasing the plant height and leaf area and in turn leading to higher DMP. The grain yield was significantly enhanced by the treatment (T_4) 100% RDF+foliar application of 3% panchakavya on 30 and 45 DAS, giving a maximum grain yield of 935 kg/ha, haulm yield of 2921 kg/ha, and a higher harvest index (HI) (24.25). The control treatment (T_1) resulted in minimum grain, haulm yield, and HI. Higher yield might be due to IAA and GA present in panchakavya which could have created stimuli in the plant system and in turn increased the production of growth regulators and action in the plant system coupled with better translocation and accumulation of photosynthates from source to sink and increase in the grain yield (Yadav and Tripathi, 2013). From this study, it can be concluded that the application of a recommended dose of fertilizer with foliar application of 3% panchakavya results in profitably higher grain and haulm yield in green gram.

Table 1 Effect of the recommended dose of fertilizer with foliar nutrition on growth attributes and yield of green gram

Treatment	Plant height (cm)	LAI	DMP (kg/ha)	Grain yield (kg/ha)	Haulm yield (kg/ha)	Harvest index
T_1: Control (100% RDF – 25:50:25 kg/ha)	45.86	2.61	2679	654	2316	22.02
T_2: 100% RDF+foliar application of 5% Cow urine on 30 and 45 DAS	48.82	2.87	2893	762	2489	23.44
T_3: 100% RDF+foliar application of 5% Vermiwash on 30 and 45 DAS	56.52	3.64	3381	921	2878	24.24
T_4: 100% RDF+foliar application of 3% Panchakavya on 30 and 45 DAS	57.19	3.72	3431	935	2921	24.25
T_5: 100% RDF+foliar application of 5% Seaweed extract on 30 and 45 DAS	53.23	3.34	3167	849	2709	23.86
T_6: 100% RDF+foliar application of 5% Jeevamruth on 30 and 45 DAS	50.22	3.06	2982	791	2559	23.61
T_7: 100% RDF+foliar application of 0.5% Fish amino acid on 30 and 45 DAS	49.61	2.97	2924	775	2510	23.59
T_8: 100% RDF+foliar application of 2% Humic acid on 30 and 45 DAS	53.61	3.39	3190	858	2726	23.94
SEm±	0.94	0.07	59.80	17.97	48.69	0.40
CD (p=0.05)	2.89	0.22	183	55	149	1.24

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7.12 Growth and Yield Parameters of Rajmash (*Phaseolus vulgaris* L.) as Influenced by Tillage and Residue Management Under Temperate Conditions

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Keywords: Rajmash; Residue; Tillage

1. Introduction

Common bean or rajmash is a major source of protein, carbohydrates, fats, and minerals, making it a vital part of a balanced diet. The per capita availability of pulses in India is 36 g per capita per day compared to a recommended dietary requirement of 80 g per capita per day. In temperate Kashmir valley, the crop is being raised under rainfed conditions during the summer season. Tillage influences several aspects of soil and crop performance. Excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil and ultimately have adverse effects on the crop. Therefore, the crop performance of rajmash was evaluated under different tillage and residue management in the temperate Kashmir valley.

2. Materials and methods

The experiment was carried out at the Faculty of Agriculture, Wadura, SKUAST-Kashmir during *Kharif*, 2018. The experimental soil was silty clay loam with good drainage and normal reactions and salinity. The soil organic carbon and available NPK were in the medium range. The experimental design was RBD with two factors. The first factor was the tillage system, namely, conventional tillage (CT), rotary tillage (RT), minimum tillage (MT), and zero tillage (ZT). The other factor was residue management, namely, no residue (NR) and brown sarson residue (SR). After harvesting the previous crop of brown sarson, one-third of the residues were left on the soil surface intending to enhance soil properties. It was incorporated into soil through conventional, minimum, and rotary tillage treatments, while it was retained on the soil surface under zero tillage treatment. CT was achieved by many successive tillage operations with MB plough followed by harrowing. RT was accomplished by rotavator machine while MT was performed with only primary operations using a disc harrow. Herbicide glyphosate (1.0 kg/ha) was sprayed before sowing in plots of ZT and MT. Growth parameters, yield attributes, seed yield, and soil parameters were statistically compared among the treatments.

3. Results and discussion

Crop growth parameters, namely, plant height, LAI, and DMA, were influenced by the treatments of tillage and residue management. Significantly taller plants were observed with RT and CT treatments. DMA was significantly higher with RT treatment. LAI was found significantly lower with MT at 60 DAS. However, LAI was at par among the treatments of CT, RT, and ZT. The residue management did not influence the plant heights and LAI of rajmash, but significantly higher DMA was observed with SR. Saha *et al*. (2010) also reported that CT performed better than ZT, while Sandoval-Avilla *et al*. (1994) reported that DMA and LAI did not vary between tillage systems. The number of pods per plant was significantly higher with RT followed by CT and ZT. The number of seeds per pod was significantly higher with residue application. The seed index was neither influenced by tillage nor by residue management. Seed yields obtained in CT were at par with RT. Bhat *et al*. (2019) reported that the productivity of the maize and bean additive intercropping system (1:1) was significantly higher with the CT system followed by ZT. Physicochemical properties of soil, namely, electrical conductivity, soil reaction, bulk density, and soil organic carbon, were not influenced by tillage and sarson residue application. However, significantly higher available soil nitrogen and phosphorus were observed with RT and CT irrespective of residue management. Available soil K was significantly higher with RT followed by CT. No significant variation was observed between SR and NR for these available soil nutrients. The yield effect of zero tillage and residue application would improve after some extended period of the treatment application.

Table 1 Growth parameters of rajmash influenced by tillage and residue management under temperate conditions

Plant height LAI DMA						
Treatment	**60 DAS**	**90 DAS**	**60 DAS**	**90 DAS**	**60 DAS**	**90 DAS**
Tillage system						
CT	57.1	91.8	3.41	6.75	7.51	14.83
RT	57.5	92.9	3.46	6.81	7.75	15.97
MT	55.2	87.6	3.14	6.63	7.29	13.49
ZT	57.0	88.0	3.28	6.66	7.39	14.66
Sem ±	0.54	0.94	0.06	0.05	0.15	0.21
CD (p<0.05)	1.6	2.9	0.20	NS	NS	0.64
Residue management						
NR	55.1	89.3	3.29	6.70	7.19	14.47
SR	58.3	90.9	3.36	6.73	7.78	15.01
Sem ±	0.38	0.67	0.05	0.04	0.10	0.15
CD (p<0.05)	1.16	NS	NS	NS	0.32	0.45

Table 2 Yield parameters of rajmash influenced by tillage and residue management under temperate conditions

Treatment	Number of pods/plant	Number of seeds/pod^{-1}	Seed index (g)	Seed yield (kg/ha)
Tillage system				
CT	9,95	4.97	23.75	1936
RT	10.72	4.87	25.02	2094
MT	8.50	4.63	22.30	1731
ZT	9.22	4.97	23.08	1873
Sem ±	0.36	0.13	0.64	60.1
CD (p<0.05)	1.08	NS	NS	182
Residue management				
NR	9.35	4.68	23.06	1839
SR	9.84	5.00	24.01	1978
Sem ±	0.25	0.09	0.45	42.5
CD (p<0.05)	NS	0.28	NS	129

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Table 3 Physiochemical properties of soil and available soil nutrients (NPK) as influenced by tillage and residue management

Treatment	Bulk density (Mg/m^3)	E.C (dS/m)	Soil reaction (pH)	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Tillage system							
CT	1.34	0.25	6.72	0.76	418.07	23.23	204.71
RT	1.33	0.29	6.76	0.73	428.63	24.65	224.35
MT	1.34	0.25	6.70	0.77	344.83	20.36	183.85
ZT	1.37	0.23	6.68	0.79	386.70	20.89	194.25
SEm ±	0.008	0.02	0.05	0.02	10.27	0.523	4.18
CD (p<0.05)	NS	NS	NS	NS	31.5	1.59	12.68
Residue management							
NR	1.35	0.26	6.72	0.75	391.93	22.27	198.02
SR	1.34	0.26	6.73	0.77	397.19	22.29	205.57
SEm ±	0.006	0.01	0.03	0.01	7.26	0.37	2.96
CD (p<0.05)	NS	NS	NS	NS	NS	NS	NS

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7.13 Effect of Various Land Use Systems on Physicochemical Properties of Soil Under Subtropical Region of Jammu

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Keywords: Bulk density; Land uses; Soil aggregation; Soil organic carbon

1. Introduction

Land use and land cover change have been recognized as important drivers of global environmental change. Ecologically incompatible human land use and management practices implemented locally such as deforestation and soil fertility depletion have led cumulatively to an alteration in the global biogeochemical cycles. Land use changes affect many natural resources and ecological processes such as surface runoff and erosion and change soil resilience to environmental impacts. The increasing intensity of land use may cause erosion and soil compaction through changes in the physical and chemical properties of the soil. Thus, a study was conducted to evaluate the effect of different land uses on the physicochemical parameters of soil. Geo-referred soil samples were collected from five different land uses in the subtropical region of Jammu and analyzed for physical and chemical attributes.

2. Materials and methods

A total of 184 soil samples were collected from five different land use systems, namely, agriculture, horticulture, forest, agroforestry, and grasslands. At each location, samples were collected from two depths, that is, 0–15 and 15–30 cm. The core method was used for determination of soil bulk density. Maximum water holding capacity (MWHC) was determined by the Keen Roezkowski box method The mean weight diameter (MWD) of aggregates was calculated as

$$\text{MWD (mm)} = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i}$$

Here, w_i is the aggregates retained over the sieve (g) and x_i the mean diameter of the size class (mm). Available N was determined by the alkaline $KMnO_4$ method. Available P was determined by Olsen's method. Available K was determined by the flame photometer using neutral normal ammonium acetate as an extractant and SOC was determined by the modified Walkley and Black method. The data were analyzed statistically using single factor ANOVA.

3. Results and discussion

The agricultural land use system registered the greatest bulk density in both surface and subsurface soil depths (1.47, 1.51 Mg/m^3, respectively), which was at par with horticulture, agroforestry, and grassland but significantly higher as compared to forest land use. The maximum WHC observed in forest land use at both soil depths was at par with grassland but significantly higher than that under all other land uses. The MWD of aggregates in surface and subsurface soil layers was highest in forest land, followed by grassland, agroforestry, horticulture, and least in agriculture. Lower MWD of aggregates in agricultural land use could be attributed to lower organic matter inputs from vegetation and loss of SOC by water erosion. Forest land had the lowest soil pH in both depths, followed by agriculture, horticulture, agroforestry, and grassland. Forest soils had lower pH values than degraded lands, which could be attributed to their higher SOC content. The maximum content of available N in the surface and subsurface soil layers of forest land use was significantly higher than that in agriculture but at par with that in all other land uses.

Table 1 Effect of different land use systems on physical properties of soil

Land use	B.D. (Mg/m^3)		Maximum WHC (%)		MWD (mm)	
Depths→	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
Agriculture	1.47	1.51	32.53	31.16	2.09	1.94
Horticulture	1.45	1.47	36.72	35.28	2.27	2.14
Forest	1.39	1.44	38.74	37.19	3.18	2.64
Agroforestry	1.46	1.48	35.66	34.01	2.88	2.56
Grassland	1.44	1.47	36.65	35.00	3.05	2.58
LSD@5%	0.05	0.04	1.55	1.56	0.17	0.17
SE(m)±	0.02	0.01	0.54	0.54	0.06	0.06

The maximum available P content in surface and subsurface soil layers of agriculture was at par with that of grassland and forest but significantly higher than that of agroforestry and horticulture. The maximum content of available K found in both the soil depths of the forest was significantly higher than that in agriculture but was at par with that in all other land uses. According to Singh *et al*. (2018), available N and K were higher in forests than in all other land uses. Cultivated land had more available P than bare land, which was significantly higher than grasses, followed by forest, horticulture, and bare land. The maximum soil organic carbon content found in both the depths of the forest was significantly higher than that in all other land uses. Sharma *et al*. (2014) reported that the SOC was higher in the forest and lowest in agricultural land use.

Table 2 Effect of different land use systems on chemical properties of soil

Land use	Soil pH		Available N kg/ha		Available P kg/ha		Available K kg/ha		SOC (g/kg)	
Depths→	0–15 cm	15–30 cm	0–15 cm	15–30cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
Agriculture	6.8	6.9	266.27	246.15	21.49	19.94	230.50	213.32	6.03	5.14
Horticulture	6.9	7.0	321.92	290.04	19.45	17.87	264.70	250.16	7.09	6.08
Forest	6.6	6.7	326.07	317.12	20.41	19.06	273.39	259.37	8.01	7.36
Agroforestry	6.9	7.0	293.78	276.64	19.90	18.62	246.35	240.21	6.38	5.71
Grassland	7.0	7.1	300.02	282.26	21.16	19.41	262.60	241.69	6.28	5.56
LSD@5%	0.38	0.39	41.87	46.83	1.08	1.05	31.87	33.84	0.49	0.51
SE(m)±	0.13	0.13	14.35	16.05	0.37	0.36	10.94	11.64	0.17	0.18

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7.14 Effect of Sulphuric Acid and AM Fungi on the Growth of *Melia azedarach*

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Keywords: *M. azedarach*; Collar diameter; Drupes; Glomus mosseae; Leaf area; Seedling height

1. Introduction

M. azedarach is a deciduous, fast growing, native to the Indian subcontinent tree. In spite of its wide adaptability in different soils and agro-climatic conditions, its wood has high pulp recovery and exceptional strength. To reduce the dependence for energy, housing materials, timber, fodder, and medicine on exotics trees, the study of indigenous trees like *M. azedarach* is needed in the country. The poor germination of its drupes and late nursery establishment are the main constraints in its extensive cultivation. Thus the study is required to enhance its germination and obtain faster growth of its seedlings. *G. mossae* is one of the most important and widely prevalent AM fungi in soil and many encouraging results are available in the literature on its effect on the growth and establishment of seedlings of different trees. To overcome this problem, an experiment was designed with the pre-sowing treatment of drupes with sulphuric acid and the sowing of these treated drupes in *G. mossae* incorporated soil on the seedling's growth and biomass.

2. Materials and methods

The pure cultures of *G. mosseae* were collected from the Department of Plant Pathology, Chaudhary Charan Singh Haryana Agricultural University, Hisar. Soil application of this AM fungi was applied at the rate of 400–500 sporocarp/kg of soil at the time of sowing of drupes of *M. azedarach* for only those treatments that were in combination with *G. mossae* and were evaluated for their performance when pre-treated drupes with sulphuric acid for the different duration (4, 6, and 8 min) were sown in *G. mossae* incorporated soil at Nursery, Department of Forestry, CCSHAU Hisar. The experiment was replicated three times with 250 seedlings per replication. The untreated drupes were also sown in soils incorporated with *G. mossae* and without *G. mossae* which served as check-1 and check-2. Observations on seedling height (cm), collar diameter (mm), and leaf area (cm^2) were recorded after 90 days after sowing (DAS). Five seedlings were selected randomly from each treatment for recording the above-ground parameters and the mean was worked out.

3. Results and discussion

The growth parameters of *M. azedarach* as influenced by different pre-sowing treatments are presented in Table 1. The difference in seedling height of *M. azedarach* due to different pre-sowing treatments was found statistically significant. The seedling height was significantly higher in Conc. H_2SO_4 for 8 min+*G. mosseae* treatment (40.38 cm) which was at par with Conc. H_2SO_4 for 6 min+*G. mosseae* (40.15 cm) and check-1 (39.85 cm), whereas the lowest seedling height was recorded in check-2 (i.e., 30.51 cm). The drupes treated with Conc. H_2SO_4 for 8 min and sown in the soil incorporated with *G. mosseae** recorded a maximum collar diameter of 7.86 mm which was at par with Conc. H_2SO_4 for 6 min and sown in the soil incorporated with *G. mosseae* (7.76 mm) and check-1 (7.50 mm), whereas the minimum collar diameter was recorded in check-2 (i.e., 4.53 mm). Similar findings have been reported by Joshi *et al.* (2017) in *Buchnania lanzan*. They reported maximum collar diameter when the seeds were treated with H_2SO_4 (5%) for 10 min of soaking. The maximum leaf area of 140.25 cm^2 was also recorded in the treatment when drupes were treated with Conc. H_2SO_4 for 8 min and sown in the soil incorporated with *G. mosseae* which was at par with Conc. H_2SO_4 for 6 min and sown in the soil incorporated with *G. mosseae* (139.95 cm^2) and check-1 (138.95 cm^2), whereas a minimum leaf area of 105.26 cm^2 was recorded in check-2. Therefore, it may be concluded that the sulphuric acid with *G. mosseae* has a significant effect on the seedling growth of *M. azedarach* and can be recommended to the grower for obtaining better growth and yield.

Table 1 Effect of sulphuric acid and *G. mosseae* on seedling height (cm), collar diameter (mm), and leaf area (cm^2)

Treatment	Seedling height (cm)	Collar diameter (mm)	Leaf area (cm^2)
Conc. H_2SO_4 for 4 min	30.65	4.56	105.80
Conc. H_2SO_4 for 4 min+*G. mosseae*	40.13	7.71	139.80
Conc. H_2SO_4 for 6 min	30.70	4.62	108.58
Conc. H_2SO_4 for 6 min+*G. mosseae*	40.15	7.76	139.95
Conc. H_2SO_4 for 8 min	30.55	4.52	105.69
Conc. H_2SO_4 for 8 min+*G. mosseae*	40.38	7.86	140.25
Check-1	39.85	7.50	138.95
Check-2	30.51	4.53	105.26
CD significant at a 5% level	2.78	0.52	9.73

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7.15 Effect of Soil Salinity on Relative Leaf Water Content and Electrolyte Leakage Content of Brinjal (*Solanum melongena* L.)

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Keywords: Brinjal; Salinity; Stress; Tolerant

1. Introduction

Abiotic stresses arise from a change in environmental, soil, and water conditions around the plant. There are mainly four types of abiotic stresses, that is, drought, flooding, salinity, and temperature, that affect plant survival, biomass production, and yields of staple food crops by up to 70% (Thakur *et al.,* 2010). Abiotic stresses have resulted in a 50–70% decline in the productivity of major crops (Mittler, 2006). Salinity is the major abiotic stress reducing the growth and productivity of economically important crops all over the world. Soils having a high concentration of soluble salts in the root zone are known as saline soils. Salinity affects various physiological, biochemical, and morphological characteristics. Relative leaf water content and electrolyte leakage content are also important factors among other attributes to estimate the salinity tolerance level in brinjal. In the future, salinity may create a big problem for the cultivation of crops. Therefore, screening tolerant genotypes to salinity will ensure the growth and production of crops in the future. Brinjal is a moderately salt-sensitive crop and can tolerate salinity up to 1.1 dS/m.

2. Materials and methods

The experiment was conducted at the Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana during 2017-18 and 2018-19. One hundred and two genotypes varying in texture, shape, and size were selected for the study from the available brinjal germplasm. The best tolerant genotypes were selected on the basis of nursery evaluation under different salinity levels. These studies were laid out in a split plot design keeping three replications. Three salinity levels along with control (2, 4, and 6 dS/m) were considered the main plot treatments and genotypes (nineteen) were considered the sub-main plots for the statistical design. For artificial salinity, sodium chloride, magnesium sulfate, and calcium chloride were used in a ratio of 2:1:1 in the field and pot. Salinity was regularly checked and maintained. Salinity levels along control (2, 4, and 6 dS/m) were maintained with these salts. Quality parameters, that is, relative leaf water content and electrolyte leakage content from leaves after the first and second months of transplanting were estimated by using the procedure given below.

Relative leaf water content (RLWC) (%): RLWC from the leaves of control and stressed plants was recorded. For this five leaf discs from each salinity level were weighed immediately to obtain their fresh weight. Then the leaf discs were submerged in distilled water in beakers till saturation. After 6 h, the leaf discs were removed from the beakers. The surface water of the leaf discs was blotted off without putting any pressure and then they were weighed to obtain saturated weight. After drying the discs at 70°C for 72 h, their dry weight was determined to calculate RLWC.

Electrolyte leakage (%) (Fletcher and Drexler, 1980): Leaves (0.1 g) were immersed in glass vials having 25 mL of distilled water for 20 h at 25°C. Electrical conductivity (EC) of leakage was recorded by using an EC meter. The leaves were then placed in a boiling water bath for 30 min and cooled at 25°C and conductivity was measured again.

3. Results and discussion

Relative leaf water content from leaves (%): RLWC content is an important character for abiotic stress. RLWC is the appropriate measure of plant water status in terms of cellular hydration. It is the ratio of tissue fresh weight to tissue turgid weight. It increases with salinity. Data showed that after 30 and 60 days of transplanting, the maximum RLWC content was observed in genotype SL-8 and PB-1-3-1-4 (171.63% and 55.53%, respectively), which was significantly higher than all the other genotypes. Among all the salinity levels, the highest RLWC content was observed in the 6 dS/m level of salinity (95.08% and 28.58%, respectively, after 30 and 60 days of transplanting) and it was significantly higher than all other salinity levels.

Electrolyte leakage from leaves (%): Electrolyte leakage is harmful to plants. It is the indicator of stress responses in intact plant cells. As the salinity increases, electrolyte leakage also increases, giving a signal to plant cells for abiotic stress. Data showed that the maximum electrolyte leakage content was observed in the genotype SL-8-PB-1-3-1-4 (135.15%), which was significantly higher than all other genotypes. Among all the salinity levels, the highest electrolyte leakage content was observed in the 6 dS/m level of salinity (78.95 %) and it was significantly higher than all other salinity levels.

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7.16 Water Stream Rejuvenation through Nature-based Solution (Live Vegetative Barriers) – An Innovative Approach in Watershed Management in Jalna District of Maharashtra

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Keywords: Groundwater; Vegetative barriers

1. Introduction

The Jalna district of Maharashtra state is a region that has been facing challenges in land management, dwindling rainfall patterns, and periodic drought for the last two decades, and this has led to adverse consequences in terms of yield and quality of cotton grown. The results of this trend have been seen in the form of depleted organic matter of soil, moderate erosion leading to loss of topsoil, and declining groundwater levels in many areas. The region's semi-arid climate has also contributed to the continual evaporation of surface water, limiting the levels of groundwater recharge. Water stream rejuvenation can increase the groundwater recharge potential by reducing stream runoff velocity (Singh *et al*., 2017). Approaches like nature-based solutions are required to fulfil the purpose of *in situ* soil and moisture conservation in water streams associated with agricultural catchment areas under climate change scenarios.

2. Materials and methods

The concept of the nature-based solution is to rejuvenate the water streams by a combination of vegetative barriers at regular intervals across the water streams and bamboo plantations along the water stream on both sides in the riparian zone. Vegetative barriers will slow down the runoff rate and reduce the silt load carrying capacity of runoff, thus supporting groundwater recharging and rejuvenating water streams. The bamboo plantation will reduce the soil erosion from cultivated fields, improve groundwater recharging, and reduce indirect evaporation from water streams. The vegetative barrier is a combination of four rows of Napier grass (*Cenchrus purpureus*) and one row of bamboo (*Dendrocalamus strictus*) at the center, spanning across the water stream. The interval between the two rows was kept at 0.6 m, and plant-to-plant distance in a row for Napier was 0.3 and 2 m for bamboo. The distance between two such barriers was kept at 50 m. The justification for choosing this design was the ability of the grass to serve as a vegetative barrier for 4 or 5 years till the bamboo reaches maturity to act as a functional barrier. A total of 853 vegetative barriers were constructed in various water streams. Bamboo (*D. strictus*) plants were planted on both sides of water stream in a riparian zone in a 61 km stretch of water streams.

3. Results and discussion

The impact has been incremental as the interventions were initiated in June 2021. The outputs are mentioned in Table 1, which shows that a minimum of 36,849 cum water can be stored by 853 vegetative barriers and a minimum of 3685 cum of water can be added to the existing groundwater (lack of data on the addition of surface water to groundwater by the bamboo plantation due to lack of current evaluation measurement). The maximum cost per unit of stored water through a nature-based solution is Rs 133. The output is based on 1 year of data, and the trapped silt height by the vegetative barriers is on average 0.15 m. It is expected that the trapped silt's height will increase over the years and more water can be stored on the upstream side of the barriers, thereby enhancing the potential for groundwater recharge. Table 2 shows that a minimum of 25,590 kg of green fodder from 853 vegetative barriers will be available during the non-monsoon period, which the farmers can use as cattle feed since Napier grass provides 1.8% of digestible crude protein and 14% of total digestible nutrients (Kiddar, 1945) for livestock. In conclusion, nature-based solutions are efficient and economical and can be a good solution for climate change adaptation. It can easily be constructed and maintained by the local community. A series of live barriers built on water streams can rejuvenate the streams and support the groundwater recharge and source of green fodder during drought periods.

Table 1 Groundwater recharge potential and water storage cost per cum

Number of vegetative barriers (No.)	Average fodder quantity per year from the single vegetative barrier as per discussion with farmers (kg)	Total fodder quantity available from 853 vegetative barriers (kg)	The market price of green fodder as per discussion with farmers (Rs/kg)	Value of green fodder available (Rs)
853	30	25,590	5	127,950

*Unpublished data of WWF-India

Table 2 Collateral benefits of the nature-based solution in terms of fodder availability

Number of vegetative barriers (No.)	Average stream width (m)	Average storage depth (m)	Average fetch length (m)	Water storage capacity due to siltation considering six times fill (m^3)	Infiltration factor for basalt rocks	Amount of groundwater (Cum)	Cost of 853 vegetative barriers* (Rs)	Cost of 24,200 bamboo plantation* (Rs.)	Cost per unit of minimum stored water due to nature-based solution (Rs/m^3)
853	8	0.15	15	36,849	0.1	3685	1,475,097	3,460,600	133

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7.17 Evaluation of Short-duration Varieties of Paddy Through Frontline Demonstrations in Punjab

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Keywords: Returns; Short duration; Water; Yield

1. Introduction

Punjab is producing about 139.91 lakh metric tons of paddy from an area of 31.49 lakh hectares (GOP 2021). So high irrigation water requirement of paddy coupled with a large area under paddy is eroding the groundwater resources of Punjab. At such a withdrawal rate, the groundwater resources of Punjab are likely to be used in 20–25 years (Anonymous 2018). With such scarcity of groundwater resources in Punjab, unrecommended long-duration varieties are amplifying the threat to water resources. So, Punjab Agricultural University (PAU) has developed short-duration varieties of paddy, which can sustain the water resources as well as give sufficient produce and further to transfer these sustainable technologies to farmers' fields, PAU is conducting a number of Frontline Demonstrations (FLDs) under Farmer FIRST Programme (FFP). Thus this study was conducted to evaluate the performance of these short-duration varieties as compared to other long-duration varieties.

2. Materials and methods

Farmer FIRST Programme was implemented in Punjab in 2016-17 and two villages from district Sangrur were selected under this programme. To sensitize the farmers regarding water saving and popularization of recommended short-duration varieties, 300 FLDs having an area of 0.4 ha for each demonstration of PAU recommended short-duration varieties (PR 121 and PR 126) were conducted on farmers' fields each year from 2017-18 to 2021-22, thus totaling 1500 FLDs in the last 5 years (Table 1). To evaluate the performance of FLDs, adjacent local checks of Pusa 44 were selected to record the data. The economic aspects of the frontline demonstrations were thoroughly recorded and further evaluated for comparing the profitability of local checks and PAU's short-duration varieties. Data regarding yield, cost of cultivation, and returns were collected for the FLDs and check plots. B:C ratio was calculated using the net returns and cost of cultivation.

$$\text{Gross return} = \text{Yield} \times \text{Market price}$$

$$\text{Net returns} = \text{Gross returns} - \text{Cost of cultivation}$$

$$\text{B:C ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

3. Results and discussion

The study evaluated the performance of PR 121 and PR 126 on the basis of yield as compared to Pusa 44. Findings revealed that farmers obtained a comparable yield of PR 121 and PR 126 to the Pusa 44. However, a slightly higher yield of Pusa 44 is not advantageous while taking into consideration the maturity time of varieties, which is 25–30 days more for Pusa 44. The net returns from the FLDs on PR 121 are similar to or more than Pusa 44 each year due to the lower cost of cultivation leading to the higher benefit-cost ratio of PR 121. PR 126 variety of paddy gained much popularity among the farmers due to its short maturity period and comparable yield to the other varieties and due to its enormous popularity, only PR 126 variety was selected for FLDs in the year 2021-22. In the years 2017-18, 2018-19, 2020-21, and 2021-22, PR 126 gave a slightly lower but comparable yield to the check variety (Pusa 44), but in the year 2019-20, PR 126 outperformed Pusa 44 with a slight increase in yield. Further economic data revealed that farmers had spent about Rs 3500–6500 less on the cultivation of PR 126 than Pusa 44 each year. FLDs on PR 126 proved to obtain similar net returns as Pusa 44 due to the lower cost of production and similar yield. The maximum increase in net returns was in the year 2019-20 of Rs 6615 per ha due to higher yield and lower cost of cultivation of PR 126. This ultimately resulted in the higher benefit-cost ratio of PR 126. Thus it can be concluded that farmers can generate higher revenue while using these short-duration varieties of PAU, which ultimately can save resources such as water, agro-chemicals, and time further due to the smaller height of these varieties resulting in lower paddy residue, which also encourages the use of different in situ paddy stubble management practices.

Table 1 Economics of FLDs on PR 121 and PR 126 during the 5-year study

Particulars	FLDs (PR 121)	Local check (Pusa 44)	Change	FLDs (PR 126)	Local check (Pusa 44)	Change
2017-18						
Yield (q/ha)	80.69	82.52	–1.83	80.60	82.03	–1.43
Cost of cultivation (Rs/ha)	28,199	31,139	–2940	28,943	32,486	–3543
Gross returns (Rs/ha)	117,001	119,654	–2653	116,866	118,940	–2074
Net returns (Rs/ha)	88,801	88,515	+286	87,923	86,454	+1469
B:C ratio	3.15	2.84	+0.31	3.04	2.66	0.38
2018-19						
Yield (q/ha)	78.69	80.52	–1.83	78.60	80.30	–1.70
Cost of cultivation (Rs/ha)	34,779	38,039	–3260	35,905	40,003	–4098
Gross returns (Rs/ha)	137,707	140,910	–3203	137,550	140,052	–2502
Net returns (Rs/ha)	102,928	102,871	+57	101,645	100,049	+1596
B:C ratio	2.96	2.70	+0.26	2.83	2.50	+0.33
2019-20						
Yield (q/ha)	79.90	78.50	+1.40	79.60	78.30	+1.30
Cost of cultivation (Rs/ha)	36,628	39,394	–2766	36,920	40,772	–3852
Gross returns (Rs/ha)	140,624	138,160	+2464	140,096	137,333	+2763
Net returns (Rs/ha)	103,996	98,766	+5230	103,176	96,561	+6615
B:C ratio	2.84	2.51	+0.33	2.79	2.36	+0.43

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2020-21						
Yield (q/ha)	77.80	82.50	–4.70	78.50	82.50	–4.00
Cost of cultivation (Rs/ha)	40,780	45,430	–4650	40,380	46,324	–5944
Gross returns (Rs/ha)	145,330	154,110	–8780	146,638	153,549	–6911
Net returns (Rs/ha)	104,550	108,680	–4130	106,258	107,225	–967
B:C ratio	2.56	2.39	+0.17	3.63	3.31	+0.32
2021-22						
Yield (q/ha)	–	-	–	79.50	81.20	–1.70
Cost of cultivation (Rs/ha)	–	–	–	38,200	44,625	–6425
Gross returns (Rs/ha)	–	–	–	154,230	157,528	–3298
Net returns (Rs/ha)	–	–	–	116,030	112,903	+3127
B.C ratio	–	–	–	3.04	2.53	+0.51

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7.18 Effect of Tillage, Mulching, and Fertility Levels on Maize Production Under High Hill Rainfed Conditions of Jammu

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Keywords: FYM; Maize; Pine Needles; Rice straw; Tillage

1. Introduction

Maize is widely cultivated in UT of Jammu and Kashmir, especially in the Kandi, Karewa, and plain areas. It needs well-drained soils and about 30°C temperature at the time of germination, growth, and development and over 20°C at the time of ripening. The low productivity of maize in rainfed is attributed to the lack of quality seeds of high yielding varieties, moisture stress due to low and erratic rainfall, high temperature, low soil fertility, competition by weeds, inappropriate tillage and sowing system, lack of nutrient supplying capacity of the soil, and timely nonavailability of the fertilizer to the farmers. In addition to these, the degraded land with limited soil moisture availability at critical stages of crop growth is one of the major constraints for its low productivity. Therefore, the present study was undertaken to develop a production technology for composite maize under high hills rainfed conditions in the Jammu region.

2. Materials and methods

A field experiment was conducted at the research farm of Regional Horticultural Research Substation Bhadarwah, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu at Sartangal Farm E with′ and 34° 15′N, 32° 30,′ and 76° 30′located at 74° 34 E altitude almost 1800 m amsl during *Kharif* 2018. The experiment consisted of 16 treatment combinations with two crop establishment methods, namely, minimum tillage and conservation tillage, four mulches treatment, namely, no mulch, rice straw, pine needles, and local bhang/grass, and two fertility levels, namely, recommended dose of fertilizers (RDF) and 50% RDF+50 N, through FYM were tested in split plot design. The crop establishment methods were taken in main plots and mulches and fertility levels in subplots under sandy clay loam soil having slightly acidic nature, well drained with high organic carbon, (0.81), medium in available nitrogen (310 kg/ha) and potassium (115 kg/ha), and high in available phosphorous (35 kg/ha). The crop was shown on the 05th of May for both years by using a 20 kg seed per hectare rate and nutrients were applied as per the technical programme of the experiment.

3. Results and discussion

Among the crop establishment methods, maximum plant height (268 cm) and number of grains/cob 257.17 were observed in minimum tillage while 100 grain weight (23.60 g) and grain yield (52.66 q/ha) were observed in the conventional; tillage was significantly superior over minimum tillage. A similar finding was observed by Ahmed *et al.* (2010). This might be because the use of conservation tillage has been reported to increase short-term immobilization due to the slower plant decomposition process when tillage is limited (Wood and Edwards, 1992). However, among the mulching, maximum plant height (273.39 cm) and the number of grains/cob (265.50) were observed in mulching treatment with bhang/local grass, whereas grain weight 100 seeds of (23.93 g) and grain yield of 59.72q/ha was observed in mulch with rice straw; this could be attributed to better supply of moisture and suppression of weeds. A similar result was also reported by Mishra (1996). However, in fertility treatments, the application of the recommended dose of fertilizers recorded maximum plant height (271 cm), number of grains/cob (256.12), 100 grain weight (24.02 g), and grain yield (52.23 q/ha).

Table 1 Effect of various treatments on growth and yield of maize

Treatments	Plant height (cm)	No. of grains/cob	100 grain weight (g)	Yield (q/ha)
Crop establishment methods				
Minimum tillage	268.00	257.17	23.60	50.61
Conventional tillage	266.32	247.04	23.67	52.66
C.D. (p=0.05)	NS	6.36	NS	1.34
Mulch				
No mulch	252.33	242.75	23.76	49.84
Mulch with rice straw	271.56	250.42	23.93	59.72
Mulch with pine needles	271.36	249.74	23.28	49.96
Mulch with bhang/local grass	273.39	265.50	23.57	55.03
C.D. (p=0.05)	5.70	10.13	NS	2.31
Fertility levels				
Recommended dose of fertilizers (RDF)	271.01	256.12	24.02	52.23
50% RDF+50 N through FYM	263.31	248.88	23.25	51.04
C.D. (p=0.05)	4.03	7.16	N.S	1.63

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7.19 Promotion of Natural Resource Management Technologies Through Frontline Demonstrations in Punjab

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Keywords: Burning; Direct seeded rice; Groundwater; Happy seeder; Stubble

1. Introduction

The early success of the Green Revolution in Punjab prompted the Government of India to target the state as a source of rice and wheat. The huge amount of rooted and uprooted remains of paddy crop in the field results in burning in Punjab at a mass level and it causes air pollution at a hazardous level during the early winters every year (Venkatramanan *et al*., 2021). The rice-wheat system also demands a large amount of water which has been met by exploiting groundwater resources. Thus, the conventional practices in rice-wheat crop rotation have negative consequences on the natural resources of Punjab in terms of groundwater depletion, air pollution, and loss of soil microorganisms (Roy *et al*., 2018). So, this study was conducted to access the performance of these Frontline Demonstrations (FLDs) on Happy Seeder (HS) and Direct Seeded Rice (DSR), which are the potential solution for conserving the natural resources of Punjab.

2. Materials and methods

Farmer FIRST Programme (FFP) was introduced in Punjab in the year 2016-17. Two villages Chatha Nanhera and Tranji Khera in district Sangrur were selected under FFP. To evaluate and popularize the sustainable resource conservation technologies, 1000 FLDs (200 in 2017-18; 200 in 2018-19; 200 in 2019-20; 300 in 2020-21; 100 in 2021-22) of happy seeder sown wheat for in situ management of paddy stubble and 300 FLDs (50 in 2017-18; 50 in 2018-19; 50 in 2019-20; 100 in 2020-21; 50 in 2021-22) of direct seeded rice were conducted from 2017-18 to 2021-22. The area under each demonstration was 0.4 ha. The performance of FLDs was evaluated by comparing these with their counterfactuals, that is, happy seeder sown wheat with conventionally sown wheat and direct seeded rice with transplanted rice. Data regarding yield, cost of cultivation, and returns were collected for the FLDs and check plots. B:C ratio was calculated using the net returns and cost of cultivation.

3. Results and discussion

The study evaluated the performance of happy seeder sown wheat for in situ management of paddy stubble and direct seeded rice on the basis of yield in the comparison of conventional methods. Findings revealed that happy seeder sown wheat gave a similar yield to the conventional sown wheat, whereas in the case of direct seeded rice, there was no particular trend in the yield. Further, as happy seeder replaces the multiple operations (cultivating, planking, sowing) with a single operation, that is, direct sowing of wheat in standing stubbles, data revealed that the saving in cost of cultivation with happy seeder ranged from Rs 4346 per ha to Rs 6785 per ha. Further due to comparable or higher yield, happy seeder sown wheat also resulted in higher gross returns and ultimately higher net returns and benefit-to-cost ratio (Table 1). Further, while comparing the economic return of the direct seeded rice and transplanted rice, it can be observed that direct seeded rice saved the cost of cultivation in rice. The saving ranged from Rs 6212 per ha in 2019-20 to Rs 7450 per ha in the year 2021-22. The gross returns in DSR were also slightly lower than the transplanted rice in the year 2017-18, 2018-19, and 2021-22 due to lower yield whereas higher in the remaining years. Due to large savings in the cost of cultivation, FLDs on DSR proved to fetch higher net returns in all years resulting in a higher benefit-to-cost ratio for DSR as compared to transplanted rice. Thus, it can be concluded that these technologies can also offer significant economic returns along with the conservation of natural resources.

Table 1 Benefit-to-cost ratio of FLDs on happy seeder technology and direct seeded rice

Particulars	Happy seeder sowing in wheat		Direct seeded rice	
	FLD (HS)	Check plot (CS)	FLD (DSR)	Check plot (TR)
2017-18				
Cost of cultivation (Rs/ha)	21,068	25,414	25,380	32,474
Gross returns (Rs/ha)	90,146	87,971	115,217	116,713
Net returns (Rs/ha)	69,078	62,557	89,837	84,239
B:C ratio	3.28	2.46	3.54	2.59
2018-19				
Cost of cultivation (Rs/ha)	22,508	27,325	25,420	32,474
Gross returns (Rs/ha)	103,500	101,200	140,280	140,857.5
Net returns (Rs/ha)	80,993	73,875	114,860	108,383.5
B:C ratio	3.60	2.70	4.52	3.33
2019-20				
Cost of cultivation (Rs/ha)	22,680	27,845	26,114	32,326
Gross returns (Rs/ha)	104,250	102,230	141,082	137,984
Net returns (Rs/ha)	81,570	74,385	114,968	105,658
B:C ratio	3.60	2.67	4.40	3.27
2020-21				
Cost of cultivation (Rs/ha)	23,745	30,530	29,680	37,514
Gross returns (Rs/ha)	97,763	96,775	144,583	142,902
Net returns (Rs/ha)	74,018	66,245	115,903	107,069
B:C ratio	3.12	2.17	4.81	3.81

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2021-22				
Cost of cultivation (Rs/ha)	31,400	36,250	37,000	44,450
Gross returns (Rs/ha)	85,638	77,981	153,066	156,364
Net returns (Rs/ha)	54,238	41,731	116,066	111,914
B:C ratio	1.73	1.15	3.14	2.52

HS=Happy seeder, CS=Conventional sowing, DSR=Direct seeded rice, and TR= Transplanted rice.

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7.20 Effect of Tillage Practices and Mustard-based Cropping Systems on Soil Biological Properties in Drylands

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Keywords: Biological properties; Cropping systems; Drylands; Tillage practices

1. Introduction

Soil is a valuable natural resource, and its quality is a key element that determines crop productivity and sustainability. Unfortunately, with the advent of the green revolution, soils are being degraded at an alarming rate resulting in a substantial increase in environmental degradation that includes soil salinization, eutrophication, depletion of the underground water table, soil erosion, and decline in soil fertility. Therefore, the need to devise strategies to combat the problems in the existing agriculture production system is the need of the hour. Several research publications have addressed the importance of conservation agriculture practices in preventing soil degradation and restoring soil properties. Soil tillage is one of the key factors that governs soil properties and crop yield. Tillage systems are known to have a major influence on the soil's physical, chemical, and biological properties. Conventional tillage practices for a long time have been known to affect soil organic matter and modify soil organic carbon. A significant loss of soil organic carbon caused by the long-term use of conventional tillage practices resulted in the decrease of soil biological activity and impairment of soil physical properties over time (Liu *et al.*, 2010). When used judiciously, they are often known to reduce the undesirable effect produced by traditional tillage practices such as soil structure destruction and loss of organic matter in the soil. Accordingly, this study has been proposed with the aim to compare the short-term effects of contrasting tillage treatments and mustard-based cropping systems on physiochemical and biological properties of soil under dryland conditions.

2. Materials and methods

A field experiment was conducted at Advanced Centre for Rainfed Agriculture ($32^0$17'N latitude and $75^0$36'E longitude and at an elevation of 332 m above mean sea level) of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India. The experiment was laid out in an established permanent experimental plot consisting of 12 treatments arranged in split plot design with three replications and was maintained since the *rabi* season of 2016-17. The strip constituted three tillage treatments, namely, raised beds (RB), zero tillage (ZT), and conventional tillage (CT), arranged in main plots with four mustard-based cropping systems, namely, mustard-green gram (M-G), mustard-pearl millet (M-P), mustard-sesamum (M-S), and mustard-maize (M-M), arranged in subplots. The mustard crop was grown during *rabi* seasons from 2016-17 to 2019-20, whereas the crops in mustard-based cropping systems, that is, green gram, pearl millet, sesamum, and maize, were grown during the *kharif* seasons from 2017 to 2020. The effect of different tillage systems and mustard-based cropping systems on soil biological properties was studied after 4 years of experiment, after the *rabi* season of 2020. Soil samples were taken from two soil depths, that is, 0–15 and 15–30 cm.

3. Results and discussion

The results revealed that the soil microbial biomass carbon (SMBC) was observed to be in the range of 29.9–35.4 g/kg. A significant difference was observed in 0–15 cm soil depth under tillage practices with zero tillage (ZT) showing the maximum SMBC (35.4 g/kg). This might be due to the reason that the retention of agricultural waste under ZT increased soil microbial biomass carbon that promoted soil biological activity. The dehydrogenase activity was significantly affected by tillage practices having a range from 22.7 to 27.7 µg TPF/g soil per 24 h. ZT exhibited the highest DHA (27.7 µg TPF per gram soil per 24 h^1) compared to other tillage practices. It might be because under zero tillage the soil is disturbed to a minimum level leading to improvements in organic carbon status compared to traditional agricultural treatments, which is also correlated to greater enzyme activity.

Table 1 Effect of different tillage practices and cropping systems on soil microbial biomass carbon (SMBC) and dehydrogenase activity in the soil

	SMBC (g/kg)		Dehydrogenase (µg TPF per g soil per 24 h)	
Depth (cm)	0–15	15–30	0–15	15–30
Tillage systems				
Zero tillage	35.4	33.4	27.7	25.3
Conventional tillage	31.5	29.9	23.4	22.7
Raised beds	34.0	31.5	26.8	24.5
C.D. 5%	1.3	NS	0.7	NS
Cropping systems				
Mustard-maize	33.5	31.4	25.7	24.0
Mustard-pearl millet	32.9	30.8	25.2	23.0
Mustard-sesamum	33.6	31.5	26.0	24.5
Mustard-green gram	34.4	32.7	26.8	25.2
C.D. 5%	NS	NS	NS	NS

Note: Figures in the parenthesis are standard deviations. C.D. 5%=Critical difference.

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7.21 Effect of Application of Nano-DAP and Conventional Fertilizers on Rice Yield

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Keywords: Foliar spray; Nano-DAP; Productivity; Rice; Seedling dip

1. Introduction

The world is currently facing the ongoing crises of ever-rising population and food security with a continuously shrinking resource base. The present global population of 7.7 billion is expected to grow exponentially and reach 9.7 billion by 2050, which will put up 70% more food demand as of today (Meghana *et al*., 2021). Rice, with 11% of the global agricultural area under its cultivation and a supply of around 60% calories to 2.7 billion people globally, is the second most important cereal crop in the world. Enhanced rice productivity is a must to feed the global population as well as most of the people residing in South Asia. Low nitrogen (30–40%) and phosphorus use efficiency (15–20%) is a major constraint globally and is responsible for the declined rice productivity (Meghana *et al*., 2021). Phosphorus, with such low use efficiency and being low in most of the soils in India, can be a major limiting factor in enhancing rice productivity along with nitrogen; therefore, the present study was considered to explore the impact of nano-diammonium phosphate (Nano-DAP) on rice productivity with partial substitution of conventional fertilizers such as urea and DAP that are highly susceptible to losses when applied in the soil (Bhatta *et al*., 2021).

2. Materials and methods

The present field experiment was conducted to explore the impact of seedling dip and foliar application-based Nano-DAP application in transplanted rice. The field experiment was conducted at Research Farm, Department of Soil Science, College of Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, India. The experiment consisted of 10 treatments (Table 1), which were replicated thrice in a randomized complete block design. The soil of the experimental site was silty clay loam in texture, acidic in reaction, and low in available nitrogen, medium in available potassium, and high in available phosphorus.

Table 1 Treatment details

Treatment	Treatment details
T_1	0% nitrogen (N) and phosphorus (P)
T_2	100% N and P (*University recommendation)
T_3	75% N and P
T_4	50% N and P
T_5	T_3+SD with Nano-DAP @ 5 mL/liter+FS with Nano-DAP @ 2 mL/liter at 25 days after transplanting (DAT)
T_6	T_3+SD with Nano-DAP @ 5 mL/liter+FS with Nano-DAP @ 4 mL/liter at 25 DAT
T_7	T_4+SD with Nano-DAP @ 5 mL/liter+FS with Nano-DAP @ 2 mL/liter at 25 DAT
T_8	T_4+SD with Nano-DAP @ 5 mL/liter+FS with Nano-DAP @ 4 mL/liter at 25 DAT
T_9	T_4+SD with Nano-DAP @ 5 mL/liter+first FS with Nano-DAP @ 2 mL/liter at 25 DAT+second FS at one week before flowering
T_{10}	T_4+SD with Nano-DAP @ 5 mL/liter+first FS with Nano-DAP @ 4 mL/liter at 25 DAT+second FS at one week before flowering

*University recommendation (100%)=90 kg nitrogen/ha, 40 kg phosphorus/ha, 40 kg potassium/ha

**SD=Seedling dip, FS=Foliar spray, and DAP=Diammonium phosphate

3. Results and discussion

The results of the experiment revealed that Nano-DAP-based application significantly improved yield attributes and yield of rice especially when rice seedlings were treated and exposed to foliar application in combination. The number of grains/panicle (446.7) and test weight (24.84 g) was found to be the highest for T_{10} while the lowest for T_1 (326.8 and 22.46 g, respectively). T_{10} recorded significantly higher grain (5245.8 kg/ha) and straw yield (6941.7 kg/ha) than T_1 (3336.8 kg/ha and 4510.4 kg/ha, respectively), T_4 (4358.3 kg/ha and 5502.8 kg/ha, respectively), and T_7 (4675.0 kg/ha and 6054.2 kg/ha, respectively), which was further reported to be at par with T_9 (5129.2 kg/ha and 6745.8 kg/ha, respectively), T_6 (5114.6 kg/ha and 6725.7 kg/ha, respectively), T_2 (5063.9 kg/ha and 6359.7 kg/ha, respectively), T_5 (5014.6 kg/ha and 6409.0 kg/ha, respectively), and T_8 (4820.8 kg/ha and 6151.4 kg/ha, respectively). Initial basal application of conventional fertilizers and Nano-DAP as seedling dip might have helped the crop in better establishment followed by foliar application of Nano-DAP at reproductive stages that enhanced the number of grains/panicle and test weight and ultimately resulted in significantly higher yield. The control treatment (T_1) with no nutrient application of nitrogen or phosphorus recorded a significantly lower grain (3336.8 kg/ha) and straw yield (4510.4 kg/ha).

Table 2 Effect of application of Nano-DAP and conventional fertilizers on yield attributes and yield of rice

Treatments	Number of grains/panicles	1000-grain weight (g)	Straw yield (kg/ha)	Grain yield (kg/ha)
T_1	326.8	22.46	4510.4	3336.8
T_2	425.2	24.68	6359.7	5063.9
T_3	405.4	24.12	6280.5	4795.8
T_4	382.0	23.88	5502.8	4358.3
T_5	416.0	24.38	6409.0	5014.6
T_6	431.2	24.46	6725.7	5114.6
T_7	398.3	24.12	6054.2	4675.0
T_8	407.2	24.25	6151.4	4820.8
T_9	432.5	24.60	6745.8	5129.2
T_{10}	446.7	24.84	6941.7	5245.8
SEm±	3.9	0.17	291.9	179.1
CD (p=0.05)	11.7	0.51	867.3	532.0

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7.22 Maximizing Wheat Productivity Through Higher Nutrient Levels and Use of Plant Growth Regulators

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Keywords: Genotype; Growth regulators; Nitrogen; Wheat

1. Introduction

Wheat (*Triticum aestivum* L.) is a staple food crop with over 770 million tons harvested globally, and it contributes to over 20% of the global calories and proteins for humankind (FAO, 2019). Nitrogen (N) is one of the most widely used nutrients in agricultural production, which has a great impact on the growth and yield of crops (Duan *et al*., 2019). However, the excessive application of N fertilizer may decrease yield due to excessive vegetative growth, weak shoots, and a small capacity of the sink to mobilize assimilates. Lodging is still a constraint of yield potential in wheat production. In order to increase grain yield, an intensive management system is necessary to increase N fertilizer rates and reduce lodging with PGRs (Tripathi and Hazra, 2003). PGRs like chlormequat may prevent yield loss due to lodging by shortening plants. The objective of this study was to evaluate different genotypes at higher levels of nutrients and the use of plant growth regulators for maximizing wheat productivity.

2. Materials and methods

The field experiment was conducted during the *rabi* seasons of 2019-20 at Research Farm, Wheat & Barley Section, Chaudhary Charan Singh Haryana Agricultural University, Hisar. Geographically the experimental site is situated at 29°10'N latitude and 75°46'E longitude, with an elevation of 215.2 m from the mean sea level. In this trial, 15 wheat genotypes, namely, DBW 327, HD 3086, DBW 332, DBW 303, HD 2967, DBW 187, DBW 329, WH 1252, HD 3378, WH 1270, DBW 333, DBW 330, DBW 328, DBW 331 and DBW 222, were evaluated at three levels of fertility, that is, RDF (150 kg N:60 kg P_2O_5:40 kg K_2O:25 kg $ZnSO_4$/ha), 150% RDF+15 t FYM/ha, and 150% RDF+15 t FYM/ha+Growth Regulator spray (Chlormequat chloride (*Lihocin*) and Tebuconazole (*Folicur*)). The experiment was conducted in the split-plot design with three replications. The soil of the experimental field was sandy loam in texture, organic carbon (0.35%) with pH (7.8), available nitrogen (150 kg/ha), available phosphorus (17.2 kg/ha), and available potassium (275 kg/ha) with an EC of 0.22 dS/m. The crop was sown manually with a hand plough in the last week of October using the seed rate of 100 kg/ha at a row-to-row spacing of 20 cm. Other management practices including irrigation, weeding, and hoeing were adopted as per the package and practices of the wheat crop.

3. Results and discussion

The result of the experiment revealed that on an average basis a significant improvement in grain yield from 57.29 to 65.20 q/ha was recorded when 150% RDF+15 t FYM/ha+Growth Regulator was applied as compared to RDF (Table 1). The use of PGRs increased the grain yield significantly as compared to the control treatment because PGRs improved photosynthesis and more assimilates were mobilized toward grains, leading to the increase in grain yield (Shekoofa and Emam, 2008). However, an additional application of 15 t FYM/ha with 150% RDF did not improve the grain yield significantly as compared to RDF. The maximum numbers of effective tillers (438) and grains/earhead (59.36) were also recorded when 150% RDF+15 t FYM/ha+Growth Regulator were applied to the crop. On a mean basis, genotype DBW 327 produced the highest grain yields of 70.85 q/ha, which was significantly higher than all other genotypes.

Table 1 Effect of fertility levels on yield attributes and grain yield of wheat genotypes

Treatments	Effective tillers/m^2	Grains/earhead	1000-grain weight	Grain yield (q/ha)
Fertility levels				
RDF (150 kg N:60 kg P_2O_5:40 kg K_2O:25 kg $ZnSO_4$/ha)	402	51.96	41.27	57.29
150% RDF	413	53.93	42.51	59.01
150% RDF+15 t/ha FYM+Growth Regulators*	438	59.36	40.90	65.20
S.Em±	**3**	**0.56**	**0.28**	**0.54**
LSD (*p*=0.05)	**13**	**2.25**	**1.13**	**2.19**
Genotypes				
DBW 327	436	49.13	44.56	70.85
HD 3086	418	52.42	38.73	60.90
DBW 332	410	61.60	38.80	58.41
DBW 303	429	64.52	39.81	62.30
HD 2967	403	51.13	41.54	50.45
DBW 187	397	55.14	40.34	54.77
DBW 329	425	54.34	43.21	62.08
WH 1252	428	52.86	41.98	62.97
HD 3378	404	56.62	43.91	58.99

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Treatments	Effective tillers/m^2	Grains/earhead	1000-grain weight	Grain yield (q/ha)
WH 1270	406	56.01	39.72	56.35
DBW 333	412	53.71	44.80	61.35
DBW 330	413	52.84	41.71	58.91
DBW 328	433	54.43	42.71	63.64
DBW 331	433	57.88	41.37	65.51
DBW 222	414	53.57	40.24	60.00
S.Em±	**8**	**0.84**	**0.47**	**1.03**
LSD (*p*=0.05)	**23**	**2.37**	**1.34**	**2.89**

[*]Two sprays as tank mix – Chlormequat chloride (Lihocin) @ 0.2%+tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at First Node and Flag leaf (tank mix application).

The lowest grain yield (50.45 q/ha) was recorded in the genotype HD 2967. The highest grain yield in genotype DBW 327 was mainly due to the maximum number of effective tillers/m^2 (436) recorded in this genotype. Maximum grains/earhead (64.52) was recorded in genotype DBW 303. However, the boldest grains were recorded in genotype DBW 333 but the number of effective tillers/m^2 and grains/earhead was lower in genotype DBW 333 resulting in lower grain yield (61.35 q/ha).

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7.23 Optimization of Drip Irrigation and Fertilizer Levels for Higher Yield and Water Productivity of Indian Mustard (*Brassica juncea* L.) in North-Western India

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Keywords: Drip irrigation; Fertigation; Seed yield; Water productivity

1. Introduction

Improving crop productivity with scarce water resources has become a major concern of present-day agriculture. Crop water productivity could optimize with either higher production from the same water resources or the same production with less water utilization. The consequent increase in water usage will further intensify the pressure for irrigated croplands to produce more with less. Thus, high-frequency drip irrigation (DI) has evolved as a resourceful technology to assuage water shortage and optimize production per unit of water used in agriculture. It offers good scope for reducing the water requirement of crop plants due to the precise and site-specific application of irrigation water near the root zone of plants (Kumar *et al*., 2021). Crop and water productivity can be greatly improved by the adoption of this technology under a limited water application system by decreasing the leaching losses. Fertigation also provides a timely and consistent amount of nutrients to plants which allows uniform distribution of applied nutrients and improved uptake, ultimately resulting in increased fertilizer use efficiency. Hence, the present investigation was conducted to study the effect of drip fertigation levels on the growth, yield, and water productivity of Indian mustard.

2. Materials and methods

The field experiment was conducted at Research Farm, Department of Agronomy, Punjab Agricultural University (PAU), Ludhiana, during the *rabi* seasons of 2015–2017. A randomized complete block design (RCBD) was used in the present experiment with a treatment combination of three irrigation (crop evapotranspiration (ET_c) at 60%, 80%, and 100%)) and three nutrient levels (recommended dose of fertilizers (RDF) at 60%, 80%, and 100%) through drip with one conventional practice (flood irrigation with the basal application of RDF, that is, 125 kg N, 30 kg P_2O_5, and 25 kg S per ha). Irrigation was applied through drip at 7 days interval as per treatment. The Indian mustard variety RLC 3 was sown using 3.75 kg/ha seed with inter- and intra-row spacing of 30 × 10 cm. In the conventional practice, half N and full P_2O_5 and gypsum (200 kg/ha) were applied at the time of sowing. The remaining half N was applied at 4 weeks after sowing, that is, after first irrigation. Fertigation was started with 15 DAS and applied in 10 equal splits at weekly intervals. Urea, monoammonium phosphate (MAP), and elemental sulphur (90% S) were used as the source of N, P_2O_5, and sulphur (S), respectively, in drip fertigated plots.

3. Results and discussion

Yield and yield components of Indian mustard were significantly influenced by differential drip irrigation and fertigation levels as compared to the conventional practice (CP), which is flood irrigation and manual application of fertilizers. It is worth mentioning here that all drip irrigation and fertigation combinations recorded significantly higher seed yield than CP except ET_c 60% with all fertigation levels and 80% ET_c with 60% RDF. Similar results were recorded by Sinha *et al*. (2017).

The application of irrigation water at 80–100% ET_c with 100% RDF also made better deployment of N, P, and S within the root horizon while poor translocation and assimilation of nutrients were observed by reducing 40% fertilizer dose, that is, at 60% RDF. Higher water productivity was recorded from DI at 60%, 80%, and 100% ET_c with fertigation of 80% and 100% RDF as compared to CP, although the increase was non-significant. Further, increased water application at higher levels provided vigorous growth and stimulated cell water potential into sizeable crop yield at each cubic meter of ETa. While conventional flood irrigation provided enough water, the crop was unable to utilize the water competently because of constant drainage, percolation, and evaporation losses. Subsequently, plants always remained under intermittent stress, which hampered their yield and ETa.

Table 1 Effect of drip irrigation and fertigation levels on seed and water productivity of *B. juncea* L. (*rabi* seasons of 2015–2017)

Drip irrigation levels	Fertigation levels			Mean	CP	Fertigation levels			Mean	CP
	60% RDF	80% RDF	100% RDF			60% RDF	80% RDF	100% RDF		
	Seed yield (t/ha)					Water productivity (kg/m^3)				
ET_C 60%	1.86	2.15	2.29	2.10	–	1.020	1.175	1.253	1.149	–
ET_C 80%	2.16	2.36	2.47	2.33	–	1.027	1.126	1.178	1.110	–
ET_C 100%	2.24	2.46	2.52	2.41	–	0.945	1.038	1.060	1.014	–
Mean	2.09	2.32	2.42	–	–	0.997	1.113	1.163		–
Conventional practice (CP)	–	–	–	–	2.10	–	–	–	–	0.839
LSD 5 %	IS=0.154, FS=0.154, RP vs. IS × FS=0.198					IS=0.071, FS=0.071, RP vs. IS × FS=0.090				

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7.24 Effect of Plant Growth Promoting Rhizobacteria on Growth of Strawberry (*Fragaria* x *ananassa* Duch.) cv. Chandler

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Keywords: Chlorophyll; Growth; PGPR; Strawberry

1. Introduction

The cultivated strawberry (*Fragaria* x *ananassa* Duch.) is grown over a wide range of climatic zones, extending from temperate to subtropical regions. In recent years, the concern for environmental pollution and food safety has increased. Studies show that fertilizers used in agriculture percolate into the earth and contaminate the soil and underground water. Plant growth promoting rhizobacteria (PGPRs), when inoculated in growing media, hasten these microbial and physiological processes which aid in the absorption of nutrients by the plants. Besides the direct effect on nitrogen fixation and phosphorous mobilization, PGPRs are also known to upsurge microbial activities of the soil which in turn help the plant to grow better. These beneficial microorganisms need to be used in place of synthetic fertilizers, as they are equally capable of improving plant growth through the supply of plant nutrients and may help to sustain soil health and productivity in the long run. Strawberry tends to respond well to the application of PGPRs and the response to bacterial inoculation is cultivar dependant, so there is tremendous scope for commercialization of these inoculants in strawberry production.

2. Materials and methods

The study was carried out at the Research Farm, Division of Fruit Science, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu during the year 2019-20. The experiment was laid out in randomized block design with eight treatments and three replications. Planting was done on raised beds with a spacing of row to row distance of 45 cm and plant to plant distance of 30 cm, accommodating nine plants per bed. The $PGPR_1$ and $PGPR_2$ which were liquid formulations were procured from Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The third inoculum, Arka Microbial Consortium (AMC), is a powder formulation that was procured from IIHR, Hesargatta, Bengaluru. The treatments consisted of the application of PGPR alone or in combination with different levels of the recommended dose of fertilizers (RDF) and farmyard manure (FYM). PGPRs were applied as a soil drench, after 15 and 30 days of transplanting. Plant height was measured by erecting the measuring scale at the base of the crown and measuring the vertical distance to the highest point. Plant spread was measured in east-west and north-south directions and expressed as the mean of the two measurements. Petiole length was measured with the help of a measuring scale by placing it on leaf petioles randomly selected from the plants. The leaf area of representative leaves was measured with the help of a leaf area meter. The leaf area index was calculated by dividing the total leaf area by the total ground area. Chlorophyll was measured by chlorophyll meter (SPAD 502) and the value was read from the fourth or fifth leaf from the top.

3. Results and discussion

The study revealed that the application of $PGPR_1$ in combination with $PGPR_2$ and Arka Microbial Consortium along with 70% of N, P, and recommended K and FYM resulted in maximum plant height (19.26 cm), plant spread (26.20 cm), root length (171.33 mm), number of leaves (29.55), petiole length (8.49 cm), chlorophyll value (47.46), and leaf area (333.43 cm^2). This may be the overall outcome of nitrogen fixation by *Azotobacter* while *Pseudomonas* aided in potassium mobilization, and *Bacillus pumilus* MK_5, *B. subtilis* PM_9, and *Bacillus* spp. (Arka Microbial Consortium) together played a role in phosphorous solubilization. Better growth of plants inoculated with different PGPRs in the present investigation might be due to the fact that PGPR influenced the chlorophyll content in strawberry cv. Chandler is a result of siderophores synthesized by *Pseudomonas* which induces gene expression in operons that synthesize siderophore because of its high affinity with iron (Cornelis, 2010) in the presence of suitable pH, trace elements, nitrogen, phosphorus, and carbon (Duffy and Défago, 1999). As we know, iron is involved in the physiological synthesis of chlorophyll.

The increased leaf area could be attributed to the increased nitrogen availability through the application of biological nitrogen-fixing culture in combination with fertilizers and farmyard manure. An increase in chlorophyll encouraged nitrogen uptake and in the assimilation of the amino acids into proteins and nucleic acid, which constitute the basis of chloroplast, mitochondria, and other structures in which biochemical reactions occur (Awasthi *et al*., 1998). Furthermore, the presence of *Azotobacter* facilitated nitrogen fixation once they establish in the rhizosphere (Subba Rao, 1993) and there was increased vegetative growth. The increased leaf area could be attributed to the increased nitrogen availability through the application of biological nitrogen-fixing culture in combination with fertilizers and farmyard manure. The higher petiole length obtained by the application of PGPRs in the present study is in consonance with the findings of Ansari *et al*. (2018) who also reported maximum petiole length with the inoculation of Azotobacter and PSB along with RDF in strawberry cv. Chandler. The results obtained in the experiment on increased root growth indicate that PGPRs play an important role in rhizosphere activity and stimulate better rooting as a result of their colonizing and biological activities. These activities possibly enhance root length, branching, and surface area available for absorption (Borda *et al*., 2009).

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Table 1 Effect of plant growth promoting rhizobacteria on plant growth characteristics of strawberry cv. Chandler

Treatment	Plant height (cm)	Plant spread (cm)	Root length (mm)	Number of leaves	Petiole length (cm)	Chlorophyll (SPAD)	Leaf area per plant (cm^2)	Leaf area index
Control (recommended dose of fertilizers)	15.66	18.57	121.33	20.99	6.39	39.64	231.53	1.54
$PGPR_1$+90% N, P, and recommended K and FYM	15.76	18.63	134.33	21.88	6.72	40.88	245.09	1.63
$PGPR_2$+90% N, P, and recommended K and FYM	15.81	19.03	135.67	23.22	6.69	41.52	250.18	1.66
AMC+90% N, P, and recommended K and FYM	17.50	21.76	144.67	24.77	7.16	44.58	285.89	1.90
$PGPR_{1+}PGPR_2$+80% N, P, and recommended K and FYM	16.50	20.63	153.33	23.22	6.81	42.99	261.53	1.74
$PGPR_1$+AMC+80% N, P, and recommended K and FYM	18.53	24.13	159.33	26.11	7.50	46.61	305.17	2.03
$PGPR_2$+AMC+80% N, P, and recommended K and FYM	18.90	24.56	166.33	26.44	7.90	46.31	298.29	1.99
$PGPR_1$+$PGPR_2$+AMC+70% N, P, and recommended K and FYM	19.26	26.20	171.33	29.55	8.49	47.46	333.43	2.22
SE(m) ±	0.22	1.06	1.89	0.43	0.20	0.59	3.71	0.02
CD (≤0.05)	0.66	3.17	5.64	1.29	0.61	1.75	11.04	0.07

AMC=Arka Microbial Consortium.

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Theme 8

Agriculture and Forestry on Paths Towards Carbon Neutrality

8.1 Cutting Frequencies and Foliar Application of Nutrients on Green and Seed Yield in Spinach beet (*Beta vulgaris* var. *bengalensis*)

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Keywords: Cutting frequencies; Micronutrients; RDF; Seedling vigorindex

1. Introduction

Spinach beet/Indian spinach (*Beta vulgaris* var. *bengalensis*) is a cool season leafy vegetable that can be grown all the year round under slightly cool conditions. The leaf yield in this crop can be obtained by trimming all of the leaves and new shoots and taking multiple cuttings during the growing season, but in some areas it is grown for seed production without giving any cut. Excluding green cuttings may deprive the growers of taking monetary benefits of the green leafy crop. Because of multiple cuttings, the crop needs a robust supply of nutrients to grow quickly. Cutting the main shoot is necessary for generating abundant vegetative growth as lateral shoots emerge that further increases the number of leaves per plant and ultimately increases the yield that necessitates periodic macro and micronutrient feeding. So, cuttings operations in a combination of foliar spray of nutrients could be a viable method for improving spinach beet growth, development, and seed yield.

2. Materials and methods

The experimental material consisted of a variety Jammu Spinach Beet-07 that was grown consecutively for 2 years (2020-21 and 2021-22) at Vegetable Experimental Farm-I, Division of Vegetable Science &Floriculture, SKUAST-Jammu. The experiment was replicated thrice in Factorial Randomised Block Design consisting of two factors, namely, cutting frequencies with four levels, that is, C_0(no cut), C_1 (one cut),C_2(two cut), and C_3(three cut), followed by foliar application of macro and micronutrients with five levels, that is, A_0(RDF), A_1(RDF+10 ppm micronutrient +75 ppm WSF 19:19:19), A_2(RDF+10 ppm micronutrient +100 ppm WSF 19:19:19), A_3(RDF+15 ppm micronutrient +75 ppm WSF 19:19:19), and A_4(RDF+15 ppm micronutrient +100 ppm WSF 19:19:19). The seed sowing was done in the second fortnight of October during 2021 and 2022 in a plot size of 20cm × 5cm.All standard production techniques were followed as per the Package of Practices of Vegetables of Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu.

3. Results and discussion

The cutting frequencies and nutrient application had a significant effect on all parameters recorded during both years (Table 1).

Table 1 Cutting frequencies and nutrient application on green and seed yield in spinach beet (*Beta vulgaris*) (pooled data for two years)

Cutting frequencies (C) / Nutrient Application (A)	Plant height(cm) At seed stalk formation	Green leaf yield (q/ha)	Interval between successive cuttings (days)	Days to 50% flowering	Seed yield per plant(g)	Seed yield per hectare (q)	Germination (%)	Seedling vigor index
C_0	225.25	0.00	0.00	102.73	22.84	22.31	80.33	1238.81
C_1	209.20	105.86	45.93	122.20	23.22	22.44	81.73	1365.01
C_2	204.40	172.15	75.60	132.33	19.86	19.39	78.73	1125.45
C_3	178.53	220.01	96.40	143.06	18.31	18.07	75.46	995.65
C.D(at 5%)	**3.19**	**6.83**	**1.72**	**1.86**	**0.97**	**1.02**	**1.49**	**12.29**
A_0	196.68	102.78	58.42	122.33	17.95	17.55	77.58	979.40
A_1	199.05	117.31	56.66	123.66	19.17	18.73	78.25	1087.20
A_2	201.86	124.04	54.33	125.33	20.07	20.29	78.58	1164.36
A_3	206.03	137.36	51.66	126.42	23.27	22.40	80.08	1288.18
A_4	208.00	141.04	51.16	127.66	23.94	23.26	80.83	1390.00
C.D(at 5%)	**3.56**	**7.64**	**1.92**	**2.08**	**1.09**	**1.14**	**1.67**	**13.75**

C_0: No cut
C_1: One cut
C_2: Two cut
C_3: Three cut
A_0: RDF
A_1: RDF+10ppm (micronutrients) +75ppm (WSF-19:19:19)
A_2: RDF+10ppm (micronutrients) +100ppm (WSF-19:19:19)
A_3: RDF+15ppm (micronutrients) +75ppm (WSF-19:19:19)
A_4: RDF+15ppm (micronutrients) +100ppm (WSF-19:19:19)

Maximum plant height (225.25 cm) noted at seed stalk formation phase was treatment where no cut was given (C_0). Similarly, the maximum plant height (208.00 cm) was also recorded in the A_4 nutrient treatment. The findings are in agreement with studies conducted in fenugreek by Singh *et al.* (2018). Lesser height was recorded as the crop was given more cuts because regular pruning promoted the development of side shoots that resulted in bushy habits with decreased plant height. Maximum green leaf yield (220.01q/ha) was obtained in C_3(three cuts) with A_4 nutrient application treatment (141.04 q/ha). The interval between successive cuttings was decreased as cutting frequency progressed. First cutting took more days as compared to successive intervals between second and third cutting.

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Similarly, the nutrient application comprising RDF+15ppm (micronutrient) + 100ppm (macronutrients) took a lesser number of days for producing economic yield. Earliness of the crop directly corroborates with 50% flowering. Three cuttings delayed flowering, whereas RDF +15ppm (micronutrients)+100ppm (macronutrients) advanced the earliness. It might be due to the change in the source-sink relationship, thereby advancing the reproductive phase (Vasudevan *et al*., 2008). The seed parameters responded favorably to the cutting frequencies and nutrient application. One cutting (C_1) followed by a foliar spray of nutrients with RDF+15 ppm (micro)+100ppm (macronutrients WSF19:19:19), that is, A_4, yielded maximum seed with improved germination and seedling vigor index during both the years. The enhancement in seed quality was due to the involvement of nutrients in catalytic activity and the breakdown of complex substrates into simple forms such as glucose, amino acids, and fatty acids resulting in the improvement in seed quality parameters (Santosh, 2012).

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8.2 Variation in Tree Biomass and Carbon Stock of *Pinusroxburghii*Sarg.Along the Altitudinal Gradient in Jammu, J&K, India

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Keywords: Altitude; Biomass; Carbon stock: Pinus roxburghii

1. Introduction

Altitude is an important environmental gradient that affects the precipitation and temperature and brings about a change in climate along the elevation. It is also responsible for the diversification and distribution of forest species as well as their growth, thereby affecting the carbon stock (C). Twenty-four percent of the global land area is covered by mountains that are facing the brunt of climate change. In the past, many studies have been carried out in relation to the species composition and distribution along the altitudinal gradient, but the studies related to the pattern of biomass and carbon stock distribution along the altitudinal gradient are limited. The present study was conducted at the Billawar forest division of Kathua district of Jammu, India to observe the pattern in biomass and carbon stock distribution in *P.roxburghii* along analtitudinal gradient.

2. Materials and methods

The study was carried out in the year 2020-21 in the *P.roxburghii* forest of Billawar forest division of the Kathua district in Jammu. The whole altitudinal gradient was divided into three altitudinal ranges, that is, lower (1000–1300 m),middle (1300–1500 m), and upper (1500–1800 m). The data were collected by adopting a randomized sampling technique. Five quadrates of size 20 × 20 m^2 were laid out in each altitudinal range. The diameter at breast height (DBH) and tree height of all the trees within the quadrate were measured. The regression equation $\sqrt{V}=0.05131+3.98598D-1.0245\sqrt{D}$ (FSI, 1981) was used for determining the growing stock volume density (GSVD). Aboveground biomass density (AGBD) was calculated by multiplying GSVD by wood density (0.46 gm/cm^3). Belowground biomass density (BGBD) was calculated by multiplying AGBD by a factor of 0.28 (Mokany *et al*., 2006). Total biomass density (TBD) was obtained by adding AGBD and BGBD. Similarly, the total carbon density (TCD) was determined by multiplying TBD by a factor of 0.47. The data were analyzed through one-way ANOVA at a $p \leq 0.05$ level of significance.

3. Results and discussion

Tree density per hectare was maximum (433±30.05) at the lower altitudinal range, while minimum tree density (269±52.42) was observed from the upper altitudinal range. A similar trend was observed for GSVD, which was reported as maximum (377.87±23.47 m^3/ha) at lower altitudes and minimum (217.29±37.03 m^3/ha) at upper. There was a decrease in biomass and carbon stock with an increase in the altitudinal range. AGBD, BGBD, and TBD in Mg/ha were observed at maximum (225.97±14.04, 63.27±3.93, and 289.24±17.97, respectively) from the lower elevation whereas minimum (129.94±22.15, 36.38±6.20, and 166.32±28.35, respectively) from the upper elevation. Likewise, TCD was also maximum (135.94±8.44Mg/ha) at the lower altitude while minimum (78.17±13.32Mg/ha) at the upper altitude. There were significant ($p \leq 0.05$) differences in biomass and carbon stock along the altitudinal gradient (Table 1), which may be due to the result of one or more factors such as temperature, moisture, nutrient deficiency, and runoff or their combinations. A decrease in net primary productivity (NPP) with increasing altitude may also be one of the reasons for lower biomass production at upper altitudes. *P.roxburghii*, which has a vast altitudinal stretch of approximately500–2200 m, recorded maximum growth and biomass production at an altitudinal range of 1000–1300 m and, therefore, resulting in maximum CO_2 sequestration in this range.

Table 1 Biomass and carbon stock of *P.roxburghii* along the altitudinal gradient in Jammu, J&K, India

Altitude gradient (m)	Tree density (trees/ha)	GSVD (m^3/ha)	AGBD (Mg/ha)	BGBD (Mg/ha)	TBD (Mg/ha)	TCD (Mg/ha)
Lower, 1000–1300 m	433±30.05	377.87±23.47	225.97±14.04	63.27±3.93	289.24±17.97	135.94±8.44
Middle, 1300–1500 m	350±62.91	302.86±29.47	181.11±17.62	50.71±4.93	231.82±22.55	108.96±10.60
Upper, 1500–1800 m	269±52.42	217.29±37.03	129.94±22.15	36.38±6.20	166.32±28.35	78.17± 13.32
Mean	351±47.51	299.34±46.39	179.01±27.74	50.12±7.76	229.13±35.50	107.69±16.69
($p \leq 0.05$)	0.140	0.027	0.027	0.027	0.027	0.027

±standard error.

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8.3 Potential of Different Fruit-Based Agroforestry Models for Improving Livelihood in Humid and Subtropical Regions of India

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Keywords: Fruit-based agroforestry; Productivity; Red and lateritic zone

1. Introduction

For improving livelihood security by increasing the total productivity per unit area of land to meet the growing demands of the people for food, fruits, fuel wood, timber, fodder, bioenergy, and other ecological services, agroforestry can be considered the best preferred diversified land use management practice (Sarkar, 2019). Monocropping played a significant role in increasing food production during the green revolution, but since then it has increased the probability of higher pest incidence and deterioration of soil health. Agroforestry is a diversified land use practice that integrates the cultivation of agronomic crops, vegetable crops, fruit trees, and silvi components and improves the livelihood of poor farmers, biodiversity conservation, and environmental sustainability. Hence, the present investigation is based on the effect of different fruit-based agroforestry systems on the production of diversified products, restoration of soil health, and economic returns incurred in humid and subtropical regions of India.

2. Materials and methods

The present study was carried out at the Regional Research Station (Red and Laterite Zone) of Bidhan Chandra Krishi Viswavidyalaya at Jhargram, West Bengal, India. The soil of the site of study is coarse-textured, acidic (pH 5.5), poor in organic matter, highly susceptible to erosion hazards, and situated in a humid subtropical climatic zone characterized by short winter and long hot summer. The experiment was initially started in August 2007, with one-year-old saplings of mango grafts cv. Amrapali (100 Nos.) planted along with Gamhar (*Gmelina arborea*) seedlings of about 2 months old at 10 m × 10 m spacing. Gamhar seedlings were planted in between two mango plants at a spacing of 5 m in between two mango rows and as also boundary plantation of the experimental field. The size of plots for planting different intercrops was 20 m × 20 m for each treatment. The intercrops were planted in the years 2015 and 2016. The experiment was laid out in a randomized block design having eight treatments (T_1: Gamhar+ Mango+ Cowpea; T_2: Gamhar+Mango+Black gram- Mustard; T_3: Gamhar+ Mango+Groundnut-Mustard; T_4: Gamhar+ Mango+ Okra-Mustard; T_5: Gamhar+Mango+Maize-Mustard; T_6: Gamhar+Mango; T_7: Sole Gamhar; T_8: Sole Mango) with three replications.

3. Results and discussion

The total returns obtained from all were inferred to be higher than the sole cropping of both mango and gamhar. T_3 (Gamhar+Mango+Groundnut-Mustard) agroforestry model gave the total highest returns of Rs 846,420.62 ha^{-1} yr^{-1} in Indian rupee (INR). The model T_3 was followed by T_5 (Gamhar+ Mango+Maize-Mustard) with a total of Rs 819,122.33 ha^{-1} yr^{-1}. T_1, T_2, and T_4 ranked third, fourth, and fifth in terms of gross income of Rs 667,512.69 ha^{-1} yr^{-1}, Rs 607,634.08 ha^{-1} yr^{-1}, and Rs 508,335.22 ha^{-1} yr^{-1}, respectively. The model T_7 gave the minimum gross income of Rs 146,287.29 ha^{-1} yr^{-1} (sole Gamhar) among all models. The results were similar to those of Murmu *et al.* (2017). The integration of crops with components of tree and fruit gave higher gross income than tree and fruit tree alone (Basanda *et al.*, 2017).

Table 1 Economic returns obtained from different AFS systems

AFS models	Returns from different components of AFS					
Treatments	**Return from tree (Rs/ha/year)**	**Return from fruit crops (mango) (Rs/ha/year)**	**Return from mustard crop (Rs/ha/year)**	**Return from intercrop (Rs/ha/year)**	**Total return (Rs/ha/ year)**	**B:C ratio**
T_1: Gamhar+Mango+Cowpea	335,862.69	223,900	–	107,750	667,512.69	1.05
T_2: Gamhar+Mango+Black gram-Mustard	269,484.08	213,850	37,600	86,700.00	607,634.08	1.03
T_3: Gamhar+Mango+Groundnut-Mustard	412,020.62	241,400	40,200	152,800.00	846,420.62	1.82
T_4: Gamhar+Mango+Okra-Mustard	229,851.88	192,950	34,600	50,933.33	508,335.22	0.96
T_5: Gamhar+Mango+Maize-Mustard	285,822.33	200,100	46,400	286,800.00	819,122.33	1.73
T_6: Gamhar+Mango	187,814.84	173,750	–	–	361,564.84	0.81
T_7:Sole Gamhar	146,287.29	–	–	–	146,287.29	0.17
T_8: Sole Mango	–	159,400	–	–	159,400.00	0.59

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8.4 Impact of Sowing Depth on Early Growth Performance of *Melia composita* in Jammu Subtropics Under Nursery Conditions

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Keywords: Biomass; *M. composita*; Sowing depth

1. Introduction

Sowing depth is an important factor both in nursery and in plantation determining the emergence, growth performance, and yield of the crop. Depending on the plant species, some seeds need a deep planting depth for roots to grow for firm anchorage while the seeds of some other plant species need to lay on top of the soil without any coverage for germination. There is less information available on the effect of sowing depth on the early growth performance of *M. composita.* Hence, the present study investigated the early growth performance of *M. composita* in relation to sowing depth under nursery conditions.

2. Materials and methods

The study was carried out at the experimental farm of the Division of Agroforestry of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu located at 32°40'N latitude and 74°58'E longitude at an elevation of 332 m above the mean sea level. Drupes of *M. composita* were collected in early January (4 weeks before starting the experiment) from three healthy growing trees located on the experimental farm. Drupes were under dried and seed extraction was done manually. Prior to sowing, seeds were soaked in running tap water for 5 min. The experiment was laid out in a factorial completely randomized design (CRD) with three treatments at sowing depths 0.2 mm (T_1), 0.4 mm (T_2), and 0.6 mm (T_3) with five replications using a vernier calliper. Seeds in each replication were taken for conducting the experiment. Seed sowing was carried out on 10 March 2022 and data were recorded since the beginning of the experiment. Data on growth performance were recorded after 8 weeks of seed sowing.

3. Results and discussion

The data pertaining to the effect of sowing depth on the early performance of *M. composita* in Jammu subtropics are given in Table 1. It was observed that the first emergence was after 15 days in shallow sown seeds (0.2 mm) depth. It was delayed by 22 and 26 days for seeds sown in the soil depth of 0.4 and 0.6 mm, respectively, indicating that seedling emergence was significantly affected by sowing depth. Mean values for seedling height and number of branches generally declined with increasing sowing depths. Maximum seedling heights were recorded in seeds sown at 0.2 mm depth (Table 1), followed by 0.4 and 0.6 mm, that is, treatments T_2 and T_3. It was also noticed that the seeds sown at 0.2 mm depth had a significantly higher branch number of 12.0±2.0 compared to those sown at 0.4 and 0.6 mm depth with 9.0±1.0 and 8.0±2.0, respectively. Kibru *et al*. (2015) and Chima *et al*. (2017) reported that when the seeds are sown too deep, the germination of seeds are forced to push their tender shoots through the soil and the seedling may die or the seeds cannot germinate due to lack of oxygen, light, and temperature fluctuation. Depth of sowing did not influence the rate of biomass accumulation significantly and shoot biomass at 0.2, 0.4, and 0.6 mm was 0.561, 0.442, and 0.381 g, respectively. Seeds sown at 0.2, 0.4, and 0.6 mm soil depth produced root length of 8.17±1.12, 7.98±1.09, 7.01±1.05, respectively, with the highest values at 0.2 mm soil depth. Similar findings were also observed by Dong *et al*. (2011), who reported that seeds buried in the deeper soils may deplete all stored carbohydrates before new shoots reach the soil surface, which will increase the risk of plant regeneration.

Table 1 Effect of seed sowing depth on early growth performance of *M. composita* under the nursey condition

Growth parameters	Treatments (sowing depth) 0.2 mm (T_1)	0.4 mm (T_2)	0.6 mm (T_3)	C.D
Emergence	34.40±3.80	24.60±3.15	12.50±3.01	4.54
Shoot length (cm)	33.25±4.55	27.31±4.02	23.06±5.15	6.03
Number of branches	12.00 ±2.00	9.00±1.00	8.00±2.00	2.60
Shoot biomass (g)	0.56±0.16	0.44±0.08	0.38±0.12	N.S
Root length (cm)	10.33±1.12	7.88±1.09	5.05±1.05	1.66

N.S.: non-significant

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8.5 Tailoring Forest Foods to Suit Consumer Taste: A Case Study of *Parkia timoriana* Pods in Mizoram

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Keywords: Ideotype; Pod traits; Tree bean; Web diagram

1. Introduction

Tree bean (*P. timoriana* (DC.) Merr.) is an indigenous tree species of north-east India that yield pods of high economic value. A mature tree can yield 500 to 1500 pods annually with prices ranging between 65$ to 90$ for 100 pods during the peak season. With the growing acceptance of traditional foods among the urban population and where opportunities for expanding the market exist, there is a need to identify traits that are suited to consumer preferences. Although many traditional varieties of tree bean have been identified in the region, their characteristics have not been related to consumers' tastes. In the present case study, we gathered information on pod traits that influence consumer choice and then conducted a structured interview to list traits in decreasing order of importance and then choosing categories within each trait to develop an ideal pod type.

2. Materials and methods

The study was conducted in Serkawn village (22°54’30″ N; 92°45’27″ E), Lunglei district, Mizoram in 2022. A total of seven quantitative and qualitative traits, namely, pod length, pod width, seed size, seed number, aroma, color, and harvest stage, were identified as important traits. With a sample intensity of 7.9% corresponding to 40 households, respondents were asked to rank them in the decreasing order of importance. The most favored trait scored 1 and the least preferred scored 7. Further, all traits were then categorized, and respondents were asked to choose the categories they most preferred under each trait. Thereafter, the percentage was calculated based on the total count for each category under a particular trait to obtain the most preferred category. The most preferred category for each attribute received a score of 3, the moderately desired category received a 2, and the least desired category received a 1 (category ‘any’ was ignored). Based on these scores, the characteristics were organized into several axes with a common origin and presented in a radar diagram (Leakey and Page, 2006). All radiating axes were joined to form a web diagram, which depicts the ideal pod type.

3. Results and discussion

Among the seven traits that were listed, respondents identified seed number as the most important trait with a mean rank of 1.975 and the harvest stage as the least important with a mean rank of 6.3. Ranking of five other traits in the decreasing order of importance was pod length, seed size, color, pod width, and aroma. The Friedman test showed significant differences in the mean rank for each trait. In terms of the preference of categories under each trait, pods with relatively large seeds (45%), numerous seed number (82.5%), long pod length (90%), and wide pod width (45%) were most preferred by respondents. Other pod traits that received the highest response were light green color (70%) and mid-harvest stage (45%). Based on this information, the ideal pod type had scores of 3, 3, 3, 3, 1, and 2 corresponding to large seeds, numerous seed number, long pod length, wide pod width, light green color, and mid-harvest stage. The web diagram of an ideal pod based on the above score is shown in Figure 1.

Through our study, it is clear that consumers identified good tree bean pods based on three prime characters, which are seed number, pod length, and seed size. The inclusion of these traits in the tree selection promises a more systematic approach to improve the types of pods that enter the market for greater acceptability and better pricing.

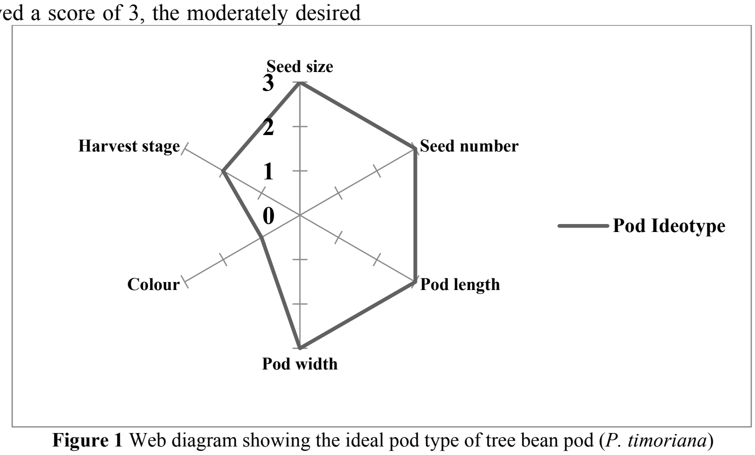

Figure 1 Web diagram showing the ideal pod type of tree bean pod (*P. timoriana*)

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8.6 *Terminalia chebula* Based Demonstration for Upliftment of Farmers of Kandi Villages of Jammu

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Keywords: Cost-benefit; Harad; Kandi

1. Introduction

On-farm demonstrations is a process to demonstrate various integrated agriculture activities on a farm to provide an understanding of a holistic farm to a sizeable number of farmers. Under the holistic farming concept, farmers get exposed to the number of activities such as agriculture, horticulture, medicinal and aromatic plants, apiculture, poultry, and animal rearing through the farm demonstration process. On-farm demonstration is effective means of bringing down the risks perceived by the farmers. Frontline demonstrations are used first to display the results of adopting a new practice and then to give the farmer an opportunity to practice new methods.

Harad (*T. chebula*) based agroforestry is practiced according to the needs and circumstances and cultivated on the bunds of farmer's fields or village common lands popularly known as ghasnies (Choudhary *et al*., 2019) under traditional agroforestry systems in the union territory of Jammu and Kashmir. These agroforestry practices are the source of livelihood for the resource-poor farm families of the villages (Choudhary and coworkers, 2021). The tree of this species is also lopped for fodder in some areas during the lean period. Besides, it provides good quality durable timber, which can be used for building agricultural implements and other purposes (Jain, 1994).

2. Materials and methods

Resource-poor farm families from Mathwar and Rabta of the Jammu district that are solely dependent upon the collection and sale of fruits of medicinal trees grown wild for livelihood were selected and trained to produce quality planting material on scientific lines for entrepreneurship development among the selected families in the field of nursery establishment through the preliminary surveys of the area and in consultation with the local residents.

Superior planting stock procured from Dr Y S Parmar University of Horticulture and Forestry, Solan (Himachal Pradesh), Research Horticulture Research Station, Nurpur, Jachh (Himachal Pradesh), Rainfed Research Sub-station for Sub-tropical Fruits, Raya of SKUAST-Jammu (Jammu and Kashmir), and quality planting material developed at KVK Jammu were provided to 308 farm families of Mathwar, Rabta, Sagun, Kharota, Kathar, Chawa, Manwal, and Akhnoor villages of the Jammu district during the month of July–August in 2016–2019 for laying out frontline demonstrations of superior clones with the objective of gradual replacement of the inferior clones and for promotion of cultivation of medicinal trees in Kandi villages of Jammu and Samba districts for achieving sustainable livelihood options. The yield of the fruit is estimated based on the number of fruits from a single tree planted from 2016 onward and weighted in kilograms (kg). Economic returns are estimated on per ha basis.

3. Results and discussion

The annual income per household from agriculture ranges between Rs. 35,000 and Rs. 50,000 per year. The average yield of the green fruit of Harad ranged between 100 and 120 kg per tree, whereas there are reports of trees bearing 5–7 quintals (q) of fruits/tree generating an average income of Rs. 1600–2000 per tree per year (Choudhary and coworkers, 2021). Results of field demonstrations revealed that the survival percentage ranged between 66.5% and 72.0% for Harad and height varied from 2.32 m to 2.39 m after 3 years of establishment.

The expected economic returns from the superior grafted clones of Harad at an early bearing age of 7 or 8 years will be Rs 593,750 per ha, which will be almost double than the existing seedling plantations fetching an amount of Rs 300,000 and that too after 12–15 years of bearing. The continuous efforts of KVK Jammu to provide superior planting material of Harad, capacity buildings programme, exposure visits and laying out frontline demonstration, and on-farm trials at the farmer's field will result in the production of superior quality and large-sized fruits that will help farmers in doubling their income. Now the farmers have become desirous of having plants with bearing early and better yield attributes (Srivastava, 2000). Harad cultivation is a boon for farmers of Jammu district (J&K) with net returns of 348,622.36 per 100 trees with cost-benefit ratio of 5.25:1 (Kumar *et al*., 2022). The diversification helped the farmers to utilize the human and capital resources to the maximum extent in the Kandi area. Clonal plantations of quality planting material provided through KVK will boost the production and enhance the overall income and socioeconomic status of farmers of Kandi villages of Jammu.

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8.7 Standardization of Surface Sterilization Chemicals for Leaf, Root, and Epicotyl Explant Cultures of *Citrus jambhiri* Lush.

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Keywords: Citrus; Epicotyl; Leaf, Root; Surface sterilization; Tissue culture

1. Introduction

Citrus (*Citrus* spp.) is a collective generic term comprising a number of species and varieties of fruits known to the world for their characteristic flavor, attractive range of colors, and uses. The well-known examples of group citrus are oranges, lemons, grapefruits, and limes. In Jammu and Kashmir and adjoining states, rough lemon has been considered to be the most important rootstock for lemons, oranges, mandarins, and kinno because of its high vigor, well adaptation to warm-humid zones with deep sandy soils, and resistance to *C. tristeza* virus. The development of the *in vitro* regeneration protocol is essential to be used routinely as a research tool for the improvement of this rootstock species. Therefore, the present study was undertaken to standardize protocols for aseptic cultures of leaf, root, and epicotyl segments of *C. jambhiri*.

2. Materials and methods

The study was carried out at Plant Tissue Culture Laboratory, Division of Fruit Science and School of Biotechnology in collaboration with the Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu from 2016 to 2018. The explant segments were treated with Tween 20 (2 or 3 drops/100 mL of water) for 5 min and washed thoroughly with distilled water to remove surface contaminants. After that, they were treated with (0.2%) carbendazim for 5 min and washed thoroughly in running tap water for 10 min. Finally, sterilization procedures were carried out under aseptic conditions in a laminar air flow chamber to isolate contamination-free *C. jambhiri* explants. The data were analyzed according to completely randomized block design (CRD) and data scored on percentage were subjected to the arc sine transformation for the analysis of variance (ANOVA).

3. Results and discussion

The explants collected from field grown seedlings harbor microbial pathogens in addition to adhered soil particles. A critical stage in the multiplication of plants through tissue culture is to obtain contamination and disease-free cultures, and thus it necessities thorough and effective surface sterilization of explants before culturing. Pre-sterilization of isolated explants with Benomyl (0.2%) can improve the cleanness and aliveness of all types of explants, especially when followed through surface sterilization with mercury chloride ($HgCl_2$). In the present investigation (Table 1), the application of mercuric chloride 0.1% ($HgCl_2$) for 3 min (T_2) was found to better sterilize epicotyl explants of *C. jambhiri* than all other treatments, which resulted in the least rate of contamination (15%) and the maximum epicotyl explant survival (85%). Gupta (2018), who worked on *in vitro* propagation of strawberries, found that the treatment of explants with 0.1% $HgCl_2$ for 3 min was the most effective surface sterilization procedure for registering the maximum survival and minimum contamination of cultures. Our results are also supported by Rajiv *et al*. (2015) who used different concentrations of $HgCl_2$ and sodium hypochlorite (NaOCl) for surface disinfection of citrus seeds.

From the results obtained in the present investigation, it is concluded that *C. jambhiri* Lush may be successfully raised under *in vitro* conditions by employing leaf, root, and epicotyl as explants with a good multiplication rate.

Table 1 Standardization of surface sterilization chemicals for leaf, root, and epicotyl explants on MS medium

Treatment	Contamination (%)	Survival (%)
T_1: Mercuric chloride 0.1% (2 min)	60 (50.79)*	40 (39.13)*
T_2: Mercuric chloride 0.1% (3 min)	19 (25.64)	81 (64.68)
T_3: Mercuric chloride 0.1% (2 min)+Ethanol 70% (30 s)	35 (36.12)	65 (53.84)
T_4: Mercuric chloride 0.1% (3 min)+Ethanol 70% (30 s)	29 (32.46)	71 (57.62)
T_5: Sodium hypochlorite 5% (5 mi)	91 (73.14)	9 (17.16)
T_6: Sodium hypochlorite 5% (10 min)	82 (64.96)	18 (24.31)
T_7: Sodium hypochlorite 5% (5 min)+Ethanol 70% (30 s)+Mercuric chloride 0.1% (2 min)	45 (42.07)	55 (47.89)
T_8: Sodium hypochlorite 5% (5 min)+Ethanol 70% (30 s)+Mercuric chloride 0.1% (3 min)	41 (39.76)	59 (50.24)
T_9: Sodium hypochlorite 5% (10 min)+Ethanol 70% (30 s)+Mercuric chloride 0.1% (2 min)	43 (40.90)	57 (49.06)
T_{10}: Sodium hypochlorite 5% (10 min)+Ethanol 70% (30 s)+Mercuric chloride 0.1% (3 min)	40 (39.19)	60 (50.83)
$CD_{(0.05)}$	**7.97**	**9.95**

*Values in parenthesis are arc sine transformed values.

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8.8 Evaluation of Factors Influencing Adoption of Agroforestry Systems in Ladakh Region

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Keywords: Agroforestry; Apricot; Juniper; Ladakh; Salix

1. Introduction

According to CAFRI (2015), by the year 2050 there is a scope of increasing the area under agroforestry by another 28.0 million ha and thus a total of 53.23 m ha or 17.5% of the country's reported area under agroforestry. Much of this field would come from fallows, cultivable fallows, degraded and wasteland and would have the ability to transform the fortunes of small and marginal farmers and rural citizens by providing livelihood and food security opportunities together with the region's economic development. Agroforestry systems are also capable of producing 100 million cubic meters of commercial and domestic timber/pulpwood that meets 65% of the country's timber demand, two-thirds of small timber demand, 70–80% of plywood demand, and 60% of paper pulp raw material demand. It also produces 150 million tons of firewood, which meets half of the demand for firewood in the world (Chavan *et al*., 2015). Due to harsh winters and poor vegetation cover, the highly motivating factors responsible for the introduction of agroforestry activities in the Ladakh region were fuel wood and fodder. In addition, for much of the year, the area being remote remains cut off from the rest of the world, so agroforestry in the vicinity meets the needs of people in terms of food, fodder, and timber and also makes the environment more stable. Poplar, Salix, Juniper species, and a few fruit trees, that is, apricot and apple, are the main trees growing in the area.

2. Materials and methods

The study was conducted in the cold arid area of Ladakh (Leh district). The blocks, villages, and households were chosen using a multistage random sampling technique. In the first stage, out of 16 blocks, seven blocks, namely, Leh, Chuchot, Thiksay, Kharu, Khaltsi, Nimo, and Nyoma, were selected by the random sampling method. In the second stage, 11 villages were selected among the total of 53 villages in Leh district based on a simple random sampling technique, namely, Phey among 5 villages of Leh block, Stakna among 6 villages of Chuchot block, Nang among 4 villages of Thiksay block, Upshi, Hemis, Shara among 15 villages of Kharu block, Nurla, Skinding among 9 villages of Khaltsi block, Umla, Chilling among 9 villages of Nimo block, and Nyoma from 5 villages of Nyoma block. A total of 164 households were selected for the field study from the sample villages, that is, 14 out of 57 households from Phey village, 22 out of 88 from Stakna, 18 out of 74 from Nang, 6 out of 26 from Upshi, 6 out of 24 from Hemis, 14 out of 57 from Shara, 13 out of 52 from Nurla, 9 out of 38 from Skinding, 5 out of 21 from Umla, 7 out of 31 from Chilling, 50 out of 202 from Nyoma village, with a 25% sampling intensity using a basic random sampling technique. Either household heads or eldest members were the respondents interviewed.

Primary data were collected by personal interviews of the respondents through a well-structured pretested interview schedule for collection of the household data while secondary data were collected from different sources, namely, literature from numerous newspapers, forest service papers, village records, internet, prior studies, annual reports and other related documents, and various governmental and non-governmental agencies. To evaluate the relationship, Pearson's product-moment coefficient of correlation and regression model analyses were used. Pearson's product-moment coefficient correlation was carried out using the formula

$$r = \frac{\sum(\mathrm{xi} - \bar{\mathrm{x}})(\mathrm{yi} - \bar{\mathrm{y}})}{\sqrt{\sum \mathrm{xi} - \bar{\mathrm{x}})\ 2\ \sum(\mathrm{yi} - \bar{\mathrm{y}})\ 2}}$$

Here,
r=correlation coefficient
x and $\bar{x}$=values and mean values of x variables
y and $\bar{y}$=values and mean values of y variables
Regression analysis was carried out using the following formula: $Y=a+bX$
Here,
Y=dependent variable; X=independent variable
b=slope of the line; a=y intercept

3. Results and discussion

The highest number of respondents (24%) were illiterate, followed by those below primary (23%), primary (16%), high school (15%), middle (13%), and graduate and above (9 %). Maximum respondents (75%) were marginal having <1.00 ha land followed by small (23%) 1.01–2.00 ha land and medium (2%) 2.01–4.00 ha. The average score of landholding was 1.26 ha. The main occupation of respondents was farming (35.3%) of the respondents followed by service (26%), business (16%), wage labor (13%), caste occupation (5%), and others (3.6%). The results in Table 1 show that out of 10 socioeconomic, forest resources, and biophysical variables, seven attributes, namely, education, family size, main occupation, livestock size, landholding, and annual income exhibited positive and significant relationship with agroforestry resources-based livelihood, whereas the proximity to forest, access to alternate forest resources, and forest visit showed negative and significant correlation. The relationship between age and agroforestry resources-based livelihood was nonsignificant.

Table 1 Correlation analysis of household variables with the agroforestry resources-based livelihood

Household variables (code)	Coefficient of correlation (r)
Age (X_1)	0.166
Education (X_2)	0.843*
Size of the family (X_3)	0.615*
Size of landholding (X_4)	0.847*
Livestock possession (X_5)	0.794*
Main occupation (X_6)	0.614*
Annual income (X_6)	0.381*
Proximity of forests (X_7)	–0.852*
Access to alternate forest resources (X_9)	–0.787*
Forest visit (X_{10})	–0.756*

*Significant at $p \leq 0.01$.

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Table 2 Regression analysis method of household variables with the agroforestry resources

Source	DF	Adj MS	F value	*p* value	R^2
Regression	26	32439175947	5.35	0.000	
Age	1	11221765647	1.85	0.176	
Education	5	6362267785	1.05	0.392	
Family Size	1	3306775031	0.55	0.462	
Size of landholding	2	53168917531	8.76	0.000*	
Livestock	3	6245733370	1.03	0.382	
Proximity to forest	2	3626847893	0.60	0.551	50.36%
Access to alternate forest resource	2	1936262546	0.32	0.727	
Main occupation	5	44789504593	7.38	0.000*	
Forest visit	2	3555622700	0.59	0.558	
Income from all sources	3	87883141718	14.48	0.000*	
Error	137	6067388572			
Total	163				

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8.9 Climate Smart Integrated Farming System for Livelihood Security

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Keywords: Greenhouse gas emissions; Livelihood security; Income enhancement; Resource recycling

1. Introduction

To meet the multiple objectives of poverty reduction, food and nutritional security, competitiveness, and sustainability, several researchers have recommended the farming systems approach to research and development. Integrated Farming System (IFS) is a multidisciplinary whole farm approach and is very effective in solving the problems of small and marginal farmers (Devendra, 2002). The approach aims at increasing income and employment from smallholding by integrating various farm enterprises and recycling crop residues and by-products within the farm itself. Therefore, the study was conducted at Punjab Agricultural University, Ludhiana under 'All India Coordinated Research Project on Integrated Farming Systems (ICAR)' during 2020-21 with two main objectives: (i) To ensure optional utilization and conservation of available resources and effective recycling of farm residues and by-products within a system without damaging the resource base and environment and (ii) to raise the overall profitability of the family farm by complementing main and allied enterprises with each other.

2. Materials and methods

The Integrated Farming System model under a 1.0 ha (10,000 m^2) area was developed during *Kharif* 2010. The various components included in the IFS model were crops, horticulture, aquaculture, dairy, and agro-forestry. During *Kharif* season, the crops such as paddy, basmati rice, maize, and turmeric are grown in an area of 6400 m^2 followed by wheat, gobhi sarson, pearl millet, berseem, potato, onion, baby corn, and spring maize during *rabi* and summer season. Horticulture activities are being practiced in an area of around 1600 m^2 involving citrus and guava plantation with an inter row spacing of 1500 m^2 utilized for the cultivation of vegetable crops. Similarly, an area of 200 m^2, 1000 m^2, and 300 m^2 was utilized for dairy, aquaculture, and agro-forestry, respectively. In addition, cranberry (Karonda) and galgal were grown as boundary plantations. The greenhouse gas emissions were calculated by using a greenhouse gas estimation tool for integrated farming systems developed by ICAR-Institute of Farming System Research, Modipuram, Meerut (Dutta *et al*., 2017).

3. Results and discussion

The study indicated that the adoption of an integrated farming system comprising crop-based enterprises, dairy, horticulture, and aquaculture has recorded average net returns of Rs 503,399 with the dairy component as the main contributor (Rs 286,428) followed by crop (Rs 122,239), boundary plantation (Rs 30,331), aquaculture (Rs 24,612), horticulture (Rs 23,096), kitchen gardening (Rs 14,917), and agro-forestry (Rs 1776). Moreover, the study also concluded that an integrated farming system generated 280 man-days/ha of employment. The total value of recycled farm products was Rs 85,332/ha/annum amounting to a 23.41% saving on recycled farm products of input cost. Therefore, the 1.0 ha IFS model developed for small and marginal farmers provided gross returns of Rs 875,126/ha, costs incurred were Rs 371,728/ha, and hence net returns by deducting all variable costs were Rs 503,399/ha, which was quite higher than that of the prevailing dominant rice-wheat cropping system (Table 1). In addition, Table 2 reflects the sustainability index of various components of the integrated farming system indicating the sustainability of the farming system.

Table 1 Relative efficacy of different farm enterprises of the IFS model

Farm enterprises	Size of the unit (area/number)	Gross returns (Rs/year)	Cost of production (Rs/year)	Net returns (Rs/year)
Field crops	6400 m^2	206,825	84,587	122,239
Horticulture	1900 m^2	Veg – 36,958	36,959	23,096
		Fruits – 23,097		
Agro-forestry	300 m^2	4976	3200	1776
Dairy	200 m^2	516,310	229,882	286,428
Aquaculture	1000 m^2	24,900	5100	24,612
	High-density guava plantation	4812		
Boundary plantation	–	Galgal – 11,231	7200	30,331
		Karonda – 26,300		
Kitchen gardening	200 m^2	19,717	4800	14,917
IFS model – total allocated land (m^2)	10,000 m^2	845,126	371,728	503,399

Table 2 Sustainability index (SI) of different components and net returns over the years

Enterprises	**Sustainability index (SI=net return – standard deviation)/maximum net return)**	**Net returns (Rs lac/ha)**	
Crops	0.62	2012-13	2.03
Horticulture	0.75	2013-14	3.28
Vegetables	0.78	2014-15	3.80
Agro-forestry	0.83	2015-16	4.01
Dairy	0.61	2016-17	4.08
Aquaculture	0.71	2017-18	4.76
Kitchen gardening	0.65	2018-19	4.80
		2019-20	4.91

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Net GHG emission in the IFS model (Co_2-e in kg)

The ecological sustainability of agricultural production systems mainly depends on their carbon footprints. The CO_2 emission varied significantly among the cropping systems. It was observed that more than 50% of the total CF from crop production resulted from N inputs. Wide variation ranging from 65.0 to 276.8 CO_2-e (kg) among eight cropping systems was observed in the present study with maximum emission from the maize-gobhi sarson-summer moong cropping system. This was due to differences in input and management practices adopted, as CF and energy input were positively related to each other. However, the total amount of carbon added and sink is 3042.0 CO_2-e (kg) and 11319.7 CO_2-e (kg), respectively, thereby making the IFS model a climate smart agriculture system with negative greenhouse gas emission measured at –5451.5 CO_2-e (kg). An integrated farming system approach to agricultural research and development efforts would accelerate agricultural growth and thereby provide leverage for transforming poverty-prone rural India into a prosperous India. This approach might revolutionize agricultural development in the 21st century to make India a developed nation.

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8.10 Effect of Precision Silvicultural Packages on Leaf Litter Fall and Major Nutrient Addition Through it of *Melia dubia* Plantation in Tamil Nadu

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Keywords: Agro based; Evaluation; Litter fall; Nutrient addition

1. Introduction

The National Agroforestry Policy (2014) emphasizes the production of wood-based raw materials required for agro-based industrial purposes on farmers' fields. *M. dubia* is one of the indigenous fast growing alternate pulpwood species adaptive to wide agro-climatic conditions of India. The industrial and ecological importance of *M. dubia* has encouraged the farmers to take large-scale plantations with various intercrops. The choice of planting density and nutrient management is the primary silvicultural decision which influences the quality and quantity of wood products throughout the rotation. Little is known about the overall leaf litter and nutrient input in an agroforestry system. Considering the foregoing, the present study evaluated the influence of spacing and nutrient management approaches on leaf litter fall and nutrient addition using this short rotation pulpwood species.

2. Materials and methods

The present investigation was accomplished in Tamil Nadu Paper Limited Plantation Research Block, Karur, Tamil Nadu with a location of latitude 11°03.448′N, longitude 077° 59.444′E, and altitude of 459 ft above MSL from 2018 to 2021. The *M. dubia* clonal variety GK-10 was selected as the test variety. The experiment consisted of four different spacing in main plots, namely, S1: 1.5 m × 1.5 m, S2: 2.0 m × 2.0 m, S3: 2.0 m × 2.5 m, and S4: 3.0 m × 1.5 m, and four different doses of fertilizers in subplots, that is, F_1: Control – no fertilizer, F_2: 100:50:100 NPK kg/ha, F_3: 150:75:150 NPK kg/ha, and F_4: 200:100:200 NPK kg/ha. The experiment was carried out in a strip plot design and replicated four times. Each treatment's *M. dubia* leaf litter fall was collected annually using litter traps. For each treatment, the addition of nitrogen, phosphorous, and potassium to the soil was calculated in kg/ha.

3. Results and discussion

Litter fall production

In the present study, the highest litter fall production was registered with the spacing of 1.5 m × 1.5 m (4444 trees/ha) along with an application of 200:100:200 kg of NPK per ha. Higher tree density and higher growth rate due to the application of chemical fertilizers might have enhanced leaf litter production in this combination of treatments. This result was supported by the findings of Isabel *et al*. (2020) who reported higher leaf litter fall on *Populus alba*. The addition of major nutrients through leaf litter production to the soil was significant in the current study. Adopting closer spacing and fertilization with a higher dose registered higher addition of NPK nutrients to the soil. At the harvest stage, the highest addition of NPK was recorded with closer spacing along with an application of 200:100:200 kg of NPK/ha. The nutrient addition was reduced with increased tree spacing and lesser fertilizer application and the lowest nutrient addition was recorded with the unfertilized plot. This might be due to increased litter fall production with closer spacing and a higher dose of fertilizer application which enhanced the nutrient addition to the soil. A similar finding on *M. azedarach* plantation was reported by Mahmood Hossain *et al*. (2010).

Thus, from the above results, it can be concluded that the highest leaf litter fall production and enhanced nutrient addition to the native soil with closer spacing along with higher doses of fertilizer application in *M. dubia* plantation clearly paves way for sustainability in energy services and reduces fossil fuel dependence by reducing the use of external inputs in long-duration silvicultural systems.

Table 1 Silvicultural packages on the leaf litter fall and nutrient addition to soil (kg/ha) of *M. dubia* plantation

Fertilizer/spacing	Litter fall (kg/ha)	Nutrient addition through litter fall (kg/ha)		
		N	P	K
F1S1	2294.56	6.37	2.00	4.85
F1S2	2256.47	6.26	1.96	4.77
F1S3	2169.37	6.02	1.89	4.59
F1S4	2200.5	6.11	1.91	4.65
F2S1	2476.88	6.87	2.15	5.24
F2S2	2429.08	6.74	2.11	5.14
F2S3	2353.54	6.53	2.05	4.98
F2S4	2388.44	6.63	2.08	5.05
F3S1	2519.35	6.99	2.19	5.33
F3S2	2478.43	6.88	2.16	5.24
F3S3	2410.9	6.69	2.10	5.10
F3S4	2446.65	6.79	2.13	5.17
F4S1	2623.7	7.28	2.28	5.55
F4S2	2547.26	7.07	2.22	5.39
F4S3	2411.72	6.69	2.10	5.10
F4S4	2484.67	6.89	2.16	5.26
SED				
Spacing (S)	22.92	0.10	0.02	0.08
Fertigation (F)	19.48	0.13	0.02	0.08
S at F	16.58	0.12	0.02	0.06
F at S	18.37	0.11	0.01	0.07

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CD (*p*=0.05)				
Spacing (S)	46.80	0.18	0.04	0.15
Fertigation (F)	39.00	0.21	0.03	0.16
S at F	33.20	0.22	0.02	0.12
F at S	36.80	0.22	0.02	0.13

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8.11 Carbon Storage Potential and Allometric Models for *Acacia Catechu* in Forest Land-use Systems in Subtropics of Jammu

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1. Introduction

Forests play a critical role in the global carbon cycle as growing trees remove carbon dioxide from the atmosphere through photosynthesis and have the potential to sequester carbon, thus forming an important climate change mitigation option (Kumar and Singh, 2003). The study was carried out in the Kandi region of Jammu province to assess carbon storage potential and allometric models for *A. catechu* in forest land-use systems involving Jammu, Samba, and Kathua districts. The general floristic composition in the study area of this subtype includes *Pinus roxburghii*, *A. catechu*, *Dalbergia sissoo*, *Butea monosperma*, *Mallotus philippensis*, *Zizyphus jujuba*, *Syzygium cumini*, *Ficus glomerata*, and so on. *A. catechu* being one of the main species was selected to assess the carbon storage potential and predict biomass models.

2. Materials and methods

In all, 15 sample points were selected in the study area comprising three districts, namely, Jammu, Samba, and Kathua. Global Positioning System (GPS) was used during the field survey exercise to locate the geo-coordinates and altitude of sampling points. The phytosociology of *A. catechu* under the forest land-use system was calculated. The relative dominance, relative density, relative frequency, and importance value index (IVI) were computed. The aboveground standing biomass comprising all woody stems, branches, and leaves of the living trees was calculated for marked *A. catechu* trees in the selected sample point. The non-destructive method was used, which is more rapid and covers a much larger area and a number of trees can be sampled, reducing the sampling error encountered with the destructive method. Carbon concentration in plants was calculated using the combustion method as suggested by Negi *et al.* (2003). Allometric models/ equations for estimating aboveground biomass and carbon were developed and applied to the inventoried data based on direct measurements. Diameter at breast height (DBH) and height were taken as independent variables.

3. Results and discussion

The phytosociology showed that the highest IVI was found in *A. catechu* (61.62), which shows its predominance in the study area. The total carbon stock from *A. catechu* was 4.45 Mg/ha, out of which 74.15% (3.30 Mg/ha) is contributed by aboveground components and 25.85% (1.15 Mg/ha) from belowground components.

Table 1 Volume, biomass, and carbon stock of *A. catechu* in forest land-use system

Average diameter (m)	Average height (m)	Average total volume (m^3/ha)	Basal area (m^2/ha)	Biomass (Mg/ha)			Carbon stock (Mg/ha)		Total C stock (Mg/ha)
				Above-ground	Below-ground	Total	Above-ground	Below-ground	
0.11	3.89	4.37	1.18	13.71	3.84	17.55	3.30	1.15	4.45

Table 2 Allometric models for *A. catechu*

Model	Dependent variable	Independent variable	Allometric equation	Estimated coefficients	F value	Solved equation	R^2 adjusted and AIC values
Model 1	Biomass	DBH × height	Biomass=$\alpha \times \beta^{DBH\times Height}$	$\alpha=3.391^{***}$ $\beta=0.74^{***}$	184.55^{***}	Biomass=3.391 × $0.749^{DBH*Height}$	R^2=0.796 AIC=41.181
Model 2	Biomass	DBH^2 × height	Biomass=$\alpha \times \beta^{DBH2\times Height}$	$\alpha=4.152^{***}$ $\beta=0.453^{***}$	13.14^{***}	Biomass=4.152 × $0.453^{DBH2\times Height}$	R^2=0.8026 AIC=39.627
Model 3	Carbon	Total biomass	CS=$\alpha \times \beta^{Total\ Biomass}$	$\alpha=-1.23^{***}$ $\beta=0.937^{***}$	659.12^{***}	CS=−1.235 × $0.937^{TotalBiomass}$	R^2=0.8819 AIC=14.67
Model 4	Carbon	DBH	CS=$\alpha \times \beta^{DBH}$	$\alpha=3.724^{***}$ $\beta=1.0665^{***}$	140.57^{***}	CS=3.724 × 1.0665^{DBH}	R^2=0.748 AIC=51.062
Model 5	Carbon	Height	CS=$\alpha \times \beta^{Height}$	$\alpha=-0.91^{***}$ $\beta=1.609^{***}$	26.457^{***}	CS=−0.914 × 1.609^{Height}	R^2=0.630 AIC=69.483
Model 6	Carbon	DBH × height	CS=$\alpha \times \beta^{DBH\times Height}$	$\alpha=2.019^{***}$ $\beta=0.769^{***}$	45.198^{***}	CS=2.019 × $0.769^{DBH\times Height}$	$R^{2=}0.845$ AIC=27.71
Model 7	Carbon	DBH^2 × height	CS= $\alpha \times \beta^{DBH2\times Height}$	$\alpha=2.775^{***}$ $\beta=0.458^{***}$	224.02^{***}	CS=2.775 × $0.458^{DBH2\times Height}$	$R^{2=}0.825$ AIC=23.317

****Significant at 1% level.

Allometric models were developed for evaluating the best-fit equation for aboveground biomass and carbon. The best allometric model for total biomass assessment was biomass=4.152 × $0.453^{DBH2\times Height}$) on DBH^2 × height with adjusted R^2=0.8026 and AIC=39.627. The selected models are tested for accuracy based on measured data. According

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to the statistical rule, the best model should have higher R^2-adj and correlation and AIC than other developed equations. The coefficients for all selected models are statistically significant, which showed a strong correlation of AGB with dendrometric variables.

It is evident from the study that assessment of the accumulated biomass is important for assessing the productivity and sustainability of the system. It also gives us an idea of the potential amount of carbon that can be emitted in the form of carbon dioxide when forests are cleared or burned. CO_2e signifies the amount of carbon dioxide absorption by the woody biomass in the land-use system.

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8.12 Effect of Different Pre-sowing Treatments to Improve Growth of *Melia composita* Under Laboratory Conditions

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Keywords: Afforestation; Mechanical scarification; Treatment

1. Introduction

India is an agriculture-based country, and a majority of its population depends on agriculture directly or indirectly. Forest-based industries go through problems of lack of sustainable supply of wood, which results in the import of timber, pulp and paper, wood, and products from other countries. *Melia composita* (Burma dek) is one of the multipurpose fast growing tree species suitable for the agri-silviculture system (Swaminathan *et al*. 2012). Poor germination is a problem in the afforestation of this species. Therefore, there is a requirement to increase its germination capacity and growth by treating its seed (drupes) to obtain quality planting stock for afforestation programmes.

2. Materials and methods

The present study was conducted in the Department of Seed Science and Technology, CCS Haryana Agricultural University, Hisar. Under laboratory conditions, the experiment was conducted in completely randomized design (CRD) with three replications. The drupes of *Melia composita* were sown on moist sand and covered with uncompressed sand. The pre-sowing treatments given to drupe to remove dormancy were soaking in normal water for 24, 48, and 72 hours (h), dipping in concentrated sulphuric acid for 5, 10, and 15 minutes (min.), and keeping in boiled hot water for 5, 10, and 15 min. Mechanical scarification was done by using sand paper. Drupes were soaking in GA3 at 100 ppm for 8, 16, and 24. For each treatment, 20 drupes were used and these trays were placed in a seed germinator at 30°C temperature with 90% humidity. Shoot length and root length were measured after 30 days of initiation of germination in the experiment. Seedling dry weight was measured at 30 days. Seedlings were dried in a hot air oven for 24 h at 80±1°C.

3. Results and discussion

The shoot length was significantly influenced by all given pre-treatments (Table 1). In the mechanical scarification+GA_3 (100 ppm), 24 h treatment shoot length was maximum (16.72 cm), which was significantly higher as compared to other treatments. The minimum shoot length (6.92) was recorded in treatment with boiling water for 15 min. Attri *et al*. (2015) also recorded higher seedling growth and biomass attributes in *Sapindus mukorossi* on immersion of seeds in concentrated H_2SO_4 for 20 min among various pre-sowing treatments. Similarly, in mechanical scarification+GA_3 (100 ppm), 24 h treatment root length was highest (7.54 cm), which was also significantly higher as compared to other treatment durations. The minimum root length (3.02) was recorded in treatment with boiling water for 15 min. The maximum seedling dry weight of 0.65 g was observed when the drupes were treated with mechanical scarification+GA_3 (100 ppm) for 24 h. The minimum (0.11 g) seedling dry weight was recorded in treatment with boiling water. Based on the present study, it is concluded that in laboratory conditions among all the pre-sowing treatments seedling growth parameters such as root length, shoot length, and seedling dry weight were recorded highest in treatment mechanical scarification+GA_3 (100 ppm) at 24 h.

Table 1 Effect of pre-sowing treatments on root length and shoot length and seedling dry weight of *Melia composita* under laboratory conditions

Treatment	Duration	Shoot length (cm)	Root length (cm)	Seedling dry weight (g)
Normal water soaking	24 h	10.18	4.19	0.31
	48 h	10.52	4.81	0.42
	72 h	11.17	4.95	0.45
Concentrated H_2SO_4	5 min	10.24	4.47	0.34
	10 min	10.33	4.72	0.40
	15 min	10.07	4.07	0.28
Cow dung slurry	5 days	10.29	4.54	0.36
	10 days	11.32	5.21	0.49
	15 days	11.69	5.32	0.51
Boiling water	5 min	7.27	3.54	0.21
	10 min	7.11	3.24	0.18
	15 min	6.92	3.02	0.11
Mechanical scarification+GA_3 (100ppm)	8 h	13.59	6.13	0.55
	16 h	14.86	7.27	0.59
	24 h	16.72	7.54	0.65
Control (without treatment)		8.52	4.05	0.25
C.D. at 5%		0.84	0.38	0.03

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8.13 Effect of Pre-Sowing Seed Treatments on Germination of *Diospyros lotus* Linn.

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Keywords: *D. lotus* Linn; Germination; Pre-sowing treatment

1. Introduction

D. lotus Linn. locally known as Amlook, is a deciduous wild fruit tree species belonging to the family Ebenaceae. It is a cultivated species of the genus *Diospyros* and distributed in the Mediterranean region, Pakistan, India, Iran, Japan, and China. It has poor germination in its natural habitat. Thus, there is a need to standardize the effect of various pre-sowing treatments on seeds of this species to obtain an early and higher percentage of seed germination with healthy and vigorous seedlings. Hence, the present study on the effect of pre-sowing treatments on germination and other growth parameters of *D. lotus* was undertaken.

2. Materials and methods

The present study was conducted in the nursery of the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu located at Chatha, Jammu (Jammu and Kashmir, India). The experimental site is situated in the subtropical Jammu region of the Union Territory of Jammu and Kashmir at an altitude 332 m above mean sea level with 32°40'N latitude and 74°58'E longitude. Healthy trees bearing a sufficient number of berries were marked for collection of seeds in village Sarola of district Rajouri (Jammu and Kashmir) from August to September 2021. Berries were handpicked from selected healthy trees in October 2021. These berries were dried in shade for 2 weeks and seeds were extracted. Seeds before sowing were subjected to nine different pre-sowing treatments, namely, T_1: soaking in cold water for 48 h; T_2: soaking in cold water for 72 h; T_3: cow dung slurry for 1 week; T_4: cow dung slurry for 2 weeks; T_5: mechanical scarification; T_6: concentrated H_2SO_4 for 2 min; T_7: concentrated H_2SO_4 for 4 min; T_8: concentrated H_2SO_4 for 6 min; T_9: control (no treatment). The pre-treated seeds were sown in four potting media: M_1: soil only; M_2: soil: sand (1:1); M_3: soil:sand:FYM (1:1:1); and M_4: soil:sand:vermicompost (1:1:1). The experiment was laid out in factorial completely randomized design having two factors (pre-sowing treatments and potting media) replicated thrice. Seed sowing was done in January 2022. Data were recorded from the beginning of the experiment.

3. Results and discussion

The pre-sowing treatments significantly affected germination parameters (Table 1). Maximum germination (66.17%) percent was recorded in T_3 (cow dung slurry for 1 week). Results can be supported by the findings of Anand *et al*. (2012) who reported that the maximum germination percentage in *Melia dubia* was obtained when seeds were soaked in cow dung slurry for 7 days. Pre-sowing treatments also had a significant influence on mean germination time. The minimum mean germination time (22.44) was recorded in T_3 (cow dung slurry for 1 week). The findings for mean germination time are in accordance with Mistry and Sitapara (2020) who reported that minimum mean germination time was observed in Karonda when seeds were soaked in cow dung slurry. The maximum germination rate index (6.85) was again observed in T_3 (cow dung slurry for 1 week). However, a minimum germination rate index (4.55) was found in T_9 (control). The coefficient of velocity of germination was recorded as maximum (16.97) in pre-sowing treatment T_3 (cow dung slurry for 1 week), whereas the minimum (10.44) was observed in control. The potting media also had a significant influence on germination percentage (Table 2). The maximum germination (49.37%) was recorded in M_3 (soil:sand:FYM in 1:1:1 ratio). Similar results were reported by Varadkar *et al*. (2020) in jackfruit. Potting media had no significant influence on mean germination time, germination rate index, and coefficient of the velocity of germination. The minimum germination was found in pure soil (Table 2). The study implies that germination of *D. lotus* can be enhanced by treating its seeds with cow dung slurry for 1 week and sowing seeds in soil:sand:FYM (1:1:1).

Table 1 Effect of pre-sowing treatment on seed germination parameters

Treatments (T)	Germination percentage	MGT	GRI	CVG
T_1 (Soaking in cold water for 48 h)	47.08 (6.84)	26.62	5.04	12.15
T_2 (Soaking in cold water for 72 h)	60.25 (7.70)	23.71	6.21	15.62
T_3 (Cow dung slurry for 1 week)	66.17 (8.10)	22.44	6.85	16.97
T_4 (Cow dung slurry for 2 weeks)	–	–	–	–
T_5 (Mechanical scarification)	37.58 (6.08)	27.62	4.76	11.71
T_6 (Concentrated H_2SO_4 for 2 min)	48.25 (6.92)	25.38	5.05	13.38
T_7 (Concentrated H_2SO_4 for 4 min)	59.00 (7.64)	24.15	5.46	14.62
T_8 (Concentrated H_2SO_4 for 6 min)	–	–	–	–
T_9 (Control)	30.42 (5.47)	28.97	4.55	10.44
$CD_{0.05}$	11.78 (0.82)	0.95	0.58	0.953
±SE(m)	4.17 (0.29)	0.34	0.20	0.337

Note: Figures in parenthesis are transformed (square root transformation) values. MGT=Mean germination time, GRI=Germination rate index, and CVG=Coefficient of the velocity of germination.

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Table 2 Effect of potting media on seed germination parameters

Potting media (M)	Germination percentage	MGT	GRI	CVG
M_1 (Soil only)	26.56 (4.74)	20.21	4.04	10.21
M_2 (Soil:sand – 1:1)	35.04 (5.38)	19.95	4.12	10.47
M_3 (soil:sand:FYM – 1:1:1)	49.37 (6.38)	19.55	4.40	10.88
M_4 (soil:sand:vermicompost – 1:1:1)	44.04 (6.06)	19.80	4.28	10.62
$CD_{0.05}$	7.86 (0.55)	NS	NS	NS
± SE(m)	2.78 (0.19)	0.34	0.20	0.23

MGT=Mean germination time, GRI=Germination rate index, and CVG=Coefficient of velocity of germination.

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8.14 Role of Regenerative Agriculture in Cotton Field for Carbon Sequestration in Telangana

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Keywords: Organic carbon; Regenerative agriculture; Soil fertility

1. Introduction

Cotton (*Gossypium hirsutum* L.) is one of the major cultivated cash crops in India. It plays a dominant role in the agricultural and industrial economy of the country. Telangana is the third highest in terms of area of cotton cultivation and production volumes after Gujarat and Maharashtra. Due to the high demand and prices of cotton fibers, farmers mostly adopt unsustainable practices in the field. This excessive use of fertilizers and pesticides affects the fertility of the soil**.**

Cotton cultivation contributes to the removal of carbon dioxide from the atmosphere. The cotton plant captures more carbon dioxide from the atmosphere for the production of fiber and also stores it in the soil. Conversely, cotton is one of the crops where farmers use unsustainable practices like excess tillage and usage of the unnecessarily vast amount of pesticides and fertilizers, resulting in the emission of greenhouse gases.

Following Regenerative Agriculture practices (RA) in agriculture helps in carbon sequestration and long-term benefits to soil and on-farm biodiversity. Regenerative agriculture has been proposed as an alternative means of producing food that may have lower or even net positive environmental and/or social impacts (Rhodes, 2017). It is assumed that if all the cotton farmers in the world practice conservation tillage, it would remove emission equivalent to taking 3.5 million passenger cars off the highways every year (Franzluebbers *et al*., 2010). The objective of the study is to understand the potential impact of using regenerative practices in cotton plantations and to analyze the carbon sequestration in the field.

2. Materials and methods

A comparative study of RA practices was conducted in selected cotton farms for 2 years to analyze the increase in soil organic carbon attributable to RA practices. The study area was in Karimnagar district, Telangana, lying between 18.4386° N latitude and 79.1288° E latitude. Black and sandy loam types of soils were found in Karimnagar, with cotton being one of the major crops cultivated in this area. For the study purpose, the project team selected demonstration plots from the Karimnagar district and analyzed the performance of farmers growing cotton using regenerative practices for 2 consecutive years, that is, 2021 and 2022. A total of 200 soil samples were collected from the farms and sent to the Regional Agricultural Research Station Labs for soil testing. Key parameters like nitrogen, phosphorous, potassium, and organic carbon were tested.

In the selected demonstration plots, farmers adopted all the recommended regenerative practices. The practices include cotton-based mango plantations, cotton with intercropping and border cropping application of compost and biochar for soil treatment, and less use of pesticides (Table 1). All these practices are ongoing in the field for the years 2020 and 2021. A variety of different layouts were adopted in the demonstration plots. Agroforestry is one such approach using Regenerative Agriculture principles, with mango-based cotton agriculture systems being promoted among farmers.

Table 1 Regenerative Agriculture practises ongoing in the field

Principles	Practises	2021	2022
Minimize tillage	Minimize tillage/no tillage	✓	✓
Maintain soil cover	Cover cropping	✓	✓
	Mulching		
Carbon sequester	Agroforestry with cotton/plantation	✓	✓
Adding soil OC	Compost	✓	✓
	Biochar application	✓	✓
Foster plant diversity	Crop rotation	✓	✓
	Intercropping with pulses	✓	✓
Avoid pesticides	No pesticides for first 45 days_IPM		

3. Results and discussion

A majority of Regenerative Agriculture practices focus mainly on soil management. About 200 soil samples were collected from the field and analyzed. To achieve consistency, the average value of all the collected samples was used for the computation.

Table 2 Regenerative Practices and their potential impact

Principle/objective	Activity	SOC +ve	Soil erosion control	Biodiversity +ve
Minimize tillage	Low tillage/avoid tillage for weeding	+	+++	+
	Controlled traffic	+	++	+
Maintain soil cover	Cover crop	++	+++	++
	Mulching	++	+++	+
	Green leaf manuring	+++	+++	*
Adding soil OC	Manure application/compost	+++	+	+
	Biochar	+++	+	+
Sequester carbon	Agroforestry/plantation	++	+++	+++
Foster plant diversity	Crop rotation	++	++	++
	Intercropping/mixed cropping	++	++	++
Avoid pesticides	No pesticides for first 45 days_IPM			++

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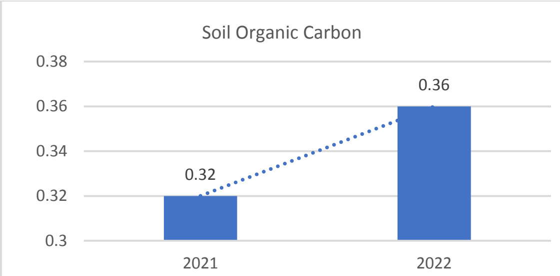

Figure 1 Soil organic carbon

Table 2 shows the impact of regenerative practices on soil organic carbon, soil erosion, and biodiversity. It is evident that practicing mulching, cover crop, green leaf manuring, and agroforestry in the cotton field had a better impact on controlling the soil erosion and increasing the soil organic carbon. Applying biochar and compost helps in adding carbon to the soil but has a low impact on enhancing the biodiversity in the area. Minimum tillage or no tillage helps in controlling soil erosion and also helps in sequestering carbon in the soil.

Table 3 Soil test results

Parameters	2021-22	2022-23
Nitrogen	198.4 kg/ha	204 kg/ha
Phosphorus	35.1 kg/ha	35.43 kg/ha
Potassium	205 kg/ha	232.29 kg/ha
CV 0.59		

The 2-year average NPK data were analyzed using two-factor ANOVA, and there was a significant increase in N and K values as a result of the regenerative practices and at par results were obtained in the case of *P* value (Table 3). According to the findings, incorporating regenerative practices improves soil nutrient content and soil fertility. Organic carbon can boost yield while also reducing climate change by capturing carbon in the soil. Soil organic carbon is the most important indicator of soil quality and agronomic sustainability (Reeves, 1997).

Figure 1 shows a significant increase in percent soil organic carbon from year 1 to year 2, that is, 0.32% to 0.36% respectively. It can be seen in the findings that there is an increase of overall 12% in the case of the soil organic matter.

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8.15 Enhancing Farmer’s Income by Promoting Crop Diversification in Cotton Regenerative Agriculture System

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Keywords: Regenerative agriculture system; Promoting crop diversification and income enhancement

1. Introduction

Cotton being a cash crop is widely cultivated as a monocrop. The intensive cropping of cotton exposes farmers to high risks such as unexpected high rainfall, frost, drought, or the sudden emergence of pest diseases. Besides, monoculture leads to a loss in soil fertility, soil compaction, degradation, and erosion. By diversifying the crop portfolio, these aforementioned risks can be mitigated.

Crop diversification is widely viewed as an approach to increase the farmer’s income by introducing crops that have complementary market opportunities and improving the status of native biodiversity, thus strengthening the ability of the agroecosystem to respond to biotic and abiotic stresses. In a diversified cropping system, the probability of crop failure is less as different crops react differently to the changing climatic conditions (Khanam *et al*., 2018). Crop diversification is one of the salient features of Regenerative Agriculture (RA) system, and hence the purpose of this study is to identify potential crops for diversification in a cotton regenerative system.

2. Materials and methods

The present pilot demonstration is carried on in the southern part of Chhindwara district (22°03’26.77″ N, 78°56’17.42″ E) in the blocks Sausar, Pandhurna, and Bichhua. The region has sandy loam black soil having medium-to-high fertility and high water-holding capacity, which is favorable for cotton growing. The organic cotton initiative is going on in 95 villages of these blocks, and 6000 organic certified farmers are registered with the Agricultural and Processed Food Products Export Development Authority (APEDA). Also, 150 acres of demonstration are ongoing at the project site with organic certified farmers who are implementing crop diversification in an RA system.

The crops are selected on the basis of their adaptability in a cotton system and rainfed conditions, local availability, ability to fix atmospheric nitrogen, and market demand. Various researchers are of the view that leguminous crops are more suitable for green manuring and intercropping, as they fix nitrogen from air with the help of beneficial bacteria hosted in root nodules. Red gram, castor, sun hemp, long beans, and marigold are selected for diversification in 1 acre demo plots and in the conventional farm, cotton is taken as the sole crop. The farm layout for demonstration is finalized after consultation with agriculture research institutions like Central Institute of Cotton Research (CICR), local agriculture extension institutes like Krishi Vigyan Kendra (KVKs), State Agriculture Universities (SAUs), experts, and selected farmers. Table 1 shows the crops considered for diversification and their benefits.

Table 1: Crops for diversification and their benefits

Crop	Demo plot	Benefits
Main crop: Cotton	Six rows of cotton	Cash crop
Inter crop: Red gram	One row of red gram	Crop diversity; retention of nutrients
Cover crop: Sun hemp	Sown in between rows of cotton	Suppression of weeds; reduction in tillage operations; addition of nitrogen and organic matter content
Border crop: Castor/long beans	Sown at borders	Reduce attack of bollworms and attract pollinators and natural enemies, viz., parasitoids and predators
Pollinator-friendly crop: Marigold	Sown in between rows of cotton and gap filling	Reduce pest incidence and attract beneficial insects and pollinators

A survey was conducted in these blocks in randomly selected villages to analyze input and production costs for both regenerative and conventional farms. The data were collected with the help of village-level community volunteers. The quality check of data is done by literature references and other primary sources to ensure reliable results.

3. Results and discussion

It is evident from Table 2 that the cost of inputs is less in regenerative farms as compared to conventional farms. The reduction in cost directly increases the net profit gained by the regenerative farmer. A study revealed that a regenerative farm is more profitable than conventional farms because of the lower input cost and premium markets.

In a regenerative farm, there is a lower yield as compared to a conventional farm, but the net profit earned in a regenerative farm is significantly more, which is Rs 26,440.89 and Rs 9270, respectively. The diverse cropping system practiced in a regenerative farm helps to compensate for the decrease in yield and thus increases the net profit. The benefit-cost ratio calculated for the organic farm (2.88) is more than the conventional farm (1.41). Mondal et al. (2020) also reported similar results in these blocks; according to them, the inorganic approach may give high returns but it needs also a very high investment whereas the organic approach brings the output almost the same but with very low input. Over time, with similar yields, lower production costs (inputs), and a premium price (usually 10–20% over market prices), organic cotton farming can be far more remunerative compared to conventional cotton farming (Eyhorn *et al*., 2005).

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Table 2 Comparison of yield and net profit in regenerative and conventional farms

Parameters	Regenerative farm	Conventional farm
Average production (seed cotton q/acre)	3.0	5.0
Average production cost (Rs)	14,050.00	27,350.00
Average income* from cotton (Rs)	23,148.00	38,580.00
Average income* from crop diversification (Rs)	17,342.89	0.00
Gross income (Rs)	40,490.89	38,580.00
Net profit (Rs)	26,440.89	9270.00
Benefit:cost ratio	2.88	1.41

*For calculating average income, visit www.agmarket.gov

Crop diversification is an integral part of a regenerative system, which creates diverse sources of income generation for farmers by reducing dependency on a single crop and hence decreasing the chances of crop failure; leguminous crops in the long run decrease the fertilizer inputs in soil and create a conducive environment for thriving of beneficial fauna. The adoption of crop diversification increases farm productivity with low risk. Hence, crop diversification can improve the livelihood of small and marginal farmers as it is comprehensive management of farm resources.

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Theme 9

Recognizing and Identifying Invasive Species

9.1 Invasiveness – An Unknown Nature of *Cymbopogon jwarancusa* Recognized during COVID-19 Total Lockdown

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Keywords: *C. jwarancusa*; COVID-19 complete lockdown; Invasive plant; Progenies; Spikelets; Wind dispersal

1. Introduction

C. jwarancusa (Jones) Schult, Poaceae, is a perennial C4 herb with medicinal and aromatic properties. Its native stretches from SE Turkey to Socotra, Western Himalayas, and Central Yunnan (Figure1a). As bunchgrass weed, it grows luxuriantly in India and adjoining countries. Foliage being aromatic is widely used in soaps and perfumes. Piperitone is its major compound and is an essential oil which is responsible for the characteristic aroma. It is a good soil binder and land reclaimer. It has a short life cycle and blooms within three months compared to other *Cymbopogon* (Sarkar *et al*., 2021). It has higher viable seed production, easier spikelets dispersal mechanism, moderately drought tolerant ability, and better germination rates than other competitive weeds growing nearby. It can also adapt to different habitats and most impressive among those are the adaptations for conserving water in its body.

The present study was carried out just after the end ofCOVID-19 lockdown and is an observation to suggest *C. jwarancusa* (Jones) Schultas an invasive aromatic monocot. This study also aims to screen better aromatic chemoprofile types compared to already existing ones.

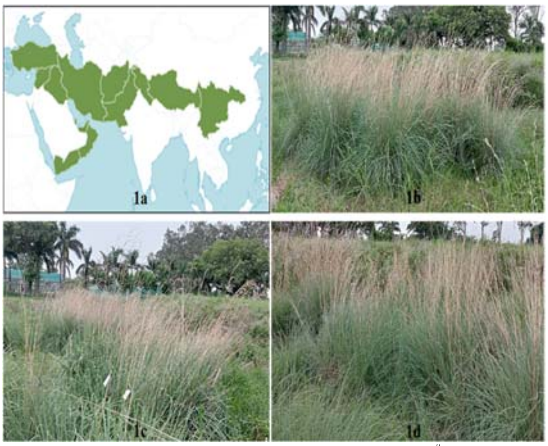

Figure 1(a) Native range (in green) of *C. jwarancusa*#. (b) Parental plants. (c) Some progenies (JK1–JK44) from parental plants. (d) Some progenies from JK1–JK44.
#Source:https://powo.science.kew.org/taxon/8817741?_gl=1*jofxgs*_ga*NTgyNzUxNTgwLjE2NTc2MjU2OTc.*_ga_ZVV2HHW7P6*MTY2NDI3NzI1NC4zLjEuMTY2NDI3NzM0Mi4wLjAuMA.

2. Materials and methods

Plants of *C. jwarancusa* growing in experimental plots were the only plants existing in that area as described by Sarkar *et al*. (2021) before the complete lockdown due to COVID-19. Since this was the only stock of such plants existing in that area, all other new plants found growing nearby it post COVIDlockdown were simply the spikelet germinated progenies of the parents in the trial. These new plants grew luxuriantly during the COVID-19 lockdown.

Forty-four progenies (JK1 to JK44) germinated from 16 mother plants which grew luxuriantly and they gave rise to another 142 progenies (JKK1–JKK142). This incident of spikelet dispersal and hence invasiveness was unprecedented in *C. jwarancusa*so far.

Morpho-chemometric observations were recorded for statistical analysis from 44progeniesand compared with the other 142 progenies with respect to 22 important traits mentioned in Table 1. The data were employed for statistical analysis using statistical software SPSS v26.

3. Results and discussion

The characteristic features of *C. jwarancusa*(Table 1) were a perfect match with those of invasive species as outlined by Gao *et al*. (2018), Herron*et al*. (2007), and Ren andZhang (2009). Moreover, unrestricted anemochory during COVID-19 complete lockdown from *C. jwarancusa* parental plants led to an invasive propagation of **44** (JK1–JK44) progenies. These progenies subsequently gave rise to **142 progenies** (JKK1–JKK142). These two sets of progenies grew luxuriantly for 1 year because of the undisturbed and conducive environment as no anthropogenic activities were observed during the lockdown.

This observation in regard to the invasiveness of *C. jwarancusa* was only possible because of the imposition of complete lockdown due to COVID-19 and no cultural activities happened in and around the trial for a year. The plants of *C. jwarancusa* attained full vegetative and reproductive growth which would not have happened during regular time. The plants bloomed after every three months and dispersal of spikelets occurred. The spikelets germinated along with the direction of the blowing wind which was N-S, thereby invading a new colony. These spikelets germinated into new plants and this cycle of invasion and colonization continued for a year which resulted in *C. jwarancusa* infestation.

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Table 1 Salient morpho-chemometric traits of two progeny sets of *C. jwarancusa* along with comparative similarities with general features of invasive species

Traits	JK1–JK44(mean values)	JKK1–JKK142(mean values)	Characters of invasive species	Types	Characters of *C. jwarancusa*
Distance of spikelets dispersal from the mother plant (cm)	876.15	2190.38	Habitat	Terrestrial Wetland Aquatic	*
Plant height (cm)	57.05	60.10	Lifespan	Annual Biennial Perennial	 *
Inflorescence length (cm)	151.71	147.28	Growth form	Grass Shrub Vine Tree	*
Number of inflorescence/clump	53.88	51.98	Family	Asteraceae Poaceae Fabaceae Amaranthaceae Etc.	 *
Leaf length (cm)	33.32	38.21	Sexual reproduction	Very easy Easy General Unusual	 *
Clump diameter (cm)	75.04	62.56	Asexual reproduction	Usual Unusual	*
Total inflorescence weight/clump (g)	227.55	212.33	Inflorescence type	Single flower Umbel Cyme Spike Capitulum Panicle Botryoid Fascicle Catkin	 *
Total flowers weight/clump (g)	31.70	29.98	Flowering season	Spring Late spring Summer Late summer Fall Late fall Winter	After every 3 months from the first flowering
Total inflorescence stalk weight/clump (g)	195.84	201.92	Fruit type	Capsule Achene Caryopsis Berries Pod Sarcocarp Follicle Sarmara Nuts Schizocarp Aggregate Utricle Mericarp Drupe Cone Silique	 *
Clump fresh weight (g)	158.72	166.76	Seed size (mm)	Less than 1 1–2 2–3 3–5 5–10 10–30	*
Clump dry weight (g)	109.51	122.67	Seed dispersal	Wind Bird Other animals Water	*
Foliar essential oil recovery (%)	0.32	0.30	Shade tolerance	Yes No	*
Inflorescence essential oil recovery (%)	0.07	0.06			
Flower length (cm)	4.52	4.49			
Flower width (cm)	1.15	1.10			
Node width of inflorescence stalk (cm)	0.53	0.50			
Weight of soil attached toroots (g)	136.48	122.26			

D-Limonene (%)	3.58	3.30
2-Cyclohexen-1-ol, 1-methyl-4-(1-methylethyl)-, *trans*- (%)	30.57	33.20
2-Cyclohexen-1-ol, 1-methyl-4-(1-methylethyl)-, *cis*- (%)	19.36	18.3
2-Carene (%)	6.41	5.53
4-Isopropyl-1-methylcyclohex-2-enol (%)	30.59	31.28

Source: Gao *et al*. (2018); Herron et al. (2007); Ren and Zhang (2009); *Characters of *C. jwarancusa*which matches with the given options.

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9.2 Prediction on the Range Expansion and Risk Assessment of the Invasive Pest Slug *Deroceras laeve* with Changing Climate in Sikkim-Darjeeling Himalayas

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Keywords: Climate change; Herbivory; Species distribution modelling

1. Introduction

The globally invasive slug *D. laeve* (O. F. Muller, 1774) (Gastropoda: Agriolimacidae) native to the Palearctic region (Wiktor, 2000) has spread to different countries beyond its native range from the beginning of the 21st century. Generally considered a pest of agriculture and horticulture in both native and invaded regions, *D. laeve* is reported to consume eggs of native beetle and acts as a host of several parasites of human and domestic animals. The chance encounter of *D. laeve* in the Darjeeling Himalayas, West Bengal, India, prompted us to predict its potential suitable habitats for range expansion in Sikkim-Darjeeling Himalayas. Additionally, the palatability of leafy vegetables and ethnomedicinal plants to *D. laeve* was assessed to investigate its potential as an agricultural pest.

2. Materials and methods

Initially, the slug *D. laeve* was identified following the morphological and molecular data. The occurrence of *D. laeve* in different geographic coordinates of the Sikkim-Darjeeling Himalayas was noted during the field survey (number of occurrence points=10; the number of absence points=4). Species distribution modelling (SDM) was carried out through the '*sdm*' package (Naimi and Araújo, 2016) in RStudio software using current and future climatic scenarios and occurrence data (the '*sdm*' package does not require 'absence points' for modelling). Ensemble models were employed to reduce the uncertainty of single-model prediction by combining the predictions of 'Maximum Entropy' (*maxent*), 'random forest' (*rf*), 'Generalised Linear Model' (*glm*), and 'Boosted regression tree' (*brt*) (Naimi and Araújo, 2016). *D. laeve* individuals were collected from several regions of Darjeeling and Kalimpong districts, West Bengal, India, brought, and reared under optimal laboratory conditions. In the laboratory, the one-month-old F_1 individuals were offered seven different leafy vegetables and ethnomedicinal plants (basil, cabbage, coriander, lettuce, mint, pumpkin, and spinach), and the consumption rates for each food type were determined. The total phenol content of the leafy vegetables was determined using the spectrophotometric method to estimate any relation between the phenol content of leaves and the respective consumption rate. One-way ANOVA was applied to determine any differences in the consumption rate due to different plant species, and Pearson product-moment correlation was applied to find any correlation between the consumption rate and the total phenol content of the leaves using *XLSTAT* software.

3. Results and discussion

The species distribution modelling showed high performance with AUC values > 0.8 (*maxent*=0.91, *rf*=0.90, *glm*=0.88, and *brt*=0.89). The SDM predicted that Kalimpong district, West Bengal, a large area of Darjeeling district, West Bengal, and discrete areas of West, South, and East Sikkim districts are susceptible to *D. laeve* invasion and establishment. The SDM based on the future climatic data indicated that the high and moderately suitable areas would increase with future climate change (RCP 4.5 and 8.5, year 2050) (Figure 1). On the other side, *D. laeve* consumed all seven types of leafy vegetables and ethnomedicinal plants in the laboratory. As indicated by the results of ANOVA, significant variation was observed in the consumption rate of *D. laeve* due to different plant species ($F_{6,209}$=4.899, p<0.0001). The maximum consumption rate was observed in the case of pumpkin leaf (10.09±1.58 mg), and the lowest consumption rate was observed in the case of basil (4.15±0.43 mg). Additionally, no significant correlation was found between the consumption rate and the total phenol content of the leaves (r=–0.590, p=0.163). Previously, *D. laeve* was reported to consume several agricultural plants and is considered a pest in different regions of the world. The high palatability of the leafy vegetables and ethnomedicinal plants may result in significant damage in the field conditions, and, therefore, *D. laeve* may act as a potential pest in the Sikkim-Darjeeling Himalayas under suitable climatic conditions. Although the low-density occurrence of *D. laeve* around the human settlements can be managed readily through manual removal, the short generation time, higher reproduction rate, and suitability of large areas in the Sikkim-Darjeeling Himalayas may facilitate further range expansion in the absence of proper management strategies.

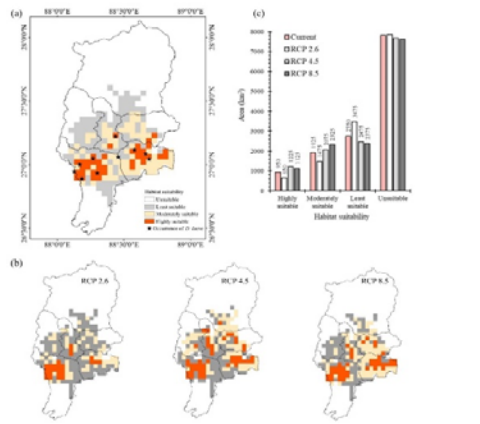

Figure 1 (a) Predicted suitable areas for *D. laeve* invasion and range expansion in Sikkim-Darjeeling Himalayas, India, based on species distribution modelling using current climatic conditions, (b) predicted suitable areas for future range expansion in Sikkim-Darjeeling Himalayas, India, based on future (the year 2050) climatic conditions, and (c) changes in the habitat suitability of *D. laeve* in terms of total area (km^2)

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9.3 Ecological Investigation and a Comprehensive Inventory of Invasive Alien Plants in Phawngpui National Park and Murlen National Park in Mizoram, an Indo-Burma Biodiversity hotspot in India

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Keywords: Control and management; Indo-Burma biodiversity hotspot; Murlen National Park; Neo-invasive; Phawngpui National Park; Protected Areas

1. Introduction

Worldwide, alien plant invasion is considered one of the major drivers of global environmental change and rapid biodiversity loss. Also, the native forests, mountains, and wetlands are invaded including protected forests by a broad array of harmful invasive alien plant species (IAPs). IAPs cause economic losses to invaded areas and communities leading to high suffering in agriculture, forestry, and human health. High-value environmental assets such as protected forest areas, wetlands, and conservation lands of both environmental and cultural value are vulnerable to the harmful impact of IAPs.

A formally established control and management framework could be implemented to reduce the vulnerability of protected areas to invasions from IAPs impact. Such frameworks would first require a comprehensive inventory to estimate the most obnoxious IAPs. In Indian Himalayan Region, as a broad estimation a total of 297 naturalized alien plant species belonging to 65 families were reported including 163 invasive alien plants reported from the Mizoram region. But the information on invasion threat in individual protected areas like national parks and wildlife sanctuaries in these biodiversity hotspots are scanty. Therefore, to formulate the necessary conservation of natural forests, the pattern of spread of IAPs in protected areas is needed. Hence, the present study was conducted in two protected areas of Mizoram with the objective to prepare a comprehensive inventory of invasive alien plants in national parks in Mizoram to investigate the ecological status along the altitudinal gradient to evaluate their potential threats. A comprehensive checklist of IAPs is presented here along with their nativity, probable mode of introduction, distribution, local uses, and so on including the 10 most obnoxious established IAPs, five neo-invasive species, and top 10 dominant native species.

2. Materials and methods

The forest cover of the state of Mizoram is 73.68% of the state's total geographical area, out of which only 6.75% is under a protected area network. The present study was conducted in two national parks in the state of Mizoram, namely, Phawngpui National Park (50 km^2) and Murlen National Park (100 km^2). The vegetation of the study area was studied based on the altitudinal gradient of tropical (up to 900 m), subtropical (900–1800 m), and temperate (1800–3600 m).

Collected voucher specimens were processed following the conventional method. A random sampling technique using the nested quadrat method was followed for the collection of phytosociological data. Plot sizes of 400 m^2 were selected randomly within which quadrats of 5 m × 5 m were laid for shrubs and 1 m × 1 m for herbs. All the phytosociological data, that is, relative densities, relative frequency, relative dominance, and importance value index (IVI), of each species were determined using formulas mentioned by Misra (1968). Simpson's diversity index (SDI) and the Shannon-Wiener information index (H') indices were also calculated.

3. Results and discussion

The results revealed a total of 207 invasive alien plant species belonging to 193 genera under 59 families recorded from both the national parks in the state. Out of these, 179 species belong to 145 genera and 48 families were dicotyledons, whereas 22 species belong to 18 genera and 6 families were monocotyledons, followed by 5 species of gymnosperms and 1 species of pteridophyte. Among these, 125 plant species were represented by herbs (60.38%), 26 trees (12.56%), 23 shrubs (11.11%), 17 climbers (8.21%), 13 grasses (6.28%), and 3 sedges (1.44%). In both the national parks, the maximum percentage of alien plants were of tropical American origin (30.91% PNP, 29.95% MNP). The present study recorded 44 additional IAPs than previously reported from the state of Mizoram (Sengupta and Dash, 2020). Additionally, the results of the study also evaluated the impact of invasion based on the altitudinal gradient in two national parks.

In the shrub layer of PNP, *Chromolaena odorata* (IVI-62.74) and *Mikania micrantha* (IVI-34.79) were most dominant in the lower altitude (up to 900 m) and *Lantana camara* (IVI-43.11) and *M. micrantha* (IVI-41.72) were the most dominant in the middle altitude. However, in the upper altitude, native plants were dominant, namely, *Hedychium villosum* (IVI-38.94) and *Maesa indica* (IVI-30.25). Similar observations were found for MNP upper altitude.

In the herb layer of PNP, *Ageratina adenophora* (IVI-63.45) and *Ageratum conyzoides* (IVI-17.77) were the most dominant in the lower altitude; *A. adenophora* (IVI-59.30), *A. houstonianum* (IVI-23.31), and *Bidens pilosa* (IVI-24.69) were the most dominant in the middle altitude; and *A. adenophora* (IVI-61.78) and *A. houstonianum* (IVI-28.51) were the most dominant in the upper altitude. A similar pattern was observed in MNP, but in the upper altitude only *A. adenophora* (IVI-42.60) is present.

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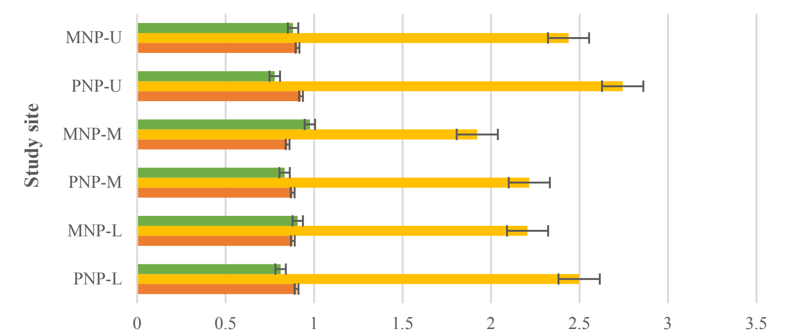

	PNP-L	MNP-L	PNP-M	MNP-M	PNP-U	MNP-U
Evenness_e^H/S	0.8107	0.9075	0.8335	0.9761	0.7775	0.8807
Shannon_H	2.498	2.206	2.216	1.922	2.744	2.438
Simpson_1-D	0.9002	0.8795	0.8785	0.8495	0.9255	0.9063

Evenness_e^H/S Shannon_H Simpson_1-D

Figure 1 Biodiversity indices of herb layer based on altitudinal gradients (PNP – Phawngpui national park, MNP – Murlen national park, L – lower altitude, M – middle altitude, and U – upper altitude)

Phytosociological investigation (Figure 1) revealed that the lowest Shannon diversity index (H'=1.992) was observed in the herb layer in disturbed habitats at the middle altitude (901–1800 m) of Murlen national park compared to the middle altitude of Phawnpui national park (H'=2.216). Based on the biodiversity indices, Shannon's species diversity index shows that undisturbed forest stands at the upper altitude had higher diversity (PNP H′=0.9255; MNP H′=0.9063) as compared to the anthropogenically disturbed forest stands (PNP H′=0.9002; MNP H′=0.8795) at lower altitude. The highest diversity index was observed for the shrub layer of upper altitude (1801–3600 m) of Murlen national park (H'=2.774). The Shannon-Weiner (H′) index for all the six study sites varied from 1.922 to 2.661, which falls well within the range of 0.67–4.86 reported for tropical forests Indian subcontinent (Devi *et al*., 2018) implying that the national parks are vulnerable to invasion where native plants are gradually subjected to competition, but there is the scope of eradication and management of the IAPs. The local forest department and the forest dwellers perform slash and burn method to eradicate the obnoxious IAPs, but additionally cut-stock-root method could be implemented for better control. From the present study, it can be concluded that *C. odorata*, *A. adenophora*, *L. camara*, *M. micrantha*, *B. pilosa*, *A. conyzoides*, *Imperata cylindrica* are the most impactful and highly invaded alien plants in various altitudinal gradient of the national parks in Mizoram causing serious damage to the natural native flora. A proper control and management strategy should further be taken up and regular awareness programmes may also need to be conducted to make the local inhabitants aware of the impacts and control of invasive alien plants.

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9.4 Natural Farming for Sustainable Yield and Soil Health of Horse gram - Garlic Cropping System

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1. Introduction

Agriculture in its prevailing form requires farmers to rely heavily on inorganic external chemical inputs such as fertilizers and pesticides. These contaminate groundwater and other water-dependent ecosystems, reduce soil fertility over time, and contribute to biodiversity loss in farmlands. The use of such inputs exposes smallholder farmers to a high degree of credit risk and traps them in a perpetual cycle of debt. Natural farming philosophy is working with nature to produce healthy food. Natural farming involving the use of organic liquid fluid (jeevamruth) is a low-input farming practice and has emerged in pockets across the world promising reduced input costs and higher yields for farmers, chemical-free food for consumers and improved soil fertility (Palekar, 2009). Keeping in view the benefits of natural farming, the current study was chosen to assess the effect of soil and foliar applied jeevamruth on horse gram – garlic system grown under rainfed situations in mid hills of Himachal Pradesh.

2. Materials and methods

The present investigation was carried out for two consecutive season of 2019 and 2020 at the experimental farm of Chaudhary Sarvan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Hill Agricultural Research and Extension Centre, Bajaura, Kullu, India. The experimental farm is situated at 31.8°N latitude and 77°E longitude at an elevation of 1090 m above mean sea level. The experiment consisted of three levels of soil applied jeevamruth (0, 500 and 1000 l/ha) and three levels of foliar applied jeevamruth (0, 5 and 10%). A total of nine treatment combinations (No soil application or foliar of jeevamruth (control), 5% foliar spray without soil application of jeevamruth, 10% foliar spray without soil application of jeevamruth, jeevamruth application @ 500 l/ha in soil without foliar spray, jeevamruth application @ 500 l/ha in soil + 5% foliar spray, jeevamruth application @ 500 l/ha in soil + 10% foliar spray, jeevamruth @ 1000 l/ha in soil without foliar spray, jeevamruth @ 1000 l/ha in soil + 5% foliar spray, jeevamruth @ 500 l/ha in soil + 10% foliar spray) replicated three times, were evaluated in a randomized block design using two factor analysis. The sowing of horse gram was performed in the first week of July and that of garlic in second week of October every year. Seeds of horse gram and cloves of garlic were treated with beejamruth before sowing. Beejamruth, a liquid fluid used as seed treatment was prepared by mixing 5 kg cow dung of local breed, 5 liters of cow urine, 50 g lime and 100 g antennae soil with 20 liters of water and was kept for 24 hours. On the day of sowing of horse gram and garlic, seeds were soaked in the Beejamruth solution. The mixture of Ghana jeevamruth (prepared from fresh cow dung) was basely applied @ 250 kg/ha in all the plots at the time of sowing. It was prepared by mixing 100 kgs of cow dung, 1 kg jaggery, 2 kg gram flour, 100 grams of antennae soil and 10 liters of cow urine, brought to thick paste and allowed to complete dry. Jeevamruth, an organic liquid formulation was prepared by placing 200 liters of water in a barrel and added 10 kg fresh cow dung of local cow breed, 10 liters of cow urine, 2 kg each of jaggery and 100 g of antennae soil. The mixture was fermented for 3 days in shade condition. The soil and foliar application of jeevamruth was done as per the treatment and its application was initiated 21 days after sowing (DAS) at 15 days interval during entire crop period (Palekar, 2009). Composite surface soil samples collected after the harvest of crop were analyzed for soil parameters as per standard procedures.

3. Results and discussion

The soil and foliar applied jeevamruth exhibited a significant effect on yield of horse gram and garlic. The pooled data of two years revealed that soil application of jeevamruth @ 1000 L/ha along with 10% foliar spray recorded highest grain yield of horse gram (Table 1) and bulb yield of garlic (Table 2). The higher yield of horse gram and garlic obtained due to use of jeevamruth in the present study could be attributed to higher microbial load and growth hormones, resulting enhanced plant growth thereby sustaining the availability and uptake of applied as well as native soil nutrients which ultimately resulted in better growth and yield of crops (Boraiah et al., 2017). The amount of soil organic carbon (Table 3) and total microbial biomass carbon (Table 4) was recorded highest due to 1000 L/ha of soil applied jeevamruth with 10% foliar spray of jeevamruth. The subsequent decomposition of organic liquid formulation (jeevamruth) might have resulted in enhanced organic carbon content of soil. The increase of soil microbial biomass carbon was probably due to the higher contents of more readily decomposable C fractions present in jeevamruth (Rochette et al. 2006) which served as a food for microbial propagation. It was concluded that soil applied jeevamruth @ 1000 l/ha along with 10% foliar spray was best choice for minimizing the dependence on inorganic fertilizers, enhancing crop yield and better soil health under rainfed conditions of Himachal Pradesh.

Table 1 Grain yield of horse gram(q/ha) as influenced by soil and foliar applied jeevamruth (2 years pooled data)

Treatment	Foliar spray (%)			Mean
Soil application (L/ha)	0	5	10	
0	5.9	9.3	12.2	9.1
500	7.7	11.2	13.1	10.7
1000	9.9	12.9	13.6	12.1
Mean	7.8	11.1	13.0	
CD (5%) Interaction=1.8 Soil application=1.0 Foliar spray=1.0				

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Table 2 Tuber yield of garlic (q/ha) as influenced by soil and foliar applied jeevamruth (2 years pooled data)

Treatment	Foliar spray (%)			Mean
Soil application (L/ha)	0	5	10	
0	78.0	90.0	98.0	88.7
500	84.0	98.0	107.0	96.3
1000	89.0	105.0	120.0	104.7
Mean	83.7	97.7	108.3	

CD (5%) Soil application = 4.9, Foliar spray = 4.9 Interaction = 8.6

Table 3 Soil organic carbon (g/kg) as influenced by soil and foliar applied jeevamruth (2 years pooled data)

Treatment	Foliar spray (%)			Mean
Soil application (L/ha)	0	5	10	
0	6.7	7.8	8.6	7.7
500	6.9	9.8	9.3	8.7
1000	7.1	9.6	9.9	8.9
Mean	6.9	9.1	9.3	

CD (5%) Soil application=0.6 Foliar spray=0.6 Interaction=1.0

Table 4 Soil microbial biomass carbon (µg/g soil) as influenced by soil and foliar applied jeevamruth (2 years pooled data)

Treatment	Foliar spray (%)			Mean
Soil application (L/ha)	0	5	10	
0	69.8	86.4	92.3	82.8
500	72.2	89.6	98.4	86.8
1000	76.2	97.6	103.2	92.3
Mean	72.7	91.2	98.0	

CD (5%) Soil application=8.4 Foliar spray=8.4 Interaction=14.5

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Addendum

1. Understanding Farmers' Perceptions and Preferences of Lentil Varieties Through Participatory Plant Breeding Approaches

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Keywords: Farmer; Lentil; Participatory rural appraisal; Perceptions; Preferences

1. Introduction

Participatory plant breeding (PPB) has evolved as a viable alternative to the conventional plant breeding that lays more emphasis on the involvement of different stakeholders' rights from deciding the varietal identification, selection of parents from segregating generations, to testing and release of the product. The greater involvement of farmers and other stakeholders ensures that their perceptions are taken care of in order to speed up the rate of adoption. The level of participation may vary depending on the stage of the PPB program, but participation has to be effective at all the stages.

2. Materials and methods

Fifty households from each site were surveyed using a predesigned Household Level Questionnaire (HLQ) to identify production constraints as well as the farmer's perception of varietal specifications. The probing technique was used to derive as much desired information as possible to have a thorough insight into the understanding of farmers' perspectives, constraints, and their willingness to effectively participate in the process of varietal evaluation and genetic resource conservation through large-scale use. Probing involves the use of specific words or other interviewing techniques by an interviewer to clarify or seek elaboration on a person's response to a survey question. A flexible approach was used in participatory rural appraisal (PRA) to derive any other information provided by farmers that was not covered within the contents of the PRA questionnaire. In the present study, 13 strains of lentil were selected out of the germplasm screening based on yield, maturity, and disease reaction. The material represented different market classes of lentils in light of their preferences and local market value. The material was grown in a replicated trial with replications using the Shalimar Masoor-1 variety as a check. Each genotype was represented by two lines of 3 m length with a spacing of 30 × 10 cm. Data were recorded from 10 competitive plants from each replication.

3. Results and discussion

The participatory rural appraisal (PRA) results revealed that in the districts of Anantnag and Budgam, the lentil crop is being grown widely. The source of seeds in the 16 locations was mainly farmers' own seeds. PRA across 16 locations revealed that lentil is being widely practiced under intercropping system, however, at the location Chakki Issardas (Anantnag) a good number of farmers (30.23%) were practicing sole cropping. It was found that most of the lentil fields were rainfed and significantly in vogue; however, 44.74% of farmers of Chadoora in the district Budgam grow lentils under assured irrigated conditions. The data revealed rainfed lentil cultivation was carried out on almost 62.17% area in district Anantnag and 63.75% in district Budgam (Table 1). PRA has sources in activist participatory research, agroecosystem analysis field research on farming systems, and rapid rural appraisal (RRA). Besides, PRA technique is used to establish benchmark information on biophysical, socioeconomic, institutional, and farming constraints, as well as farmers' needs and researchable problems (Joshi *et al*., 2001). In addition, plant PRA has been employed as an effective tool to get feedback and information regarding the likes and dislikes of end users (farmers) about various traits of lentils so as to chalk out the strategy for breeding and evaluating the genotypes at farmers' field through participatory varietal selection (PVS) in order to increase the adoption rate of released varieties (Katimgi *et al*., 2011; Gichangi *et al.*, 2012).

Table 1 District-wise participatory rural appraisal in lentil (*Lens culinaris* M.) for various traits

		Source of seed			Cropping system			Irrigation system		Maturity	
Districts	Respon-dents	Farmers' own seed	Institution	Market	Inter-crop	Sole crop	Mixed crop	Rainfed	Assured irrigation	Earliness	Uniform maturity
Anantnag	331	219	37	75	203	68	60	212	119	223	108
		–64.22	–10.85	–21.99	–59.53	–19.94	–17.59	-62.17	–34.89	–65.39	–31.67
Budgam	309	168	53	88	194	59	56	197	112	220	89
		–54.36	–17.15	–28.47	–62.67	–19.09	–18.12	-63.75	–36.24	–71.19	–28.8
Chi-square value		29.11			26.78			27.49		50.97	
p value (≤0.05)		0.002			0.001			0.01		0.0002	

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2. Intensification of Tree Cultivation in Cropland-based Agroforestry Systems: Role of Socioeconomic Factors

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Keywords: Agroforestry systems; Cropland; Intensification; Tree Cultivation

1. Introduction

Intensification of the limited arable land through the application of high-yielding crop varieties and extensive and excessive use of fertilizers, pesticides, and irrigation have resulted in degradation of the natural resources, reduction in biodiversity, and decline in the productive capacity of the ecosystem. Agroforestry is one of the sustainable land-use systems that increases the overall productivity of land, enhances ecosystem services, and helps mitigate harmful impacts of climate change. Though several studies have been conducted to identify the factors that influence the adoption of agroforestry, there is hardly any study that investigates the role of socioeconomic factors in tree intensification on cropland. This study delineates the socioeconomic factors that motivated farmers to intensify tree cultivation on cropland.

2. Materials and methods

The study was carried out in the Mandi district of Himachal Pradesh. A multistage sampling frame was adopted to select the ultimate unit of sampling, that is, households. Of the five forest divisions in the district, two divisions, namely, Joginder Nagar and Suket, were selected purposely because of the presence of hills and plains. A list of JFM program and nonprogram villages from hills and plains was prepared in consultation with divisional forestry staff. A list of program and nonprogram villages for each of the hill and plain categories was prepared with the help of the divisional forestry staff of each selected forest division. Two villages from each subcategory of villages in hills and plains were chosen in each selected forest division using simple random sampling with a replacement method. Thus there were eight sample villages in each forest division and a total of 16 villages. A list of households in each of the selected villages was prepared. One-third of households were taken as the sample from each selected village. The data were collected using a prestructured schedule and personal interviews of the heads of the households. Tree intensification was defined in terms of the number of trees per hectare on the cropland. The median number of trees was 78. Thus the dependent variable (type of farmers) was categorized in to low intensifiers (farmers with 1–78 trees) and high intensifiers (farmers with >78 trees). The association between the dependent variable and different independent variables was examined using the chi-square test of the association at a 0.001 level of significance.

3. Results and discussion

Among several factors, the education level of the head of household, cropping intensity, household food sufficiency, livestock holding, sale offorest produce, and the level of restrictions on grazing after crop harvest significantly and positively influenced the intensification of tree cultivation. This implies that there is a need to encourage households to obtain a better education for improving tree intensification on cropland. Further, there is a need to make households self-sufficient in food and increase restrictions on farm grazing to ensure tree intensification. Further, linking the production of tree products with the market would also encourage households for tree intensification for sustainable use of the land. The influence of the size of cropland holding was also significant, but the negative influence of tree intensification implies smallholders are likely to have more intensification than the larger ones. Therefore, specific efforts need to be made to encourage large holders to intensify tree cultivation. The study implies that socioeconomic factors need to be considered while formulating tree intensification strategies.

Table 1 Association between tree intensification and socioeconomic factors

Variable	Chi-square value	*p*value	Direction	Remarks
Age	5.814	0.055	+	NS
Caste Upper *vs* Lower	0721	0.788	Categorical	NS
Type of family	5.802	0.016	Categorical	NS
Size of the family	7.795	0.020	+	NS
Education level of the head of the household	28.486	0.0001	+	S
Family literacy level	8.817	0.031	+	NS
Number of government employees in the household	2.847	0.091	+	NS
Primary occupation of the head of household Non-cropping *vs* Cropping	10.209	0.002	Categorical	NS
Type of cropping pattern Self cropping*vs* share cropping	0.321	0.570	Categorical	NS
Number of family members working on the farm (AME)	11.608	0.003	+	NS
Size of cropland (ha)	24.609	0.0001	_	S
Crop diversification (number of crops grown per year)	9.540	0.008	+	NS
Cropping intensity	41.788	0.0001	+	S
Household food self-sufficiency	19.581	0.0001	+	S
On-farm income	10.281	0.016	+	NS
Off-farm income	14.997	0.002	+	NS
Livestock holding (number of adult cattle units)	18.868	0.0001	+	S
Quantity of forest produce sold	21.533	0.0001	+	S
Level of restrictions on grazing on cropland after harvesting	92.723	0.0001	+	S

S: Significant at $p < 0.001$.

Reference

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3. How Various Management Practices Would Help to Overcome Groundwater Exploitation in Punjab? A Study from Punjab

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Keywords: Groundwater; Management practices; Over exploitation; Social personal characteristics

1. Introduction

India is a major user of groundwater in the world with over 60% of irrigated agriculture and 85% of drinking water supplies dependent on aquifers (Anonymous, 2012). Groundwater exploitation in Punjab is increasing day by day. Groundwater table in central Punjab had fallen yearly by about 17 cm in the 1980s and about 25 cm during the 1990s. The sharpest decline in the groundwater table had been observed during the 2000s, which was about 91 cm per annum. The decline was about 75 cm per annum from the last decade. The rise in depletion of groundwater resources in Punjab compelled farmers to invest more in the installation of deep tubewells as well as for purchasing the centrifugal motor pump of larger horsepower, which contributed significantly toward rising in debtedness among Punjab farmers. Owing to the provision of free or subsidized power supply for agriculture since 1992, the consumption of electricity has almost doubled while the subsidy on electricity has increased to almost nine times. This increase in power subsidies is highly unsustainable and it is believed that it adversely affects the productive investments in agriculture by the government. Also, the decline in the groundwater table might be added due to the decline in average rainfall from 754.66 mm in 1990 to 365 mm in 2012 (Vatta, 2019). Owing to these reasons, we are carrying out the study as groundwater sustainability is important. This study helps to understand the relationship between socio-personal characteristics with the efficient water management practices regarding overexploitation of groundwater, which will in turn contribute towards long-term sustainability. The study is based on a survey conducted in the central zone of Punjab. The study suggests that several management practices were fully and partially used in order to reduce the overexploitation of groundwater.

2. Materials and methods

The study was conducted in the central zone of Punjab. Multistage sampling was used in this study. Eight districts of the central zone were selected purposively, where overexploitation of groundwater (i.e.,above 85%) is prevalent (Anonymous, 2011).

Districts	Fatehgarh Sahib	Gurdaspur	Jalandhar	Kapurthala	Ludhiana	Moga	Patiala	Sangrur
	↓	↓	↓	↓	↓	↓	↓	↓
Blocks	Khera	Gurdaspur	Nakodar	Bholath	Samrala	Nihal Singh Wala	Patiala	Sangrur
	↓	↓	↓	↓	↓	↓	↓	↓
Villages	ChhuniKalan	Pahra	Gill	Bagrian	Chhandaran	Bilaspur	Galwatti	Kanganwal

Further, each block was selected randomly, and from each block one village was selected randomly. Fifteen farmers were selected randomly from each village, thus comprising the sample size of 120 farmers. The data were collected by structured interview schedule method. The data were analyzed by using statistical tools such as frequency distribution, percentage, mean score, and coefficient of correlation.

3. Results and discussion

The findings of this study revealed that education, operational landholding, and extension contacts were found to have a highly significant relationship with the extent of use of various management practices regarding overexploitation of groundwater. As education is a highly significant relationship with the extent of use of various management practices it can be interpreted as they would gain the information and would be ready to adopt the new methods for minimizing the water losses occurring in the field.

As total landholding and total earning show a highly significant relationship with the extent of use of various management practices, this can be interpreted as the respondents had more income to manage their land through novel techniques like protected cultivation, mulching, drip, and sprinkler irrigation. And if the techniques are not useful to check the losses, they have an option to change the methods further. Also, the extension contacts show a highly significant relationship with the extent of use of various management practices; this means more valuable details from the personnel, who treat the respondents as their own clients and suggest them useful remedial measures regarding management practices of overexploitation of groundwater.

Table 1 Relationship between socio-personal characteristics with the extent of use for various management practices regarding overexploitation of groundwater.

Characteristics	Dependent variable	Coefficient of correlation (*r*)
Age		–0.036
Education		**0.268***
Family size		–0.019
Total landholding		**0.270***
Farming experience		–0.053
Total earnings	**Extent of use**	**0.212***
Mass media contacts		0.008
Extension contacts		**0.271***
Extension participation		–0.008

*Significant at 1% level.

The data revealed that the method of transplanting of paddy after mid-June instead of May and regular

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maintenance of water channel, zero tillage in wheat-paddy cropping rotation, and wholly cultivating crops on ridges were fully used by 79%of the respondents. Also, zero tillage in the rice-wheat cropping system was fully used by 73% of the respondents and 70% of the respondents were entirely cultivating crops on ridges.

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4. Effect of Cultural Conditions on Growth of *Cordyceps militaris* Under Liquid State Fermentation

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Keywords: *C.militaris*; Cultural conditions; Liquid state fermentation; TPC

1. Introduction

Medicinal mushrooms are a generous source of plentiful useful natural products with immense biological importance. *C.militaris*, also known as keerajari, is a traditionally used medicinal mushroom widely used in many Asian countries. It is an entomopathogenic fungus belonging to the class Ascomycetes. It mainly infects lepidopteron insects. It has been used as a folk tonic food and its medicinal properties have also been utilized for centuries (Yang *et al*. 2014). This mushroom produces many kinds of active components such as adenosine, cordycepin, many polysaccharides, mannitol, phenols, flavonoids, carotenoids, and several other bioactive compounds. Not only the fruit body but *C.militaris* mycelium also has a reserve of bioactive components. Since the fruit body of the mushroom takesa longer time to emerge, using mycelium as a source of these essential components would be of great advantage. Culture conditions and medium compositions play a very vital role in determining the yield of mycelium. Hence, standardization of culture conditions is done to yield more mycelium with enhanced bioactivities.

2. Materials and methods

The *C.militaris* culture was maintained on potato dextrose agar (PDA) slants at 22ºC for 7 days. This was further used for inoculating the liquid culture. The seed culture consists of dextrose, peptone, and yeast extract. The mycelium was grown under varying conditions like temperature (16ºC, 19ºC, 22ºC), dextrose (20–40 g/L), peptone (10–20 g/l), and pH (6–8). The mycelium was grown in 250mL flasks containing 100mL nutrient broth for 15 days in a static liquid state under different conditions to evaluate their fresh mycelia yield. The statistical analysis was performed using two-way ANOVA using R software. Total phenolic content (TPC) was analyzedby the method given by Awang*et al*. (2021) with slight modifications.

3. Results and discussion

The fresh mycelial yield was determined 15 days after inoculations. Mycelia were grown under variable conditions (Table 1). The maximum mycelial yield was obtained when the culture was grown at 22ºC, pH 6, dextrose (20g/L), and peptone (20g/L), which was 10.87 g/100 mL liquid culture, followed by 16ºC, pH 6, dextrose (20g/L), peptone (20g/L), which was 10.76 g/100mL (Table 2). To further maximize mycelium yield with minimal use of inputs (dextrose and peptone), intermediate concentration with temperature and pH was studied and results revealed that 19ºC, pH 7, dextrose (10g/L), peptone (15g/L) gave a yield of 10.07 g/100mL (Table 3). Furthermore, TPC was determined and the result revealed that treatment16ºC, pH 6, dextrose (20g/L), peptone (20g/L) had maximum TPC content, which was around 15.76 mg GAE/g (milligram gallic acid equivalent/gram).

Table 1 Various treatments (temperature and pH) and carbon and nitrogen sources used for maximizing mycelium yield

Temperature(ºC)	pH	Dextrose (g/L)	Peptone (g/L)
22ºC	6	20	20
		40	20
		40	10
		20	10
	8	20	20
		40	20
		40	10
		20	10
19ºC	9	30	15
		30	25
		30	5
		10	15
	7	30	15
		30	25
		30	5
		10	15
16ºC	6	20	20
		40	20
		20	10
		40	10
	8	20	20
		40	20
		20	10
		40	10

Table 2 Mycelial yield (g/100 mL) at different temperature, pH, and dextrose-peptone concentration

Concentration (dextrose+peptone) (g/L)	22°C		Mean	16°C		Mean
	pH6	pH8		pH6	pH8	
20+20	**10.87**	4.58	7.73	**10.76**	7.10	8.93
40+20	9.77	4.94	7.36	8.22	6.55	7.39
40+10	6.18	1.19	3.69	5.22	4.54	4.88
20+10	6.73	0.56	3.65	7.23	5.99	6.61
Mean	8.38	2.18		7.85	6.04	
Source of variation	CD	SE(m)		CD	SE(m)	
pH	0.09	0.31		0.06	0.02	
Concentration (C)	0.13	0.04		0.09	0.03	
pH X C	0.18	0.06		0.13	0.04	

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Table 3 Mycelial yield (g/100mL) at 19ºC with different concentrations of dextrose and peptone

Concentration (dextrose+peptone) (g/L)	**19ºC**		**Mean**
	pH 9	**pH 7**	
30+15	0.00	6.25	3.12
30+25	0.00	5.85	2.92
30+5	0.00	8.95	4.47
10+15	0.00	10.07	5.03
Mean	**0.00**	**7.77**	
Source of variation	**CD**	**SE(m)**	
pH	0.06	0.02	
Concentration (C)	0.07	0.03	
pH X C	0.11	0.04	

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5. Nutrient Removal by Weeds in Different Crop Establishment Methods and Weed Management Practices

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Keywords: Nutrient removal by weeds; Rice establishment methods; Weed management practices

1. Introduction

As one of the prime food crops, rice is consumed by more than half of the world population, providing around 20% of the world's dietary energy supply. It also plays a pivotal role in food security, accounting for about more than 42% of food production. The System of Rice Intensification (SRI) is a novel method of transplanting rice cultivation wherein the maximum exploitation of the rice genetic potential of the rice cultivars could be achieved by providing a congenial environment for appropriate crop growth to enhance crop productivity and monetary returns. The chemical method of weed control is one of the alternative ways to reduce the density of weeds in rice crop. Keeping in view the above facts, the present study was undertaken to evaluate the nutrient concentration and uptake by weeds under different crop establishment methods and weed management practices.

2. Materials and methods

The experiment was conducted in a split plot design with three replications. The treatment consisted of five establishment methods as main treatments, namely, M_1: Direct dry seeded rice in dry condition, M_2: Drum seeded rice, M_3: SRI transplanting, M_4: Machine transplanting, M_5: Conventional transplanting, and six weed management practices as sub-treatments, namely, S_1:Unweeded control, S_2: Two hand weeding on 20 and 40 DAT/DAS, S_3: Application of pre-emergence herbicide bensulfuron methyl 0.6%+pretilachlor 6% GR @ 10 kg/ha on 3 DAT/7 DAS+h and weeding on 40 DAT/DAS, S_4: Application of pre-emergence herbicide pretilachlor 6%+pyrazosulfuron-ethyl 0.15% GR@ 10 kg/ha on 3 DAT/7 DAS+h and weeding on 40 DAT/DAS, S_5: Application of pre-emergence herbicide bensulfuron methyl 0.6%+pretilachlor 6% GR @ 10 kg/ha on 3 DAT/7 DAS+application of post-emergence herbicide bispyribac sodium 10% SC @ 200 mL/ha on 20 DAT/DAS, S_6: Application of pre-emergence herbicide pretilachlor 6%+pyrazosulfuron-ethyl 0.15% GR@ 10 kg/ha on 3 DAT/7 DAS+application of post-emergence herbicide bispyribac sodium 10% SC @ 200 mL/ha on 20 DAT/DAS.

3. Results and discussion

Regarding direct dry seeding of rice (M_1) treatment and also the direct seeding of germinated wet seeds with drum seeder (M_2) treatment, the beneficial effects of transplanting shock like vigor crop growth resulted through the triggered productivity of growth promoting hormones and the enzymes could not be realized. Among the weed management strategies test verified, the pre-emergence (PE) application of premixed pretilachlor 6%+ bensulfuronmethy l0.6% GR @ 10 kg/ha on 3 DAT/7 DAS+post-emergence (PoE) application of bispyribac sodium 10% SC @ 200 mL/ha on 20 DAT/DAS (S_5) resulted with minimum nutrient uptake by weeds. Pretilachlor is the commonly used pre-emergence herbicide for the management of weed species in rice. However, continuous adoption of aggressive rice-based intensive cropping sequences with indiscriminate scheduling of fertilizer nutrient and irrigation regimes might favor the growth of luxurious growth and enhance the bulk accumulation of weed seed reserve in soil profile which in turn offer menace to the succeeding crops (Chauhan and Johnson,2009). The maximum values of residual soil N, P, and K are documented with the SRI system (M_3) of rice transplanting and it was followed by mechanical transplanting (M_4). Among the rice establishment methods evaluated, the SRI system of transplanting (M_3) significantly restricts the removal of nutrients by weeds at all the growth stages of the crop in the year of study. Similarly, the PE application of premixed pretilachlor 6%+bensulfuron methyl 0.6% GR @ 10 kg/ha on 3 DAT/7 DAS+PoE application of bispyribac sodium 10% SC @ 200 mL/ha on 20 DAT/ DAS (S_5) minimized the removal of nutrient by weeds at all the stages of crop growth in the year of study.

Table 1 Effect of different rice establishment methods and weed management strategies on N, P, and K removal (kg/ha) by weeds in rice during *Kuruvai* 2020

	30 DAT/DAS			60 DAT/DAS		
Treatments	**N**	**P**	**K**	**N**	**P**	**K**
Establishment						
methods	22.21	3.58	13.42	22.36	4.07	11.83
M_1	21.24	3.45	12.54	21.74	3.84	1088
M_2	14.64	3.17	8.85	18.94	3.25	8.49
M_3	17.49	3.35	9.87	20.29	3.53	9.41
M_4	17.70	3.39	9.91	20.59	3.58	9.59
M_5	1.36	0.08	0.48	0.76	0.14	0.49
SEd	2.87	0.18	1.02	1.60	0.31	1.04
CD (p=0.05)						
Weed managemen	49.88	6.35	26.45	86.05	703	42.13
practices	13.35	2.95	8.35	8.70	3.23	4.32
S_1	12.08	2.75	7.79	7.49	2.88	3.39
S_2	15.14	3.19	8.92	10.00	3.67	5.36
S_3	10.66	2.53	6.92	6.19	2.55	2.49
S_4	10.79	2.56	7.07	6.25	2.58	2.54
S_5	0.67	0.09	0.34	0.60	0.15	0.40
S_6	1.40	0.20	0.73	1.27	0.32	0.85
SEd						
CD (p=0.05)						

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6. Impact of Erosion Control Modules on Physical Attributes of Clay Loam Soil in Lower Shivaliks of District Kathua of Jammu

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Keywords: Bulk density; Erosion control modules; Infiltration rate; Maximum water holding capacity

1. Introduction

Land degradation and its potential causes on a worldwide basis are challenging the economic and social well-being of the present and future generations by declining the productivity of croplands and rangelands (Keno and Suryabhagavan, 2014). Soil erosion is considered the main cause of land degradation. Although the problem persisted on the earth for a longer period, it has become severe in recent times due to increased man-environment interactions (Rasool *et al.*, 2014). Most people in developing countries are dependent completely on agriculture for their livelihood, so it has been identified as a major threat to the sustainability of agriculture and the economy of nations (Gemechu, 2016). Continued maintenance of fertile soil is therefore essential to meet basic human needs. Therefore, different erosion control modules are necessary to implement in these areas to limit the soil loss to a tolerable limit. The different erosion control modules are designed to intercept sediments, reduce runoff velocity, and facilitate infiltration of runoff water. Besides this, these also have a role in improving different soil physical attributes and nutrient status of the soil. Thus this paper aims to assess the impact of erosion control modules on soil physical attributes.

2. Materials and methods

The study was conducted in the Merth village of the district Kathua. The total area of the investigated watershed was 24.8 acres. The experiment was laid out on a catchment that exhibited clay loam texture and a 3–6% slope gradient. The various erosion control modules employed in maize–wheat cropping system include terrace farming, perimeter runoff control, cover crop (black gram, *var.* Uttara), agrostological measures (Bhabar, Khus-khus, Bermuda grass, Vegetable hummingbird, Elephant grass), and overgrazing prevention. The composite soil samples were collected randomly from the watershed area under different erosion control modules by using GPS. The collected soil samples were then air-dried, mixed well, and passed through a 2 mm sieve for the analysis of selected soil physical attributes, that is, particle density. Infiltration rate and bulk density data, on the other hand, were taken directly from the site.

The result shows that the mean value of bulk density under various erosion control modules was highest in overgrazing prevention (1.40 g/cm) followed by perimeter runoff control, terrace farming, and contour plowing and was lowest in cover crop (1.33 g/cm^3). The highest value of bulk density in overgrazing prevention may be attributed due to low clay content and organic matter. The decrease in bulk density in cover crop might be due to the subsequent effects of reduced soil loss through erosion and the addition of organic matter through plants. The infiltration rate also gets significantly affected by erosion control modules. The mean value of infiltration rate was highest in cover crop and lowest in overgrazing prevention.

Table 1 Methods employed for the determination of various soil physical attributes and their initial values

Parameters	Methods	Initial values
Bulk density (g/cm^3)	Core sampler method	1.38
Particle density (g/cm^3)	Pycnometer	2.63
Infiltration rate (cm/h)	Mini disk infiltrometer	2.01

3. Results and discussion

Table 2 Impact of erosion control modules on soil physical attributes in clay loam soil

Erosion control modules	BD (g/cm^3) (Mean±S.E.)	PD (g/cm^3) (Mean±S.E.)	Infiltration rate (cm/h) (Mean)
Cover crop	1.33±0.02^e	2.62±0.01^a	7.05
Agrostological measures	1.35±0.03^d	2.62±0.01^a	6.10
Terrace farming	1.38±0.02^b	2.63±0.01^a	5.25
Contour plowing	1.38±0.02^b	2.62±0.01^a	5.20
Perimeter runoff control	1.37±0.02^c	2.62±0.01^a	4.75
Overgrazing prevention	1.40±0.03^a	2.62±0.01^a	2.75

Note: Means with the same letter are not significantly different.

The highest infiltration rate under cover crop and other erosion control modules was due to the addition of organic matter, which in turn increased the total pore space of the soil. It might also be due to the loosening of the surface soil due to the lateral spread of the roots. No significant impact of above-mentioned erosion control modules was observed on particle density because particle density basically depends upon the mineralogical composition of the soil and excludes pore spaces. Particle density theoretically can be changed, but, in practical terms, it needs an enormous amount of organic carbon/biomass addition along with the addition of heavy minerals.

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7. A Study of Value Chain of Kinnow in Punjab

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Keywords*: Kinnow growers; Marketing efficiency; Producer's share; Value chains*

1. Introduction

In Punjab kinnow is mostly grown in Fazilka, Bathinda, Hoshiarpur, and Shri Muktsar Sahib districts which together account for more than 80% of the total kinnow area. Kinnow accounts for 53.35 thousand hectares area with production of 1254.32 thousand metric tonnes, of which Fazilka being the south-western district and Hoshiarpur being the sub-mountainous region covered 32.0 and 5.67 thousand hectares area with 768.80 and 130.89 thousand metric tonnes production, respectively. The value chain of kinnow involved different intermediaries such as preharvest contractors, wholesalers, commission agents, processors, and retailers. Under the existing marketing system, before reaching the consumers, kinnow passes through a long chain of intermediaries due to which producers get a small share of the consumer's rupee. According to the research, the channel with a smaller number of middlemen was most efficient from a marketing perspective but the value chain with more intermediaries has a significant financial linkage (Yogi, 2019). With this background, this study was carried out to analyze the value chain and to suggest the policy implications for the improvement of marketing efficiency of kinnow.

2. Materials and methods

The present study was conducted in Fazilka and Hoshiarpur districts in 2020-21. Multistage random sampling technique was followed; at the first stage, one block from each district, that is, Abohar from Fazilka and Bhunga from Hoshiarpur, was selected at random. Two villages from each selected block were chosen randomly and 20 kinnow growers were selected from each selected village. One important fruit market in the state, two local markets, 15 whole salers and 15 retailers were also selected in order to study the marketing practices adopted in the study area.

3. Results and discussion

Value chain of kinnow

The value chain describes the arrival of kinnow from producer to consumer through various marketing agencies which play a significant role in increasing the value of the produce through different activities such assorting, waxing, grading, and marketing.

The important marketing channels followed by producers in the Fazilka district are as follows:

I. Producer–preharvest contractor–wholesaler–retailer–consumer
II. Producer–wholesaler–retailer–consumer
III. Producer–retailer–consumer
IV. Producer–consumer
V. Producer–processing unit–consumer

Channel-wise marketing cost, margin, and share in consumer's rupee of different intermediaries

Table 1 shows that in the channel I the largest difference was found between the selling price, of producer (Rs 997/q) and the purchase price of consumer (Rs 2880/q) in Ludhiana market followed, by the channel II. The price spread was found minimum in channel IV (i.e., Rs 99/q). In Acharya's method, the marketing efficiency came to be higher in channel IV, and hence this channel was more efficient than the other existing channels.

Table 1 Price spread analysis of kinnow in different channels in Fazilka, Punjab, 2020-21 (Rs/q)

Particulars/Channels	I	II	III	IV
Net price received by the producer	997 (34.6)	1240 (55.1)	1309 (58.2)	1351 (93.2)
Marketing costs of producer				
Picking, grading, and filling	–	58 (2.58)	58 (2.6)	58 (2.6)
Packing material	–	25 (1.1)	25 (1.1)	25 (1.1)
Transportation	–	28 (1.2)	28 (1.2)	0
Loading	–	15 (0.7)	15 (0.7)	0
Spoilage	–	15 (0.7)	15 (0.7)	16 (0.7)
Subtotal	–	141 (6.3)	141 (6.3)	99 (4.4)
Purchase price of PHC	997 (34.6)	–	–	–
Costs of PHCs				
Watch and ward	30 (1.0)	–	–	–
Picking, grading, and filling	60 (2.1)	–	–	–
Waxing	50 (1.7)	–	–	–
Packing material	50 (1.7)	–	–	–
Transportation	90 (3.1)	–	–	–
Loading	15 (0.5)	–	–	–
Spoilage	18 (0.6)	–	–	–
Subtotal	313 (10.9)	–	–	–
Net margin of PHCs	440 (15.3)	–	–	–
Purchase price of wholesaler	1750 (60.8)	1381 (61.4)	–	–
Costs of wholesaler				
Market fee @2%	36 (1.3)	28 (1.2)	–	–
RDF@2%	36 (1.3)	28 (1.2)	–	–
Commission charges @5%	88 (3.0)	69 (3.1)	–	–
Quantity loss	35 (1.2)	28 (1.2)	–	–
Subtotal	195 (6.8)	152 (6.7)	–	–
Wholesaler's margin	356 (12.3)	217 (9.6)	–	–
Retailer's purchase price	2300 (79.9)	1750 (77.8)	1450 (64.4)	–

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Particulars/Channels	I	II	III	IV
Costs of retailer				
Transportation	25 (0.9)	25 (1.1)	24 (1.1)	–
Labor charges	30 (1.0)	28 (1.2)	28 (1.2)	–
Polythene bags	50 (1.7)	50 (2.2)	50 (2.2)	–
Market fee @2%	–	–	29 (1.3)	–
RDF@2%	–	–	29 (1.3)	–
Commission charges @5%	–		73 (3.2)	–
Losses	46 (1.6)	35 (1.5)	30 (1.3)	–
Miscellaneous	30 (5.0)	25 (1.1)	25 (1.1)	–
Subtotal	181 (6.3)	163 (7.2)	287 (12.8)	–
Retailer's margin	399 (13.9)	337 (14.9)	513 (22.8)	–
Consumer's price	2880 (100)	2250 (100)	2250 (100)	1450 (100)
Producer's share in consumer's rupee	34.60	55.11	58.2	93.2
Price spread	1803	1010	941	99
Marketing efficiency	0.70	1.20	1.39	13.7

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8. Diversity of Lycaenid (*Lepidoptera: Glossata*) Butterflies of Tamil Nadu India

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Keywords: Butterflies; Blues; Diversity index; Lycaenidae; Richness

1. Introduction

The Lycaenidae, which are blues, coppers, hairstreaks, metalmarks, and related butterflies, are the most diverse and classified under the superfamily of Papilionoidea. They comprise between 30% and 40% of all butterfly species and considered as world's smallest butterflies. They are an important part of biodiversity and ecologically vital due to the role they play in the food chain and act as bioindicators of environmental variation and quality that reflect a particular suite of ecological conditions or indicate broader effects of environmental changes. However, there is a lack of understanding of butterfly diversity and its importance in conservation among the public. The present research was carried out to record the lycaenid butterfly species from selected localities of Tamil Nadu using various methods and to monitor the status and abundance.

2. Materials and methods

An intensive survey was made during 2017-18 to record the lycaenid butterflies from selected 12 districts of Tamil Nadu. The survey area covered the localities with plains, barren lands, cropped areas, hilly tracts, and forest covers. The study area was surveyed once a month and the data documented the Lycaenidae diversity and its abundance based on the observation of the individual species or by using photographic documentation. The hand netting and line transect count methods were followed to determine the butterfly abundance (Pollard and Yates, 1993) following the Tamil Nadu State Environment Policy 2017. Hand netted butterflies were identified and released in the place of capture.

3. Results and discussion

The results revealed that a total of 2874 butterflies were recorded under four subfamilies of Lycaenidae in the study area. Among the subfamilies, Polyommatinae was found with a maximum number of individuals (1819), followed by Theclinae (884) and Curetinae (98). Out of 36 genera recorded under four subfamilies in the study area, Polyommatinae was found with a maximum number (22) of genera, which account for 61.10%, followed by Theclinae (11) with a share of 30.50%. Polyommatinae was observed with a maximum number (28) of species and account for 62.20% share followed by Theclinae (14) with a share of 31.10% out of 45 species recorded. Based on the abundance, a maximum of 18 species were found as less common followed by 17 species as common. Nine species of lycaenids were observed as very common. Only one lycaenid species, that is, Apefly, was spotted in the study area as rare. Among the 12 selected districts surveyed for lycaenid butterflies, Coimbatore district was recorded with a maximum number of species (41) followed by Namakkal (40) and Villupuram (39). Butterfly population and weather parameters had a positive significant correlation with minimum temperature, relative humidity, and rainfall while a negative correlation with maximum temperature. The results corroborate with Hussain *et al*. (2011) who found that an increase in temperature during summer and an increase in relative humidity during the rainy season and winter influenced the population of butterflies. The maximum number of butterflies (43) was witnessed during December month, followed by November (42) and October (41), while the least number of butterflies (31) were observed during May month. The maximum Shannon-Wiener diversity index (3.59) was recorded maximum from Coimbatore followed by Namakkal (3.58). The index was found least in Kanyakumari and Tiruvannamalai with 3.33 and 3.27, respectively. The evenness index was maximum in Vellore and Thanjavur with 0.98 each followed by Cuddalore, Namakkal, Tiruvannamalai, Villupuram, and Kanyakumari with 0.97. The generic richness was 7.10 in Namakkal followed by Coimbatore (7.04). The least generic richness was observed from Tirunelveli (5.46) (Table 1). Richness represents the more species present in the sample. Rathika *et al.* (2018) reported that species richness and evenness increase indicate the increase of diversity of the particular locality. Lycaenids were diversified in the study area and had multiple dimensions as a predator (Apefly – *Spalgis epius*), pest (Pea blue- *Lampides boeticus* and Gram blue – *Euchrysops cnejus*), pollinator (Common Pierrot – *Castalius rosimon*; Striped Pierrot – *Tarucus nara*), and also their protective behaviours by having mutualistic association with ants. *S. epius* is a potential predator of mealybug pests of various crops and its incorporation into the IPM programme will lead to minimising the pesticide load on crops and also increasing the yield of crops by maintaining the population of mealybugs under control. Further, they are successful in reproduction with their behaviours like puddling and changing their forms according to the seasons for survival. Hence, this group of butterflies should be conserved to maintain their diversity to balance the ecosystem and environment.

Table 1 Diversity indices and evenness of lycaenid butterflies observed from selected localities of Tamil Nadu during 2017–2018

Study area	Shannon-Wiener diversity index	Evenness index	Generic richness
Cuddalore	3.45	0.97	5.99
Nagapattinam	3.52	0.90	6.54
Thanjavur	3.42	0.98	6.04
Namakkal	3.58	0.97	7.1
Salem	3.40	0.96	6.02
Coimbatore	3.59	0.96	7.04
Vellore	3.45	0.98	6.13
Tiruvannamalai	3.44	0.97	5.89
Villupuram	3.56	0.97	6.85
Madurai	3.51	0.96	6.99
Tirunelveli	3.27	0.96	5.46
Kanyakumari	3.33	0.97	5.49

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9. Incidence of Bee Viruses Infecting *Apis mellifera* Linnaeus Colonies in Jammu and Kashmir

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Keywords: *A. mellifera*; Incidence; Viruses

1. Introduction

A. mellifera (European honey bee or Western honey bee) is a species of crucial economic, agricultural, and environmental importance. Although the native range is large and diverse, spanning Europe, Africa, and Middle East (Han *et al*., 2012), it has now spread across the entire world due to large-scale adoption owing to its economic importance. *A. mellifera* has been used for honey production and pollination services for a long time. The honey bee population experienced losses worldwide due to unknown causes. Viruses are one of the major threats to the health and well-being of honey bees. To date, 24 viruses have been reported to infect different developing stages of honey bees, including eggs, larvae, pupae, and adults. Jammu and Kashmir is one of the most important beekeeping areas in India. The rich biodiversity across various geographical features offers great potential for migratory as well as stationary beekeeping. The presence of various diseases, predators, and pests, impairing the health and normal working of *A. mellifera*, is the major problem of beekeeping in Jammu and Kashmir. The present study was undertaken to assess the prevalence of different viral diseases of *A. mellifera* in Jammu and Kashmir.

2. Materials and methods

Samples of suspected virus infected *A. mellifera* larvae and adults were collected from beekeepers' apiaries in four selected districts (Jammu, Samba, Ramban and Udhampur) as well as Sher-e-Kashmir University of Agricultural Sciences & Technology-Jammu apiary. After completion of amplification, the RT-PCR product (5 µL) mixed with 5 µL of gel loading dye was loaded on 2% agarose gel which was electrophoresed in 1X TBE buffer at 100 V for 30–45 min. DNA marker (100 bp DNA ladder, Thermo Fisher Scientific) was loaded in one well for size comparison. Before run, the gel was stained in ethidium bromide (0.5 mg/µL) and viewed under a UV transilluminator and photographed. The incidences of viral diseases were recorded. The severity of the disease was calculated by using the following formula:

$$\text{Per cent colony infection in the apiary} = \frac{\text{Number of diseased colonies}}{\text{Total number of colonies}} \times 100$$

3. Results and discussion

The data presented in Table 1 indicated the confirmation of Israeli acute paralysis virus (IAPV), Kashmir bee virus (KBV), sacbrood virus (SBV), and Thai sacbrood virus (TSBV) in diseased samples of *A. mellifera* through RT-PCR technique. Specific primers for different viruses confirmed the presence of the virus in samples of different districts, Jammu, Samba, Ramban, and Udhampur. The primer pairs of different viruses produced clear and distinct bands of molecular size approximately 110, 122 and 119 bp for IAPV, KBV, and SBV, respectively. The average cycle threshold (Ct) values of IAPV, KBV, and SBV amplification were 26.65±1.03, 17.35± and 28.78±4.01, respectively. Thai sacbrood virus was not detected in any of the samples collected from the four districts. Israeli acute paralysis disease incidence range varied from 8.33% to 21.42%. Kashmir bee disease incidence range varied from 5.71% to 28.33%. Sacbrood disease incidence range varied from 8.0% to 18.75%. IAPV, KBV and SBV diseases incidence range varied from 0–6.25%, 0–3.77% and 0–9.43%, respectively, in the apiary at SKUAST-J, Chatha. RT-PCR technique is valid for the study of Kashmir bee virus (KBV) and sacbrood virus (SBV) as reported by Berenyi *et al.* (2006). Cagirgan and Yazici (2020) also detected the Israeli acute bee paralysis virus (IAPV), deformed wing virus (DWV), sacbrood virus (SBV) and Kashmir bee virus (KBV) with multiplex RT-PCR (mRT-PCR). The results also confirm the simulation results reported by Ward *et al.* (2007) who developed a real-time polymerase chain reaction (RT-PCR) assay for specific detection of Kashmir bee virus (KBV) which can be successfully amplified from different life stages of honey bees.

Table 1 Incidence of IAPV, KBV, SBV and TSBV diseases in the different areas of the Jammu region

District	Location	Number of apiaries surveyed	Number of colonies per apiary	Number of infected colonies				Percent colony infection			
				IAPV	KBV	SBV	TSBV	IAPV	KBV	SBV	TSBV
Jammu	Chatha	1	70	7	4	11	0	10.00	5.71	15.70	0.00
	R. S. Pura	1	60	10	14	6	0	16.70	25.30	10.0	0.00
Ramban	Digdol	1	150	17	11	12	0	11.30	7.33	8.00	0.00
	Dalwah	1	80	15	17	15	0	18.70	21.20	18.70	0.00
Samba	Purmandal	1	80	7	14	7	0	8.75	17.50	8.75	0.00
	Vijaypur	1	60	5	17	8	0	8.33	28.30	13.30	0.00
Udhampur	Sudhmahadev	1	70	15	11	10	0	21.40	15.70	14.20	0.00
	Dabrah	1	30	4	5	5	0	13.30	16.60	16.60	0.00
Total		8	600	80	94	73					

IAPV = Israeli acute paralysis virus, KBV = Kashmir bee virus, SBV = Sacbrood virus, and TSBV = Thai sacbrood virus.

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10. Comparative Analysis of Phytochemicals in Peel and Pulp of Green Fruits of Wild Pomegranate

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Keywords: Fruit waste; Secondary metabolites; Wild pomegranate

1. Introduction

Plants produce a large number of secondary metabolites in response to varying environmental conditions that help them to adapt and cope with stressful constraints during changing environments. Wild pomegranate (*Punicagranatum* L.) belonging to the family Punicaceae grows in the western Himalayas, including Jammu and Kashmir. Its peel and pulp considered agro-waste can be investigated for bioactive metabolites in order to develop new drugs (Chaouch and Benvenuti, 2020).

2. Materials and methods

Green wild pomegranate fruits were collected from five different altitudes (755–5100 mt above sea level). Peel and pulp from the fruits were separated, dried under shade, powdered, and then their methanolic extracts were prepared. The extracts were quantified for the presence of various phytochemicals. The phenolic content of both extracts from green fruit was quantified as per the protocol of Khoddami *et al*. (2013) while the flavonoid content was determined by the aluminium chloride method.

3. Results and discussion

On comparing the peel and pulp of green fruits, variation was observed in secondary metabolites among the fruits collected from the different altitudes. However, among different altitudes, the highest metabolite content was observed both in the peel and pulp of green fruits collected from Dheraki Gali. On comparing the variation between peel and pulp, it was observed that peel has higher secondary metabolites as compared to pulp in fruits collected from all the five altitudes, which might be due to more exposure of peel, being the most exposed part of the fruit,to various environmental stress factors. Pulp extracts from Dheraki Gali (4100 mt), which is located at a high altitude, showed high phenolic content (85.3±3.02 mg GAE/g extract) as well as flavonoid content (171.1±6.73 mgQE/g extract), followed by Mendhar (981mt), as compared to extracts from fruits collected from Budhal and Udhampur, both at low altitudes (Table 1). However, on comparing metabolite content, it was observed to be more in the peel as compared to pulp. This could be due to enhanced UV-B radiations and low temperature present at higher altitudes, thus causing more accumulation of metabolites (Yavas *et al*., 2020). Thus, fruit peel and pulp waste, being rich in bioactive compounds, could be utilized for food and non-food applications. Apart from fruit peel and pulp, waste can be used as a natural ingredient for cosmetics, medicines, packaging materials, and biofuels.

Table 1 Effect of altitude on secondary metabolite production

Place of collection	Green fruits (Peel)		Green fruits (Pulp)	
	Phenolics (mgGAE/g extract)	Flavonoids (mgQE/g extract)	Phenolics (mgGAE/g extract)	Flavonoids (mgQE/g extract)
DherakiGali	106.3±4.62	205.3±9.17	85.3±3.02	171.1±6.73
Patnitop	83.4±1.82	166.1±8.27	67.0±3.02	135.3±11.27
Mendhar	92.1±5.36	195.2±9.07	74.0±5.42	142.8±2.32
Buddhal	76.4±3.40	120.7±3.17	55.7±7.43	112.1±10.18
Udhampur	63.1±3.24	98.1±12.3	40.5±9.14	89.0±16.18

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11. Soil Microbial Community for Greenhouse Gas Emission (CH_4) Under Various Vegetations from the Intertidal Zone of the Coastal Area

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Keywords: *Coastal ecosystem; Greenhouse gas emission; Intertidal zone; Soil microbial community*

1. Introduction

The longest coastline in India is in Gujarat (more than 1650 km). Biogeochemical processes often occur in the intertidal zone, which is exposed to air at low tide and covered with seawater at high tide. Gujarat coastline experiences tide variation ranging from 3 to 10 m which provides the good experimental condition for methane cycling microbes. The tidal zone is rich in mangroves and halophytes, while mudflats are widespread. High flooding creates an anaerobic condition which favours methanogenesis. As part of methanogenesis, methyl-coenzyme M reductase (mcrA) catalyzes the final step of methane production, whereas particulate methane monooxygenase (pmoA) is responsible for methane oxidation. During anaerobic respiration, dissimilatory sulphate reductase (dsrA) reduces sulphate and outcompetes methanogens for CO_2/H_2, formate, and acetate. There is a wide use of mcrA, pmoA, and dsrA genes to quantify methanogens, methanotrophs, and sulphate reducers, respectively. The present study investigates the correlation between the distribution of functional genes in coastal wetlands (mangroves, halophytes, and mudflats) and their soil characteristics.

2. Materials and methods

Depth-wise sediment samples (0–100 cm) were collected from the intertidal zone of Bhavnagar, Gujarat with different vegetations (mangrove, halophyte, and mudflats). Samples were analyzed for various physicochemical characteristics and nutrient levels.

Metagenomic DNA extraction

Metagenomic DNA from soil was extracted with a FastDNA™ SPIN kit for soil (MP Biomedicals, USA) using the FastPrep® instrument (MP Biomedicals, USA). DNA was isolated from 0.5 g of fresh soil according to the manufacturer's procedure with slight modification (Kumar *et al*., 2022). DNA was eluted out in double distilled autoclaved water (50 µL) in a collection tube. The integrity of DNA was checked on 0.8% (w/v) agarose gel and quantification of DNA was done using Nanodrop (instrument name). The extracted DNA was stored at –20°C for further use.

Determination of gene copy number using real-time polymerase chain reaction (qPCR)

Gene copy number for bacterial 16S rRNA gene, archaeal 16S rRNA gene, *mcrA*, *pmoA*, and *dsrA* genes in metagenomics DNA was determined using qPCR (CFX 1000, Bio-rad, USA). PCR reaction mixture contained 10 µL of QuantiFast SYBR green (Qiagen, USA), 0.2 µL of 20 µM gene-specific forward and reverse primers, and 1 µL of template DNA, and total volume (20 µL) was maintained using RNase-free water. Primer sets used in this study were bacterial 16S rRNA gene: 338F and 518R; archaeal16S rRNA gene: ARC344 F and ARC518 R; *mcrA*: mlas F and mcr-rev; *pmoA*: A189 F and A682 R; and *dsrA*: DSR1 F and RH3-dsr R. The standard curve for respective genes was prepared using 10-fold serial dilutions of purified PCR product and copy number for each gene was calculated using the comparative CT method (Videmšek *et al*. 2009).

3. Results and discussion

In comparison to halophyte soils, mangrove soils had higher *pmoA* copy numbers, and similarly the copy number of *mcrA* was significantly highest in mangrove soils at all depths while barren and halophytesoils contained similar numbers. The abundance of *dsrA* was also observed to be the highest in mangrove soil while lower in the barren and halophyte soils. The *pmoA*/*mcrA* ratio was significantly higher in barren and halophyte soil at all depths compared to mangrove soils. The ratio of *dsrA*/*mcrA* was significantly higher at 0–20 and 80–100 cm in the mangrove soils; however, at other depthsall soil samples differed non-significantly. The abundances of bacterial and archaeal 16S rRNA, *pmoA*, *mcrA*, and *dsrA* were positively and significantly correlated with moisture, electrical conductivity, organic carbon, dissolved organic carbon, NH_4^+, P, K, Na and SO_4^- while negatively correlated with pH of the soil (Table 1).

Table 1 Correlation between soil characteristics and abundance of functional genes

Soil characteristics	Functional genes				
	Bacterial 16S	**Archaeal 16S**	***pmoA***	***mcrA***	***dsrA***
Moisture	0.688	0.599	0.624	0.864	0.901
p value	0.000	0.000	0.000	0.000	0.000
EC	0.594	0.514	0.469	0.646	0.631
*p*value	0.000	0.000	0.001	0.000	0.000
pH	-0.707	-0.598	-0.576	-0.510	-0.630
p value	0.000	0.000	0.000	0.000	0.000
OC	0.850	0.752	0.697	0.787	0.847
p value	0.000	0.000	0.000	0.000	0.000
TOC	0.521	0.498	0.475	0.748	0.745
p value	0.000	0.000	0.001	0.000	0.000
NH_4-N	0.600	0.548	0.522	0.879	0.899
p value	0.000	0.000	0.000	0.000	0.000
NO_3-N	0.112	0.055	0.076	-0.401	-0.396
p value	0.466	0.720	0.621	0.006	0.007
P	0.591	0.492	0.482	0.396	0.379
p value	0.000	0.001	0.001	0.007	0.010

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K	0.442	0.472	0.447	0.591	0.607
p value	0.002	0.001	0.002	0.000	0.000
Na	0.544	0.465	0.463	0.644	0.663
p value	0.000	0.001	0.001	0.000	0.000
SO_4-S	0.700	0.652	0.565	0.734	0.732
p value	0.000	0.000	0.000	0.000	0.000

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12. Round the Year Fodder Management Practices of Dairy Farmers in Subtropics of Jammu Region of India

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Keywords: Fodder; Livestock; Management

1. Introduction

According to the 20th livestock census, India has more than 535 million population of livestock, which was only 292 million in 1951 and 519 million in the previous survey of 2012. Although the area under fodder crops is increasing, according to the estimates of the Indian Council for Agricultural Research (ICAR) affiliated National Institute of Animal Nutrition and Physiology (NIANP), the deficit in the requirement and the availability of dry fodder, green fodder, and concentrates during 2015 were to the extent of 21%, 26%, and 34%, respectively. This is likely to increase by 21%, 40%, and 38%, respectively, by 2025. The fodder deficit in India in terms of quantity of dry fodder, green fodder, and concentrates was 104, 221, and 29 MT (million tons) in 2015, which is expected to reach 117, 400, and 40 MT by 2025, respectively. It was found in the previous research studies that 56% of the workforce of the respondent households in the Jammu region was involved in dairy activities. This fact generates the question of how the farmers are managing fodder for livestock during the whole year. Therefore, the present study was conducted to analyze the feeding management practices followed by livestock owners other than cultivated green fodder crops in subtropics of the Jammu region.

2. Materials and methods

Purposive-cum-multistage random sampling technique was employed for the study. Jammu and Kathua districts were selected purposely because Jammu district (7378 ha) has the highest area under fodder crops followed by Kathua district (6624 ha) in the Jammu region. Both these districts collectively contribute about67% of the total area under fodder crops in10districts of the Jammu region. In the Jammu district, one rainfed subdivision and one irrigated sub division were selected purposively. One agriculture zone from each subdivision was selected randomly. In the Kathua district, the Dayalachack subdivision was selected purposively as it was the only subdivision in the district which falls under subtropical climatic conditions. In the Dayalachack subdivision, out of the seven zones, one irrigated subdivision and one unirrigated subdivision were selected purposely. A sample size of 156 respondents was randomly selected. Seventy-nine respondents from unirrigated areas and 77 respondents from irrigated areas were selected for the study.

3. Results and discussion

The result (Table 1) shows that the majority (90%) of livestock rearers feed common grass to livestock during the period from mid-July to mid-September. It was found that the majority (52%) of respondents feed tree leaves to livestock from mid-November to mid-December. The findings conformed with the results of Singh *et al.* (2004) who reported that common grass, dry fodder, concentrates, and tree leaves are used to feed livestock at the time of scarcity. This might be due to the fact that tree leaves serve as the most suited option for the farmers when there is a scarcity of green fodder. The results also revealed that almost all the respondents during the whole year feed concentrates and dry fodder to livestock. The results are in line with the findings of Singh *et al.*(2004) and Sinha *et al.*(2009). Sinha *et al.* (2009) reported that the majority of farmers in the rural area feed dry fodder and concentrates to livestock during the whole year and only 22% of farmers feed tree leaves to livestock. This might be due to the fact that preservation of dry fodder and concentrates is easy and mixing of both roughages and concentrates with green fodder is good for animal health. There was no significant difference in the number of respondents feeding common grass, dry fodder, and concentrates in the unirrigated and irrigated areas, but there was a significant difference (p=0.000) in the number of respondents feeding tree leaves to livestock in unirrigated and irrigated areas; more respondents from the unirrigated area were feeding tree leaves to livestock than respondents in irrigated area.

Table 1 Distributions of respondents based on round year fodder management practices followed by respondents

Month[a] (% farmers)	Common grass	Concentrates	Dry fodder	Fodder tree leaves
Vaisakh (mid-April–mid-May)	22	96	97	7
Jeth (mid-May–mid-June)	29	97	100	0
Harh (mid-June–mid-July)	72	96	100	0
Sawan (mid-July–mid-August)	90	96	100	0
Bhadon (mid-Aug.–mid-Sep.)	90	96	100	4
Assu (mid-Sep.–mid-Oct.)	63	96	100	43
Katak (mid-Oct.–mid-Nov.)	47	97	100	49
Magar(mid-Nov.–mid-Dec.)	26	96	100	52
Poh (mid-Dec.–mid-Jan.)	24	96	99	43
Magh (mid-Jan.-Mid-Feb.)	24	96	99	16
Phagun(mid-Feb.–Mid-March)	22	96	99	4
Chet(mid-March–Mid-April)	22	96	99	0

Note: Division of months according to Vikrami calendar; [a]Multiple response

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13. Ultrasonography in Renal Affections in Dogs

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Keywords: *Dog; Renal failure; Ultrasound; Urinary obstruction*

1. Introduction

Urinary system disorders in dogs are very common and are presented as the most important clinical problem. Renal failure and urinary obstruction are frequently encountered in clinical cases. The initial signs usually go unnoticed until and unless there is enough damage to the nephrons leading to the systemic manifestation of a disease or there is a complete obstruction or marked change in the urination behavior of the patient. Such late presentation requires quicker diagnosis. Early diagnosis and treatment enhance the survival rate and decrease the chances of complications related to renal failure. So the present study was conducted to evaluate the role of ultrasonography in the diagnosis of renal system affections.

2. Materials and methods

The clinical study was conducted in the division of the Veterinary Clinical Complex (VCC) of SKUAST-J from 2017 to 2019. The study included 32 dogs brought to VCC with ahistory of symptoms suggesting renal system affections. The animals were divided into two groups, that is, Gp I included 14 dogs having symptoms of renal failure and Gp II included 18 dogs having urinary obstruction. After recording the proper history and signalment, all dogs were subjected to B-mode ultrasonographic examination using a microconvex probe (D3C20L, 2.5–6.4MHz) and linear probe (D7L40L, 5.0–10.0 MHz) of CHISON i8VET ultrasound machine. The sonographic changes were recorded and ultrasound guided biopsies were taken for final diagnosis, wherever needed.

3. Results and discussions

The average age of dogs of Gp I and Gp II were 7.2 and 5.62 years, respectively. The maximum number of renal failure cases was recorded in the 9–12 years age group, whereas the maximum cases of urinary obstruction were seen in the 3–6 years age group. In Gp I, 57% of the dogs presented were females and 43% were males, whereas in Gp II, 94% were males and only 6% were females. Oburai *et al.* (2015) reported that dogs in the age group of 8–12 years were commonly affected by renal insufficiency and Fromsa *et al.* (2011) reported the median age of dogs suffering from urinary tract calculi as 6 years ranging from 1.5 to 10 years, having predominance in male with a male-female ratio as 20:1.Major renal USG findings of Gp I were increased cortical echogenicity as compared to spleen and liver, hyperechoic foci with weak distal acoustic shadow, poor demarcation of renal pyramids and the renal sinus, decreased corticomedullary differentiation, change in the shape of kidneys, complete loss of architectural detail, and the presence of anechoic areas in renal cortex indicating the presence of renal cysts. Similar changes were also reported by many earlier workers (Kumar *et al.*,2011; Bragato *et al*., 2017). Major USG findings of Gp II were the presence of hyperechoic foci with distal acoustic shadow in the bladder and urethra. The diseases diagnosed on histopathology in Gp I were end-stage kidney disease, chronic interstitial nephritis, chronic glomerulonephritis, granulomatous nephritis, glomerulopathy, pyelonephritis, and polycystic kidney disease. The study concluded that renal failure was more common in aged dogs, whereas urinary obstruction was more in young to middle-aged dogs. The USG was highly sensitive for renal disease diagnosis; however, it was not very specific except in cases of nephroliths and polycystic kidney disease. It was 100 % accurate for the diagnosis of urinary obstruction due to calculi as reported by Tion *et al*. (2015).

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14. Impact of Biophysical Characteristics on the Fuelwood Consumption in Rural Households of North-western Himalayas

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Keywords: *Biophysical; Consumption; Fuelwood; Himalayas; Rural*

1. Introduction

Forests are vital for the existence of mankind on earth. Forests provide us with both tangible and intangible goods and services. Forests are important for soil and water conservation and for meeting the demands of the local population for timber, fuelwood, fodder, and other forest products. Fuelwood is one of the most important sources of energy in developing and underdeveloped countries. Energy generated from fuelwood is the main component of the domestic energy systems of the world, mainly in developing countries. Fuelwood is the primary energy source for cooking and heating for rural households (70%) in developing countries (Parikh, 1980). Fuelwood is preeminently a renewable source of energy whose decentralized nature is particularly suited to the scattered nature of rural habitation and usually makes it possible to obtain the fuel at a very low cost. Forests exemplify a vital component of accessible national and regional biomass supply in rural India. The exploitation of forest biomass is a universal way among forest fringe dwellers for fuelwood consumption.

2. Material and methods

The present investigation entitled 'Impact of Biophysical Characteristics on the Fuelwood Consumption in Rural Households of North-western Himalayas' was carried out during the period 2019–2021. The study was based on the primary survey and data collection through a pretested questionnaire by approaching the villagers representing different age groups and gender also. The survey has been conducted in 146 households on a random basis to obtain the real pattern of information. A house-to-house visit was followed by a field survey as well. The study was based on the primary data collected from the respondents on different aspects, namely, family size, family type, livestock holding, landholding, land use pattern, cropping pattern, and biophysical factors like distance covered by farmers to collect fuelwood, altitude, and so on.

3. Results and discussion

Metaled road distance of the house from nearest state forest and distance of the house from district headquarter had significant contribution in influencing the fuelwood consumption. The *F* value (145.59) showed that all the four biophysical characteristics had contributed significantly to the deviation of the fuelwood consumption. Among the biophysical variables, the distance of a house from the nearest state forest had shown a negatively significant association with fuelwood consumption. Altitude and distance of the house from district headquarter exhibit a positively significant relationship with fuelwood consumption. The results are also in concurrence with the studies of Sanjay and Gupta (2005) who stated that fuelwood consumption increased with an increase in the distance of the house from the district headquarters. The distance of the house from the nearest metaled road has a non-significant relationship with fuelwood consumption. Therefore, it can be concluded that people living in rural areas near forests tend to use more fuelwood for heating and cooking purposes due to the availability of resources. The reason for higher fuelwood consumption in households that are far away from district headquarters can be attributed to the less availability of alternate fuels. The findings are consistent with the reports of Silori (2004) who stated that the per capita daily and seasonal consumption of fuelwood declined with declining altitude.

Table 1 Regression analysis of biophysical characteristics with the domestic fuelwood consumption ($N = 146$)

Household variables (code)	Coefficients (ß)	S.E.	*t* value	Sig	95% confidence interval for ß		Collinearity statistics	
					Lower bound	Upper bound	Tolerance	VIF
Altitude (X_1)	5.31	2.37	2.24*	0.002	–1.374	31.211	0.392	2.55
Distance of house from the nearest metalled road (X_2)	0.223	0.254	0.87	0.380	–0.278	0.726	0.11	8.48
Distance of house from nearest state forest (X_3)	–0.1265	0.0424	–2.98*	0.003	-0.380	0.126	0.36	2.74
Distance of house from district headquarter (X_4)	0.198	0.056	3.53*	0.001	0.086	0.309	0.69	1.43

*Significant at a 5% level of probability.

$ß_0 = 9.662$, $F = 145.59^*$, $R^2 = 0.805$, Multiple $R = 0.897$, Adjusted $R^2 = 0.800$

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15. Effect of Salinity on Biomass of Different Citrus Rootstock Seedlings

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Keywords: Citrus; Biomass; Rootstock; Salinity

1. Introduction

Citrus accounting for 12.4% of total fruit crops in India is observed to be sensitive to salinity and is primarily grown in tropical and subtropical climates, which are already vulnerable to salt and drought stress (Simpson *et al*., 2015). Salinity is a result of the accretion of ions of soluble salts which hinders the physiological activities of plants by increasing toxicity and nutritional imbalance, hence deteriorating its quality and productivity. Rootstocks play a vital role in imparting tolerance to salt stress by enhancing antioxidant activities, increasing the concentrations of osmoprotectants, excluding Cl^{-} and Na^{+}, and restricting uptake and/or transport of salts between roots and shoots. Therefore, the present study was planned to investigate the influence of salinity on the biomass of citrus rootstocks, on basis of which salinity tolerance of different rootstocks was evaluated.

2. Materials and methods

The present investigation was carried out at CCS Haryana Agricultural University, Hisar for two consecutive years, that is, 2018–2020, in a completely randomized design (CRD) with three repetitions encompassing nine citrus rootstocks (i.e., Rough lemon, Cleopatra mandarin, Pectinifera, Rangpur lime, Alemow, Volkamer lemon, NRCC-3, NRCC-4, and CRH-12) and five salinity levels (viz. control (0.07), 2.5, 4.0, 5.5 and 7.0 dS/m). Ten seeds/pot for each rootstock were raised in plastic pots filled with 10 kg of dune sand and were also supplied regularly with Hoagland nutrient solution. The salinity levels were developed with aid of different ionic compositions of chloride and sulfate salts. The data on the fresh shoot and root biomass of three-month-old seedlings were measured for three representative seedlings for each replication and for dry shoot and root biomass, samples were oven-dried at 48°C till a constant dry weight and then averaged and expressed in g/plant.

3. Results and discussion

Tables 1 and 2 show that both salinity level and rootstock influenced the fresh and dry shoot and root biomass significantly and observed a gradual decrease in biomass with an increased salinity level (pooled mean of 2 years). At control, the maximum fresh shoot and root (36.5 and 9.7 g/plant) and dry shoot and root (12.3 and 5.0 g/plant) biomass was observed in Rangpur lime, respectively, along with the same fresh and dry root biomass in Volkamer lemon (9.7 and 5.0 g/plant), while the minimum fresh shoot and root biomass (9.2 and 2.7 g/plant) was recorded in Alemow and NRCC-4 and dry shoot and root biomass (2.9 and 1.2 g/plant) was recorded in Pectinifera and Alemow at 7 dS/m, respectively. As salinity levels increased from control to 7 dS/m, a significant reduction in the fresh shoot (37.2%, 37.3%, 37.9%, and 50.5%) and fresh root biomass (16.1%, 16.1%, 25.1%, and 39.8%) and dry shoot (27.5%, 27.9%, 29.7%, and 47.8%) and dry root biomass (27%, 28.2%, 28.4%, and 43.6%) over control was recorded minimum in Rangpur lime, followed by Volkamer lemon and CRH-12, whereas the reduction was found maximum in Pectinifera, respectively.

Table 1 Effect of salinity on fresh shoot and root biomass in different citrus rootstocks

Rootstock	Salinity level (dS/m)											
	Fresh shoot biomass (g/plant)						Fresh root biomass (g/plant)					
	Control	2.5	4.0	5.5	7.0	Mean	Control	2.5	4.0	5.5	7.0	Mean
Rough lemon	31.6	31.3	29.2	23.3	17.1	26.5	9.3	9.2	9.0	8.3	7.6	8.7
Cleopatra mandarin	16.5	16.2	14.7	12.5	10.2	14.0	7.3	7.2	7.1	6.5	5.8	6.8
Pectinifera	18.9	18.6	16.4	13.0	9.4	15.3	6.4	6.3	5.6	4.8	3.9	5.4
Rangpur lime	36.5	36.2	34.5	30.7	22.9	32.2	9.7	9.6	9.4	8.9	8.1	9.1
Alemow	16.6	16.4	14.3	11.8	9.2	13.6	4.1	4.0	3.9	3.4	2.8	3.6
Volkamer lemon	35.3	35.0	31.5	27.0	22.2	30.2	9.7	9.6	9.4	8.9	8.1	9.1
NRCC-3	28.2	27.8	25.6	22.0	16.4	24.0	7.1	7.0	6.9	6.3	5.4	6.5
NRCC-4	17.4	17.0	15.6	12.7	9.3	14.4	3.8	3.7	3.5	3.1	2.7	3.4
CRH-12	18.1	17.9	16.6	14.4	11.2	15.7	6.7	6.7	6.5	5.9	5.1	6.2
Mean	24.3	24.1	22.0	18.6	14.2		7.1	7.0	6.8	6.2	5.5	
C.D. at 5%	Rootstock = 2.8 Salinity = 2.4 Rootstock × Salinity = 4.5						Rootstock = 0.4 Salinity = 0.3 Rootstock × Salinity = 0.6					

Table 2 Effect of salinity on dry shoot and root biomass of different citrus rootstocks

Rootstock	Salinity level (dS/m)											
	Dry shoot biomass (g/plant)						Dry root biomass (g/plant)					
	Control	2.5	4.0	5.5	7.0	Mean	Control	2.5	4.0	5.5	7.0	Mean
Rough lemon	10.9	10.6	9.4	7.8	6.1	9.0	4.3	4.3	4.0	3.6	3.1	3.9
Cleopatra mandarin	6.3	6.1	5.8	5.1	4.3	5.5	3.7	3.7	3.3	2.9	2.5	3.2
Pectinifera	5.5	5.3	4.7	3.9	2.9	4.5	3.5	3.4	3.2	2.8	2.0	3.0
Rangpur lime	12.3	12.2	11.5	10.5	8.9	11.1	5.0	4.9	4.6	4.1	3.7	4.5
Alemow	5.6	5.4	5.0	4.2	3.0	4.6	2.0	1.9	1.7	1.5	1.2	1.7

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Rootstock	Salinity level (dS/m)											
	Dry shoot biomass (g/plant)						Dry root biomass (g/plant)					
	Control	2.5	4.0	5.5	7.0	Mean	Control	2.5	4.0	5.5	7.0	Mean
Volkamer lemon	11.8	11.7	11.0	9.8	8.5	10.6	5.0	4.9	4.7	4.2	3.6	4.5
NRCC-3	10.2	10.0	9.5	8.3	6.9	9.0	4.0	3.9	3.5	3.1	2.6	3.4
NRCC-4	5.5	5.4	4.7	4.1	3.3	4.6	2.2	2.1	2.0	1.8	1.5	1.9
CRH-12	5.7	5.6	5.3	4.8	4.0	5.1	4.1	4.0	3.8	3.4	2.9	3.7
Mean	8.2	8.1	7.4	6.5	5.3		3.8	3.7	3.4	3.1	2.6	
C.D. at 5%	Rootstock = 0.8 Salinity = 0.7 Rootstock × Salinity = 1.3						Rootstock = 0.4 Salinity = 0.3 Rootstock × Salinity = 0.8					

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16. Performance of Different Fertilizer Schedules and Varieties of Indian Mustard (*Brassica juncea* L.) under Late Sown Conditions of Jammu

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Keywords: *Fertilizer schedules; Indian mustard; Jammu; Late sown varieties*

1. Introduction

Rapeseed and mustard are the major oilseed crops of the Jammu region and are grown in Jammu and Kashmir in an area of more than 51,810 ha (Anonymous, 2020a). The average productivity of the state was 11.49 q/ha in 2017-18, which was below the national average productivity of 14.10 q/ha from an area of 5.98 million ha (Anonymous, 2020b). The lack of new high-yielding varieties of Indian mustard in Jammu has been one of the major reasons for a lower yield in the region. The major *Kharif* crop of the Jammu region is Basmati rice, which is normally harvested in the second fortnight of November, thereby necessitating the identification of a late sown variety of Indian mustard that can be sown after the harvest of Basmati rice crop under irrigated late sown conditions of Jammu region. Therefore, the evaluation of newly developed varieties of Indian mustard at the national level was done for testing its suitability under different fertilizer schedules for finding the optimum fertilizer dose for the realization of the potential yield of new varieties under late sown conditions.

2. Materials and methods

An experiment was conducted at Research Farm, Main Campus, Chatha of SKUAST-Jammu during the *rabi* season of 2019-20. The experiment consisted of 15 treatment combinations that were laid out in a split plot design with five entries, namely, Kranti (national check), DRMR 2017-15, PM 26, RVM 2, and DRMRIC-38, in the main plots, whereas three fertility schedules (100% RDF, 125% RDF, and 150% RDF) were kept in subplots with three replications to find out the most promising entry besides optimum fertility levels and spacing for yield maximization under late sown conditions in the Jammu region. The crop was fertilized with N: P_2O_5: K_2O:S @ 80:40:15:20 kg/ha during the crop growing season. The soil of the experimental area was slightly alkaline (7.1) in soil reaction and was found to be low in available nitrogen (170 kg/ha) and potassium (111 kg/ha) and medium in available phosphorus (15.1 kg/ha). The crop was sown in the first week of November 2019 and was harvested in the first fortnight of April 2020 based on the maturity of different varieties. All the standard packages and practices and procedures were followed during the period of experimentation. The economics of the treatments was calculated using standard formulae based on the prevailing minimum support price of Indian mustard, that is, Rs 4425/- per quintal, whereas the benefit-cost ratio was calculated by dividing net returns by the cost of cultivation of treatments.

3. Results and discussion

The data presented in Table1 revealed that, among the different varieties of Indian mustard, variety DRMRIC-38 (1478 kg/ha) though at par with RVM 2 (1376 kg/ha) variety of Indian mustard recorded a maximum seed yield of Indian mustard compared to other varieties Kranti, DRMR 2017-15, and PM 26. However, DRMR 2017-15 (1281 kg/ha), and PM 26 varieties (1216 kg/ha) were found to be at par with each other. The lowest seed yield was recorded in the national check variety Kranti (943 kg/ha). Among the different fertility levels, a significantly higher increase in yield was recorded in plots with 125% RDF (1297 kg/ha) than 100% RDF (1141 kg/ha), but it was found to be at par with 150% RDF plots (1337 kg/ha). However, the maximum B:C ratio was observed in the DRMRIC-38 variety (2.46) under a fertilizer schedule of 150% RDF (2.05).

Table 1 Effect of different tillage practices and mustard-based cropping systems on yield, yield attributes, and economics in late sown Indian mustard

Treatments	Seed yield (kg/ha)	No. of siliquae/plant	Seeds/siliquae	1000-seed weight	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Varieties							
Kranti	943.33	195.44	12.10	3.36	41,743	22,848	1.21
DRMR 2017-15	1281.11	265.00	16.53	4.32	56,689	37,794	2.00
PM 26	1215.56	251.67	15.64	4.26	53,788	34,893	1.84
RVM 2	1375.56	284.44	17.71	4.85	60,868	41,973	2.22
DRMRIC-38	1477.78	305.78	19.07	5.26	65,392	46,497	2.46
CD (0.05)	164.87	34.88	2.09	0.29	–	–	–
Fertility levels							
100% RDF	1161.33	236.00	14.72	4.07	50,504	32,109	1.75
125% RDF	1317.33	268.67	16.71	4.53	57,407	38,512	2.04
159% RDF	1357.33	276.73	17.21	4.63	59,177	39,782	2.05
CD (0.05)	45.53	9.51	0.59	0.23	–	–	–
Interaction of different entries at the same fertility level	NS	NS	NS	NS	–	–	–
Interaction of different fertility levels at same entries	NS	NS	NS	NS	–	–	–

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17. Analysis-based Information Need Assessment of Buffalo Farmers in Jammu District

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Keywords: *Buffalo farmers; Information needs; Information need assessment*

1. Introduction

Nowadays, livestock rearing is becoming more information oriented. Access to accurate and adequate information is very essential for increasing overall production and productivity. In the whole array of the agricultural system, the most powerful limitation to the farmers is the lack of livestock information. The farmers require various types of information for their day-to-day livestock-related activities but the rural areas of the Union Territory of Jammu and Kashmir lack proper information infrastructure and service centers. It is reported that not more than 5% of the farm households in India are able to access information about animal husbandry, the reason for which is primarily the lack of an efficient livestock extension system in place (Singh *et al*., 2016). The majority of buffalo farmers approach non-formal sources for information on scientific buffalo farming, and sometimes misinformation leads to huge losses to farmers and to animals also. Providing the right information from a credible source will boost the farmers' herd productivity. Designing appropriate policies, programs, and organizational innovations requires understanding farmers' information needs. Therefore, there lies the need to assess the information needs of the farmers.

2. Materials and methods

The study was conducted in the Union Territory of Jammu and Kashmir. Ex post facto and exploratory research design was followed. Multistage sampling plan was used for the present study. Jammu district, the locus of the present study, was selected through purposive sampling, whereas blocks, villages, and respondents were selected through a simple random sampling method. The population of buffalo farmers is more or less equal in all the blocks of the Jammu district; therefore, five blocks, namely, R.S. Pura, Suchetgarh, Miran Sahib, Satwari, and Marh, were randomly selected. From each of the five selected blocks, a comprehensive list of villages was prepared and two villages from each block were selected randomly. Thus, in totality 10 villages were selected from five blocks. A list of farmers practicing buffalo farming was prepared. Twelve respondents were selected from each of these 10 selected villages, thus constituting a total sample size of 120 buffalo farmers for the study.

3. Results and discussion

Information needs of the buffalo farmers were found to be medium with a mean score of 138.07±1.07, indicating that the majority of the respondents (80.00%) had a medium level of awareness about information needs (Table 1). With respect to the overall information needs of farmers (Table 2), the most needed information was about farm credit and marketing (36.75 WMS). These findings were in consonance with Jadeja *et al.* (2019) and Kumar *et al.* (2020). The most needed details under different buffalo rearing practices were found to be information about subsidies (92.50%), information about common zoonotic diseases (90.80%), venereal diseases (84.20%), dung disposal and manure utilization (32.50%), and feeding of the newborn (31.70%). A positive nonsignificant relationship of information needs of buffalo farmers with family type and cosmopoliteness-localiteness was observed. However, a negative significant relation of information needs of buffalo farmers with landholding, occupation, and income from animal husbandry was observed. The relation with age, education, family size, herd size, total income, social participation, mass media, and extension contact was found to be negatively nonsignificant.

Table 1 Distribution of respondents on the basis of the level of information needs

Category	Frequency	Percentage
Low (<127)	10	8.33
Medium (127–149)	96	80.00
High (>149)	14	11.67

Table 2 Distribution of buffalo farmers on the basis of overall information needs

Animal husbandry practices	Total score	Weighted mean score	Rank
Housing and management	2542	28.18	III
Feeding and nutrition	3218	26.82	IV
Breeding and reproduction	4088	34.07	II
Health care practices	2310	19.25	V
Farm credit and marketing	4410	36.75	I

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18. Potential Orthologues for Developing Haploid Inducer Stock in Rice (*Oryza sativa* L.)

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Keywords: Doubled haploids; Orthologue; Rice; Speed breeding

1. Introduction

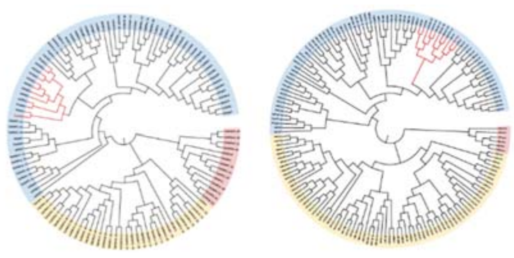
Rice (*O. sativa* L.) is a staple food crop for most of the South-East Asian countries. New varieties with higher yield potential and improved biotic and abiotic stresses are always required. The long varietal development process can be shortened with the use of new approaches such as doubled haploids (DH) and speed breeding. DHs are produced by the chromosomal doubling of haploids usually by colchicine treatment and these haploids can be generated by several methods involving tissue culture. Recently, several genes have been identified in maize for haploid induction ability, namely, *ZmMATL*, *ZmDMP*, and *ZmPLD*. Knocking out these three genes separately or in combination leads to generating haploid induction ability in maize. Moreover, knocking out of *OsMATL* in rice (Yao *et al*., 2018), an orthologue of *ZmMATL*, has been reported to induce haploids. Here, based on phylogenetic and *in-silico* expression analysis, we predict genes that can be employed for haploid induction in rice.

2. Materials and methods

Protein sequences of *ZmMTL*, *ZmDMP*, and *ZmPLD* were derived from Maizegdb (https://www.maizegdb.org). These protein sequences were then used for BLAST analysis using the Phytozome *O. sativa* Kitaake database (https://phytozome-next.jgi.doe.gov/). The gene IDs showing similarity above 40% (Pearson, 2013) were taken for phylogenetic analysis based on their protein sequences. Phylogenetic analysis was performed using MEGA-X software by using the maximum likelihood method with 1000 bootstraps. The phylogenetic tree was drawn with the help of Interactive Tree of Life, an online software (https://itol.embl.de/). Moreover, the putative genes selected based onblast and phylogeny analysis were subjected to *in silco* expression analysis using a rice expression database (http://expression.ic4r.org/faq). Expression data was downloaded in the form of FPKM (fragments per kilobase of exon per million mapped fragments) values for shoot, leaf, panicle, and anther using SRA project ID SRP047482 and SRP039045(http://expression.ic4r.org/faq). Later on, heat maps were drawn using the P heat map package of R studio version 2022.02.3 based on the FPKM values.

3. Results and discussion

OsPLA4 has been already knocked out in rice for haploid induction. Moreover, its phylogenetic and *in silico* expression analysis (23.14) strongly supports it as a candidate gene for haploid induction. To find other possible genes for HI in rice, maize *ZmDMP* and *ZmPLD* were extensively studied using phylogenetic and *in silico* expression analysis. On the basis of phylogenetic analysis, *OsDMP1*(Figure 1A) was nearest to maize *Zm DMP*, but on the basis of expression analysis, it (0.31) was not similar to *Zm DMP*. *OsDMP2*(134.14), another DMP family gene, was showing an expression pattern similar to *ZmDMP*, that is, anther specific, but was distantly related to maize *ZmDMP*. Furthermore, phylogenetic analysis of rice PLD genes with maize revealed that *OsPLD1*(Figure 1B) was sharing the same subclade with *ZmPLD3*. Later on, *in silico* expression analysis showed that *OsPLD1*(108.06) was also showing anther specific expression as compared to other tissues. It can be concluded that *OsPLA4* was showing the nearest homology and the same expression as *ZmPLA* and its knockout leads to generating haploid induction ability in rice. Moreover, the homology and expression pattern of *OsPLD1* was similar to *ZmPLD*, suggesting it a strong candidate for haploid induction in rice. Considering *OsDMP1* or *OsDMP2* as putative orthologue is still ambiguous, which can only be confirmed by knocking out both of the genes. Interestingly, extensive work has been done on knocking out of DMP genes in dicots, and in most of the cases two genes belonging to the DMP family have been found responsible for haploid induction. So, akin to that there is a high probability that both *OsDMP1* and *OsDMP2*may be responsible for haploid induction. Knocking out of *OsPLD1*, *OsDMP1*, and *OsDMP2* by using precision genome editing tools like CRISPR/Cas9 may lead to develop an efficient and robust genome editing tool in rice.



A B

Figure 1 Phylogenetic tree of (A) DMP and (B) PLD genes

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19. Effect of Organic Nutrient Management on Yield Potential of Greengram

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Keywords: Biofertilizer; Soil health; Yield

1. Introduction

India is the major pulse growing country in the world, accounting about 33%, 25%, 27%, and 14% area, production, consumption, and import of pulses in the world, respectively (Rawal and Navarro, 2019). Greengram is the third important pulse crop of India after chickpea and pigeonpea and one of the most important leguminous crops grown in arid and semi-arid regions of India. Greengram is an excellent source of high-quality protein (25%) and has the ability to symbiotically fix atmospheric nitrogen in association with *Rhizobium*. Long-term application of synthetic chemical fertilizers causes adverse effects on the environment such as chemical accumulation, increases salinity, and disparity in soil nutrients and harms the soil health. Consequently, biofertilizers and organic manures were opted to somehow reduce the adverse impact of low soil fertility, and environmental and biotic stresses, by improving the rhizospheric conditions for achieving sustainability in the crop production.

2. Materials and methods

A field experiment was conducted during *Kharif* 2020 at the research area of Deendayal Upadhyay Center of Excellence for Organic Farming, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India, comprising 13 treatments involving biofertilizers (*Rhizobium*, phosphate solubilizing bacteria [PSB], and *Trichoderma harzianum*) and different organic manures on loamy soil having moderately alkaline pH and 0.67% organic carbon with low, medium, and high available nitrogen, phosphorus, and potassium status, respectively. Different organic nutrient management practices adopted for evaluation were seed treatments, either alone or in combination, and farmyard manure (FYM) or vermicompost application @ 50%, 75%, and 100% recommended dose of nitrogen (RDN) (20 kg/ha) with combined seed inoculation. These treatments were replicated three times and allocated randomly to different plots of variety MH 1142 of greengram. The experimental field was irrigated thrice by providing sprinkler irrigation to avoid the consequences of dry spell and harvested manually. Data recorded for growth and yield parameters were statistically analyzed by Fisher's analysis of variance technique. Significance of differences in effects of treatments was tested by 'F' test and critical difference (CD) was computed at the 5% level of significance using the following formula:

$$\mathrm{CD} = \frac{\sqrt{2 \times \text{Error mean sum of square}}}{N} \times t\ (\text{error df } 5\%)$$

where CD denotes critical difference, N is the number of total observations, and t is the value of t-distribution for error degree of freedom at 5% level of significance.

3. Results and discussion

Integrated application of organic manures and biofertilizers in greeengram improved the soil nutritional status and production of growth-promoting substances, which ultimately increased the plant vigor and yield. At 30 days after sowing (DAS), *Rhizobium*+PSB+*Trichoderma harzianum*+75% RDN through vermicompost recorded significantly higher dry matter accumulation (5.0 g per plant) followed by 100% RDN through vermicompost (4.9 g per plant), whereas *Rhizobium*+PSB+*Trichoderma harzianum* +100% RDN through FYM resulted in maximum dry matter accumulation at 45 and 60 DAS (12.5 and 19.9 g per plant, respectively). The maximum number of seeds per pod and test weight was observed with *Rhizobium*+ PSB+ *Trichoderma harzianum*+100% RDN through vermicompost (9.8 and 34.4 g, respectively). Significantly superior results were obtained with the addition of organic manures owing to optimum rhizospheric conditions and recorded maximum seed and straw yield of 855 and 2949 kg/ha, respectively, with *Rhizobium*+PSB+*Trichoderma harzianum*+100% RDN through vermicompost (Table 1). Dual inoculation of *Rhizobium* and PSB significantly improved the yield pertaining to enhanced mineralization and solubilization of nutrients (Verma *et al*., 2017). Application of various levels of FYM and vermicompost significantly improved the harvest index and reported the highest harvest index of 22.7% with *Rhizobium*+ PSB+ *Trichoderma harzianum*+75% RDN through vermicompost, which was significantly superior over control (17.0%). Enhanced nutrient availability could be the reason for the increase in yield potential due to improved aeration along with the slow release of nutrients and prolonged soil moisture availability owing to the incorporation of organic manures. The greengram production may be recommended with *Rhizobium*+PSB+*Trichoderma*+100% RDN through vermicompost at Hisar conditions, although application of vermicompost and FYM @ 75 and 100% RDN gave statistically similar results and can be practiced for optimizing resources.

Table 1 Effect of organic nutrient management practices on growth and yield of greengram

Symbol	Treatments	Dry matter accumulation (g/plant)			Number of seeds per pod	1000 seed weight (g)	Yield (kg/ha)		Harvest index (%)
		30 DAS	45 DAS	60 DAS			Seed	Straw	
T_1	Control	3.4	10.1	13.1	6.9	32.0	453	2211	17.0
T_2	*Rhizobium*	3.9	10.5	15.0	8.3	32.9	565	2627	17.8
T_3	PSB	3.8	10.3	14.2	7.8	32.7	517	2432	17.7
T_4	*Trichoderma harzianum*	3.7	10.3	13.8	7.7	32.6	516	2411	17.7
T_5	*Rhizobium*+PSB	4.0	10.9	16.9	8.4	33.1	639	2633	19.5
T_6	*Rhizobium*+*T. harzianum*	3.9	10.6	15.4	8.3	33.0	614	2649	19.0
T_6	*Rhizobium*+PSB+*T. harzianum*	4.3	11.0	17.9	8.6	33.4	690	2735	20.1
T_8	T_7+50% RDN FYM	4.7	11.6	18.8	8.9	33.7	747	2760	21.5

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Symbol	Treatments	Dry matter accumulation (g/plant)			Number of seeds per pod	1000 seed weight (g)	Yield (kg/ha)		Harvest index (%)
		30 DAS	45 DAS	60 DAS			Seed	Straw	
T_9	T_7+75% RDN FYM	4.8	11.9	19.5	9.1	34.0	802	2806	22.2
T_{10}	T_7+100% RDN FYM	4.9	12.5	19.9	9.5	34.2	834	2908	22.4
T_{11}	T_7+50% RDN Vermicompost	4.6	11.4	18.6	8.9	33.8	786	2831	21.9
T_{12}	T_7+75% RDN Vermicompost	5.0	11.7	19.1	9.4	34.1	840	2863	22.7
T_{13}	T_7+100% RDN Vermicompost	4.9	12.0	19.5	9.8	34.4	855	2949	22.5
	SE (m)±	0.15	1.17	1.94	0.32	0.50	28.64	120.11	1.01
	CD (p = 0.05)	0.45	0.40	0.66	0.94	NS	84.09	352.67	2.96

NS = Nonsignificant at 5% level of significance.

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20. Rainwater Harvesting as an Adaptation to Climate Change

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Keywords: *Climate resilient technologies; Impact assessment; NICRA; Rainwater harvesting*

1. Introduction

The most alarming challenge faced in this century is food and nutritional security, and it is a challenge for all of us to feed an additional 3 billion people by 2050. About 95% of this population growth will occur in underdeveloped or developing nations where agriculture contributes to a major portion of the per capita income. Thus, the real game changer is water. The main concentration should be on upgrading rain-fed/dryland agriculture for small and marginal farmers in areas facing climatic variations in terms of rains and frequent floods. Excessive water loss in smallholder farming areas reduces water availability and leads to the loss of valuable nutrients from topsoil (Biazin *et al*., 2012). India is on the edge of an unprecedented water crisis. Water is the key input for sustainable development and food security in deciding social fate (Dile *et al*., 2013). Rainwater harvesting is accumulation and deposition of rainwater for reuse on-site rather than allowing it to run off. Rainwater is a precious resource due to the increase in demand from our ever-growing population. National Initiative on Climate Resilient Agriculture (NICRA) has promoted the application of resilient climate technologies in the most vulnerable districts to guard against drought conditions and flooding. Climatic changes and increasing climatic variability are likely to worsen the problems of future food security by exerting pressure on agriculture. The Jammu and Kashmir state enjoys a unique and varied climate in the Indian subcontinent for producing temperate fruits, particularly apples.

2. Materials and methods

Under the NICRA project, three water harvesting structures (16 × 8 × 6 feet each) were constructed at NICRA adopted village Wakherwan and adjacent villages of the district Pulwama during the years 2018-19, 2019-20, and 2020-21. This intervention aimed to collect runoff rainwater and ensure water availability during the summer months (critical growth periods). More than 4 ha of the area were covered with supplemental irrigation. Data was collected from the respondents using input-output cost.

3. Results and discussions

The average irrigated land area of NICRA farmers was much higher than that of non-NICRA farmers in the summer. The role played by the water management component is well reflected here. Positive responses were given by Wakherwan village residents as renovation of water harvesting structures led to enhancement of water storage capacity by 30%. During these years, 25 farmers benefited from this technology. Farmers use rainwater to irrigate apple and pulse crops during critical growth periods and use the water to spray pesticides. Due to this achievement under the NICRA project, farmers of the particular area get benefitted in terms of production and productivity. The difference may result from farmers' positive response to NICRA interventions and increased availability of irrigation water during the summer season from water harvesting structures (Table 1). Prasad *et al*. (2014) reported an increase in average cropping intensity across farmers by 17%. A significant increase in area under irrigation in the *Kharif* season was observed, while irrigated areas increased by 30%**.**

Table 1 Effect of intercropping on relative economics of high-density apple plantation+garden pea with or without irrigation

Technology demonstrated along with crop and variety*	Economics of demonstration (Rs/ha)			
	Gross cost	Gross return	Net return	B:C ratio
Cultivation of apple (MM-106)+garden pea (PB-89) with irrigation	65,000	177,000	112,000	2.72:1
Cultivation of apple (MM-106)+garden pea (PB-89) without irrigation	58,000	113,000	55,000	1.95:1

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21. Phytoremediation of Polluted Soil using Marble Waste in Alfalfa Plants

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Keywords: Alfalfa; Marble waste; Phytoremediation; Polluted soil

1. Introduction

Urbanization increases automobiles' production and uses; these automobiles have worsened soil pollution problems. Heavy metal contamination in the soil around vehicle garages and workshops is considered to be high, resulting in a loss of soil fertility. The application of organic and inorganic matter is a common technique to remediate polluted soils. Raklami *et al*. (2021) suggested the use of marble waste for bioremediation of heavy metal contaminated and acidic soils. Marble waste constitutes carbonates, which can influence the soil pH, accumulation, and mobility of metals; some studies suggest its usage for the contaminated soil restoration processes (Midhat *et al*., 2021). The present study focused on the phytoremediation of polluted soil by growing the *Medicago sativa* (alfalfa) and amending marble waste which has a natural counteracting and buffering effect that can be achieved at no cost at any marble stone processing facility (Barros *et al*., 2009). Alfalfa is a cover crop that has been demonstrated to be successful in crop rotation to improve soil nitrogen retention capacity and reduce artificial fertilizer use. It is a stress-tolerant plant that can withstand and remove metal contamination from the soil. Therefore, the objectives of the present study were to determine the efficiency of phytoremediation in polluted soil using different marble waste percentages by alfalfa plant.

2. Materials and methods

Polluted soil (PS) sample collection was done from auto-mechanical workshops (automobile garage) and marble waste (MW) which is commercially available in the marble industrial hub area of Rajasthan, situated in Kishangarh. Agricultural soil (AS) was collected from an agriculture farm field near to Central University of Rajasthan. The experimental setup was divided into three groups of pots with three replicates. Group one contained control (C) consisting of 50% (wt/wt) PS and 50% (wt/wt) AS (i.e., 1:1 PS and AS). The second group contained experimental pot-1 (EP1), which consisted of 15% (wt/wt) marble waste along with AS and PS in a 1:1 ratio, and the third one was experimental pot-2 (EP2), which consisted of 30% (wt/wt) marble waste along with AS and PS in 1:1 ratio. An equal number of alfalfa seeds was sown into each treatment after sprinkling a sufficient amount of water into pots containing the control and treatment soil mixture. The data were subjected to JMP 13 software (SAS Institute, Cary, NC, USA) to assess differences among treatments. The complete randomized design was used for comparing the amendments of marble waste with varying levels in both the treatments (EP1 and EP2). One-way analysis of variance (ANOVA) was used to check the significant difference between treatments for all the measured parameters. The fit of the data to a normal distribution for all properties measured was checked using the Shapiro-Wilk test for normality, and further response variables were log-transformed where necessary. Soil analysis (pH, electrical conductivity, total organic carbon, macro- and micronutrients, heavy metals) and plant analysis (malondialdehyde, ascorbic acid, phenol, and proline) (Chaudhary and Agrawal, 2015) were done to determine the efficiency of alfalfa to reduce heavy metal contamination in polluted soil of automobile areas.

3. Results and discussion

Soil analysis showed (Table 1) the reductions in electrical conductivity (EC) in EP1 and EP2 as compared to control (C); however, pH did not show a change. Total organic carbon % (TOC%) was found to be slightly higher in EP1 and EP2. Analysis of macronutrients (P and K) and micronutrients (Zn, Fe, and Mn) in the soil showed a varied trend in treatments and control. However, heavy metal (Cd, Cr, Pb) analysis results showed the effectiveness of amendments in reducing Cr and Pb concentration in treatments compared to control. Plant analysis (Table 1) showed that malondialdehyde (MDA) concentration was maximum in control (C) than in treatments EP2 and EP1. Plants encourage the development of reactive oxygen species (ROS) due to polluted soil conditions which were assessed by MDA (Gill and Tuteja, 2010). EP1 treatment had the lowest MDA, that is, 15% (w/w) marble waste content; alfalfa was shown to be protected from oxidative damage in this treatment. Total plant pigments (chlorophyll *a* and *b*) were found to be highest in EP2 followed by EP1 as compared to C. Ascorbic acid and phenolics levels were higher in EP2 than EP1 and lowest in control, suggesting tolerance to oxidative stresses caused by polluted soil. Stress increases proline production in plants, which confers stress tolerance by maintaining cell turgidity or osmotic balance, and lower concentration of proline in treatments as compared to control indicates that amendments are effective in overcoming stress in alfalfa as compared to control. The present study reveals that the treatments (EP1 and EP2) showed more tolerance to oxidative stresses compared to the control (ascorbic acid and MDA). Marble waste was found to be effective in reducing the EC and heavy metals of polluted soil. Among the amendment, EP2, which was 30% 9 w/w of MW, was found to be more effective in reducing stress in alfalfa than in treatment EP1. Therefore, 30% (w/w) of marble waste was an effective amendment used in garage area polluted soil of Bandar-Sindri highway along with agricultural soil to reduce stress in alfalfa.

Table 1 Different plant parameters, macro- and micronutrients, and heavy metals in control and treatments EP1 and EP2

Parameters Treatments	Control	EP1	EP2
Ascorbic acid (mg/g fresh wt.)	4.85^{b}±0.20	6.62^{a}±0.69	7.22^{a}±0.94
Malondialdehyde (mg/g fresh wt.)	0.05^{a}±0.002	0.04^{b}±0.001	0.04^{b}±0.001
Proline (mg/g fresh wt.)	4.45^{a} ±0.29	3.31^{b}±0.14	3.50^{b}±0.16

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Parameters Treatments	Control	EP1	EP2
Phenol (mg/g fresh wt.)	0.01^{a}±0.001	0.01^{a}±0.001	0.01^{a}±0.001
Total pigments (mg/g fresh wt.)	1.40^{a}±0.03	1.03^{b}±0.07	1.08^{b}±0.02
Ph	7.5^{b}±0.1	7.7^{a}±0.01	7.8^{a}±0.1
Electrical conductivity (µS/cm)	0.74^{a}±0.09	0.58^{b}±0.01	0.54^{b}±0.02
Total organic carbon (%)	0.62^{b}±0.02	0.74^{a}±0.01	0.75^{a}±0.01
P (kg/ha)	42.9^{a}±2.7	45.6^{a}±1.0	46.6^{a}±1.0
K (kg/ha)	308.8^{b}±4.9	311.3^{ab}±1.3	316.5^{a}±1.0
Zn (mg/kg)	0.835^{b}±0.012	1.083^{a}±0.001	1.107^{a}±0.015
Fe (mg/kg)	5.787^{b}±0.021	6.385^{a}±0.351	6.287^{b}±0.542
Cu (mg/kg)	0.493^{b}±0.005	0.598^{a}±0.011	0.499^{b}±0.002
Mn (mg/kg)	4.522^{a}±0.025	4.333^{a}±0.110	4.443^{ba}±0.120
Cd (mg/g)	0.150^{a}±0.010	0.138^{a}±0.011	0.108^{b}±0.006
Cr (mg/g)	2.167^{a}±0.296	1.777^{ab}±0.206	1.347^{b}±0.103
Pb (mg/g)	3.070^{a}±0.448	2.567^{a}±0.100	2.360^{a}±0.348

Values are mean±SD; $N = 3$ replicates for each treatment. Different letters above the values indicate significant differences ($p < 0.05$) according to level of significance between treatments based on one-way ANOVA.

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22. Prevalence of Female Reproductive Tract Abnormalities in Slaughtered Goats in the Jammu Region

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Keywords: *Pathological conditions; Prevalence; Reproductive abnormalities*

1. Introduction

Livestock constitutes an integral part of the agrarian economy in India. Small ruminants play an important role in the economy. The economic value of goats is accounted for their milk, good quality meat, proliferacy, high fertility, early sexual maturity, and good quality hair and skin. Goats give birth to multiple kids and increase the income of farmers mainly through the selling of kids (Aziz *et al*., 2010). Genital abnormalities play an important role in animal breeding either by causing infertility or sterility (Azawi *et al.,* 2010). Lesions affecting the uterus and ovary greatly contribute to infertility or sterility in small ruminants and hence reduce enterprise profitability. Investigation of the reproductive abnormalities based on an abattoir survey of the specimen provides information on the prevalence of reproductive disorders and their incidence.

2. Materials and methods

The study was conducted by collecting 200 samples of the female genital tract of goats from governmental recognized and unorganized slaughterhouses in the Jammu region. After slaughter, the specimens were collected immediately in normal saline (0.9%) and transported in thermocol containers to the Division of Veterinary Pathology, FVSc & A.H, R. S. Pura for examination within 2 h of slaughter. Thereafter, a detailed gross morphological examination of genitalia was carried out to detect abnormalities and the presence or absence of pregnant, nonpregnant uterus and corpus luteum (CL).

3. Results and discussion

Data collected from the government abattoirs showed 25.6% and unorganized abattoirs showed a 22.6% prevalence of genital tract abnormalities in goats (Table 1). Out of the 200 samples, 49 samples were found to be infected with a prevalence of 24.50%. The present observation is compatible with that of Talukder *et al.* (2015) in Bangladesh and Beena *et al*. (2016) in UP, India. A total of 15 (7.5%) were found to be pregnant. Left horn pregnancy was found to be higher (45.00%) than right horn pregnancy (Table 2). Similar findings were reported by Beena *et al*. (2016). In contrast to this finding, Francis (2009) reported 38.40% of the pregnant uterus in slaughtered goats. The highest incidence of pathological abnormalities was found to be in the uterus (53.06%), followed by the ovary (30.61%), fallopian tube (10.20%), and cervix (6.13%). Parovarian cyst showed the highest incidence of occurrence (53.34%) followed by the incidence of the follicular cyst (26.67%) and luteal cysts (13.34%) among ovarian disorders. The data collected during the present study showed the prevalence of hydrosalpinx to be 2.50%. Out of total affections of the uterus in goats (26), acute endometritis and hydrometra (15.38%) were highly prevalent followed by pyometra (11.58%), cystic endometrial hyperplasia (11.53%) melanosis (11.53%), metritis and perimetrial cyst (3.84%). The prevalence of subacute nonsuppurative cervicitis was found to be 1.50% (Table 3).

Table 1 Prevalence (%) of female genital tract abnormalities of goats in government recognized and unorganized abattoirs/slaughterhouses in Jammu (N = 200)

Slaughterhouse	Areas	Total no. of female genital tracts sample examined	Affected samples	Total no. of affected samples	Percentage of infection
Govt. recognized abattoirs	Dogra Hall	75	15	32	25.6
	Gujjar Nagar	50	17		
Unorganized abattoirs	Nagrota	45	12	17	22.6
	Bishnah	30	5		

Table 2 Pregnant uterus (%) of the female genital tract in goats

Animal species	Total specimens	Pregnant uteri (N)	Pregnant uteri						Total (%)
			Right horn (n)	%	Left horn (n)	%	Bihorn (n)	%	
Goats	200	15	6	40.00	7	46.70	2	13.40	7.50

Table 3 Pathological conditions (%) of reproductive organs in goats

Organ affected	Total affected samples	Ovary affections	Total number (n)	Total (%)	Overall percentage (N = 200)
Ovary	15	Paraovarian cyst	8	53.34	4.00
		Follicular cyst	4	26.67	2.00
		Luteal cyst	2	13.34	1.00
		Embedded CL	1	6.67	0.50
Fallopian tube	5	Hydrosalpinx	5	100	2.50
Uterus	26	Endometritis	4	15.38	2.00
		Metritis	1	3.84	0.50
		Cystic endometrial Hyperplasia	3	11.53	1.50
		Pyometra	3	11.53	1.50
		Melanosis	3	11.53	1.50
		Hydrometra	4	15.38	2.00
		Perimetrial cyst	1	3.84	0.50
Cervix	3	Subacute nonsuppurative cervicitis	3	100	1.50

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23. Focused Ultrasonography for Diagnosis of Intestinal Intussusception in Cattle

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Keywords: *Intestine; Intussusception; Ultrasound*

1. Introduction

Surgical diseases of the gastrointestinal tract are numerous in cattle and constitute a major clinical problem. Intestinal obstruction represents a life-threatening abdominal emergency. Intussusception is the single most common condition reported in the Veterinary Clinical Complex (VCC) of SKUAST-Jammu. Diagnosis of intussusception in cattle can be confirmed in a few cases on rectal palpation; in many animals, the affected intestine may be out of reach of the examiner, owing to pregnancy or rectal palpation may not be possible in young animals. The ultrasonographic examination helps to confirm or rule out the preliminary diagnosis and to decide whether to go for surgery or not (Tharwat, 2011). Focused ultrasonography (USG) provides a focused and limited examination designed to answer a brief and important clinical question in an organ system or address a symptom involving multiple organ systems. There is no literature available on the use of focused ultrasound in cattle. Therefore, the study was performed with the objective to establish focused ultrasonography for the diagnosis of intestinal obstruction in cattle.

2. Materials and methods

The present study was conducted with the objectives to diagnose intestinal obstruction in cattle by ultrasonography and to establish a focused ultrasound examination for the diagnosis of intestinal obstruction in cattle. It was conducted in two parts, part I comprising 12 healthy cattle (8 cows and 4 heifers) and part II comprised 72 animals bought to the TVCC, R.S. Pura, Jammu, with symptoms indicative of intestinal obstruction. In all the animals, ultrasonography was performed from the right hemi abdomen from the 10th rib to tuber coxae and thoracolumbar transverse processes to just ventral to the stifle fold using real-time B-mode ultrasonography, with 3.5, 5.0, and 6.5 MHz micro convex transducer as described by Braun and Marmier (1995). The systematic technique was used to scan the entire prepared area in a zigzag fashion in transverse and longitudinal planes in healthy animals. In the case of the diseased animals, USG was performed through 12 spots selected and marked over the area of the right hemi abdomen. Four scanning spots were selected at each of the three levels; I at the level of tuber coxae, II at the mid femur, and III at the level of stifle fold. The ultrasonographic findings were correlated with the intraoperative findings in cases of intestinal obstruction or any other surgical disorder. The sensitivity of ultrasonography at each selected point in diagnosing intestinal obstruction was calculated.

3. Results and discussion

A transducer with 5.0 or 6.5 MHz frequency was found to be appropriate for scanning of intestinal obstruction. In healthy animals, only the cranial duodenum, descending duodenum, jejunum, and ileum could be scanned; however, jejunum and ileum could not be distinguished from each other. The spiral end of the proximal colon, descending colon, and caecum could also be identified. Strong motility characterized by the constantly changing number, shape, and size of the intestinal lumen was seen in all the animals at all locations of the right abdomen. Peritoneal fluid could not be detected in any of the healthy animals. The findings were in agreement with Braun and Marmier (1995) and Braun (2009).

Out of 72 clinical cases suspected to be suffering from intestinal obstruction, 60 were diagnosed as having intestinal obstruction based on ultrasonography findings and further confirmed as intussusception on laparotomy. The descending duodenum with no peristaltic contractions and the passive movement of contents indicative of ileus was seen at the level I (level of tuber coxae) at the upper part of PLF in 57 out of 60 animals (95.00%). At level II (level of the mid femur), the cranial duodenum was seen at the middle 11th ICS in 32% of animals and at the 10th ICS in 70% of animals. However, distension (>32.2 mm) of descending duodenum was noted at level I at PLF in 47% of animals, at upper 12th ICS in 25%, at upper 11th ICS in 50%, and at upper 10th ICS in 25% of animals. The diameter of descending duodenum ranged from 11.1 to 59.4 mm. In duodenal obstruction (two cases), dilated duodenum (diameter 52.2 and 59.4 mm) could be seen at upper PLF, upper 12th ICS, middle 11th, and 10th ICS, while the rest of the intestinal tract appeared as collapsed with normal intestinal motility. Dilated loops of jejunum/ileum with lack of peristaltic motility and passive movement of ingesta indicative of ileus were seen at level II in 90% of animals, at 12th ICS in 95% of animals, at 11th ICS in 57% of animals, and at 10th ICS in 42% of animals. At level III at the lateral abdomen (level of stifle fold), it was seen at stifle fold in 95% of animals, corresponding to 12th and 11th ICS in 97% of animals and corresponding to 10th ICS in 95% of animals. The diameter of the jejunum and ileum was seen ranging from 15.5 to 77.3 mm. The overall mean thickness of the duodenal wall in animals with intestinal obstruction was 3.49±0.11 mm. The wall thickness of loops of jejunum/ileum indicative of ileus at all the focal spots was 3.08±0.05 mm. The number of loops visible in one scan at various focal points ranged from 1 to 7. A typical bull's eye pattern could be seen only in four animals by trans-abdominal ultrasonography without per rectal manipulation. In 58 out of 60 animals, the peritoneal fluid could be seen on ultrasonography as anechoic pockets of different shapes in between the intestinal loops.

The study concludes that the intestinal obstruction can be diagnosed with 100% accuracy in nonpregnant cattle if focused ultrasonography is performed through the upper paralumbar fossa at the level of tuber coxae, mid-10th and 11th ICS at the level of the mid femur, and any of the three points, the stifle fold, the points corresponding to 12th and 11th ICS at the level of stifle fold. In the case of pregnant animals, the point at the stifle fold can be skipped.

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24. Adoption of Buffalo Rearing Practices by the Farmers in Rajouri District

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Keywords: *Adoption; Buffalo rearing practices; Farmers*

1. Introduction

India possesses some of the best river milch breeds of Asia, for example, Murrah, Nili-Ravi, Surti, and Jaffrabadi. Among them, Murrah is the best milch breed, also known as black gold, and has the potential to play a pivotal role in the socioeconomic development of dairy farmers. Jammu and Kashmir has a rich diversity of livestock wealth in the form of cattle, buffaloes, equines, and poultry. The population of livestock in this UT is 9.20 million (excluding stray cattle) registering a decline of 16.25% of the total number of various species (Livestock Census, 2019). Among livestock, buffalo is also one of the most important animals reared by farmers. The population of buffaloes in J&K is 7.38 lakh with a decline of 29.64%. The majority of buffalo population exists in the Jammu region due to climatic conditions which are favorable to buffaloes. Murrah and Nili-Ravi are two prominent milch breeds found in this division. Rajouri district contributes 18.00% to the total buffalo population of Jammu and Kashmir. It is the second largest district in terms of buffalo population and is ideally suited for buffalo rearing owing to its agroclimatic and geophysical conditions. However, the present status of buffalo rearing does not seem encouraging. This is mainly due to the low milk production of the buffaloes as compared to their potential. The reason may be due to less adoption of the recommended buffalo rearing practices. Also, most of the buffaloes are reared in the backyard system by small, marginal, and landless farmers rearing two or three animals for milk. All these factors contribute to the less production of buffaloes. So, it is essential to know the practices adopted by buffalo farmers to understand the strengths and weaknesses of the rearing system.

2. Materials and methods

The research was carried out in the Rajouri district of Jammu and Kashmir. Five blocks were selected by using a simple random sampling technique. A comprehensive list of villages was prepared in Rajouri district. From each of the five selected blocks, two villages were randomly selected from each block, resulting in a total of 10 villages. A total of 120 buffalo farmers were chosen from each of the 10 villages.

Table 1 Selection of villages and respondents

Block	Village	No. of respondents
Sunder Bani	Lower Bajwal	12
	Kathanu	12
Siot	Balshama	12
	ThandaPani	12
Lambheri	Lambheri	12
	Bagnoti	12
Rajouri	Muradpur	12
	Chakli	12
Seri	Mangaldai	12
	Gagrote	12
5	**10**	**120**

3. Results and discussion

The average adoption score was 62.217±0.627 indicating that they had 62% adoption of recommended buffalo rearing practices. Respondents had maximum adoption about feeding practices (69%) and least adoption about management practices (55.00%). They had 68% and 64% adoption regarding health care and breeding practices, respectively. The majority of the respondents (64%) had medium adoption of 62% followed by 18% who had low adoption (52%) and only 17% of the respondents had a high adoption level (72%). Age and occupation were negatively and insignificantly associated with the adoption. Education, social participation, herd size, mass media exposure, landholding, economic motivation, extension contact, and risk orientation had a positive and significant association with the adoption. From the different areas of recommended buffalo rearing practices, ‘regular cleaning of the shed’ in management, ‘sterilization and disinfection of milking utensils’ in clean milk production, ‘feeding of colostrum to newborn calf’ in feeding, ‘practice of keeping breeding record’ in breeding and ‘burying the dead carcass which died of contagious diseases’ in health care were the most adopted recommended rearing practices by the buffalo farmers. Godara *et al.* (2018) and Singh and Meena (2018) revealed that colostrum feeding and feeding of prepared hay were the most adopted feeding practices. Similarly, Gupta *et al.* (2020) observed that allowing newborn calves for colostrum feeding just after calving was the most adopted practice.

Table 2 Adoption of recommended buffalo rearing practices by the farmers

Adoption level of buffalo farmers regarding recommended buffalo rearing practices	Possible range	Observed range	Mean±SE	Standard deviation	Percentage
Management practices	0–40	15–29	22±0.256	2.810	55.00
Feeding practices	0–20	8–18	13.767±0.170	1.868	69.00
Breeding practices	0–20	6–20	12.867±0.247	2.710	64.00
Health care practices	0–20	2–20	13.583±0.263	2.880	68.00
Total	0–100	44–76	62.217±0.627	6.873	62.00

Note: Figures in percentages are rounded up to the nearest whole numbers.

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25. Transition of *Jhumias* to Settled Farming: A Case Study of Tripura, India

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Keywords: *Agroforestry; North-East India; Settled farming; Shifting cultivation*

1. Introduction

Tripura, the second most populous state in the biodiversity hotspot region of North-East India, has about 32% tribal population which are known to practice shifting cultivation (*jhum)*. Since the practice has seen a decline due to discouragement by the government, it has also become unsustainable due to shorter fallow cycles and increasing forest fragmentation. Thus, under the resettlement programme of the Tripura State Government in 2003, *jhumias* were resettled to more accessible locations to wean them off *Jhum* cultivation, restore the forest landscape, and provide alternate livelihood options. The present study investigated the diversification of farming practices by these former *jhumias*, changes in their socioeconomic status, and benefits and constraints faced by them in planting agroforestry or horticulture species.

2. Materials and methods

Under the resettlement programme, cluster villages were formed in each district where tribal *jhumias* were relocated from interior forest areas to near roadheads; these villages are called regrouped villages. Districts Dhalai and Gomati in Tripura are characterized by the high prevalence of shifting cultivation and resettled *jhumias*. Seven regrouped villages, three in Dhalai (Strata 1), namely, Jeolcherra, Naitongcherra, Khakchangkami, and four in Gomati (Strata 2), namely, New Dhananjay Para, Twichakma, Ampinagar, and Khuripara, were sampled through stratified random sampling method through a structured questionnaire survey of households. Data were collected in November 2021 from 245 households (35 households in each village) and assessed for socioeconomic status, applying the Modified Udai Pareek scale (1964) (Majumder, 2021), farming practices (*jhum* and agroforestry), and factors affecting the adoption of settled farming. The data were also collected through open-ended interviews with State Forest Department officials and data records regarding regrouped villages and key informant interviews with Joint Forest Management Committee (JFMC) heads.

3. Results and discussion

At least 70% households' socioeconomic status in each village, 79% in Jeolcherra, 70% in Naitongcherra, 71% in Khakchangkami, 79% in New Dhananjay Para, 83% in Twichakma, 75% in Ampinagar, and 92% in Khuripara, has improved from the lowest category, that is, lower class to lower middle class, fulfilling a major objective of their resettlement.

About 82% of the sampled households that previously only engaged in *jhum* have transitioned to a combination of *jhum* and growing cash crops like arecanut and rubber, either on their patta Recognition of Forest Rights (RoFR) land (23% households) or in homesteads (77% households). A total of 15 different plant species were identified in homesteads and patta (RoFR) land. While households were asked for both productive and protective benefits of agroforestry species that help choose the species, only 13% households chose protective functions like shade and soil improvement. On the other hand, all respondents prioritized productive functions like food products, rubber products, and non-wood products to be factors important for the choice of species.

Perception of households (Hh) regarding benefits and constraints in planting agroforestry species was assessed (Table 1). The benefits of food products (97% Hh), wood/bamboo products (85% Hh), and self-sufficiency (86% Hh) were strongly agreed upon. Factors like soil improvement and maintenance of groundwater table that are important ecological benefits to be considered were met with a neutral response, which may be due to a lack of awareness about the protective functions of different species. On the other hand, constraints like additional labor requirement (73% Hh), long maturation period (69% Hh), and lack of adequate land (79% Hh) were agreed upon by most farmers. Good market connectivity in all seven villages is reflected by 88% of households disagreeing with the lack of market access.

Table 1 Benefits and constraints in planting agroforestry species

Benefits of planting agroforestry species	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)
Soil protection or improvement	–	–	88	9	3
Helped in maintaining the groundwater table	–	–	89	11	–
Provides food products (fruits, vegetables, etc.)	–	–	–	3	97
Provides wood products or timber (including bamboo)	–	–	12	3	85
Increases self-sufficiency in a household	–	–	3	11	86
Reduces the risk of income from climatic/biological/market impacts	–	–	47	48	5
Gives financial security and helps cope in stressful times	–	–	13	62	25

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Constraints in planting agroforestry species	**Strongly disagree (%)**	**Disagree (%)**	**Neutral (%)**	**Agree (%)**	**Strongly agree (%)**
Potential of trees to serve as hosts to insect pests	–	–	85	15	–
Requirement for more labor inputs, which may cause scarcity at times in other farm activities like jhum	–	–	6	73	21
A longer period required for trees to grow to maturity and acquire an economic value	–	–	7	69	24
More complex and difficult to apply, compared to single-crop farm/monoculture like rubber plantation	–	6	65	26	3
Non-availability of seedling/plantation	6	14	49	30	1
Deteriorating soil quality	–	39	37	24	–
Lack of market access for selling of produce	–	88	9	3	–
Lack of adequate land	–	–	12	79	9

Thus, the resettlement has provided an opportunity for these former hardcore *jhumias* to diversify their croplands by integration of cash crops among other horticulture plants like pineapple, jackfruit, orange, and banana (Das and Bordoloi, 2019). However, more awareness and training are needed to drive this adoption in a sustainable manner.

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26. Investigating the Influence of Attributes of Happy Seeder Technology on Its Adoption Speed: An Application of Duration Analysis

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Keywords: Adoption speed; Duration analysis; Happy Seeder; Stubble burning; Technology attributes

1. Introduction

Smoky skies and hazy grounds are common in north-western India in the early winters every year due to endemic levels of air pollution caused by paddy stubble burning. In the *Kharif* season of the year 2021, more than 70,000 farm fire burning events were recorded in Punjab. The collection of loose paddy straw from the field is very costly and laborious. So, researchers offered various paddy straw management techniques and among these techniques Happy Seeder Technology (HST) has the highest economic potential and is the most time savvy and sustainable (Shyamsundar *et al*., 2019). In the current study, we argue that attributes of technology (relative advantage, compatibility, complexity, trialability, and observability) and farmers' perceptions regarding these attributes are important factors that affect adoption speed. Thus, in this paper, we attempted to quantify the effect of these attributes on the duration (from awareness to adoption) of HST adoption.

2. Materials and methods

The study was conducted in Punjab, a north-western state of India, in the year 2018-19. Two districts were selected from each of five agroclimatic zones based on the number of happy seeder adopters (Gurdaspur, Hoshiarpur; Sahid Bhagat Singh Nagar, Rupnagar; Ludhiana, Patiala; Faridkot, Ferozpur; Mansa, Bathinda). A cluster of villages was identified from each district based on the proportion of happy seeder adopters to draw the farmers' sample. Then a random sample of 229 farmers (177 adopters and 52 non-adopters) was obtained from these selected clusters. The adoption speed was measured in terms of time duration (in months) between the awareness and adoption time of farmers if HST was adopted and the time between the awareness and study time in the case of non-adopters. To quantify the farmers' perception of selected attributes of HST (relative advantage, compatibility, complexity, trialability, and observability), indicators were developed and measured on a three-point continuum. To study the research question, we employed the duration analysis technique. Further, to estimate the duration model, Cox proportional hazards model (Cox, 1972) was used:

$$h(t,X) = h_0(t)e^{\beta_i x_i}$$

Here, the model gives an expression for hazard at time *t* with a set of explanatory variables (X) for an individual.

3. Results and discussion

The median time for adopting HST was about 38 months. The probability of continuing farming without adopting HST, that is, non-adoption at 40 and 60 months, was 0.45 and 0.25, respectively. As expected, it was found that relative advantage, trialability, and observability had a significant and positive influence on the speed of adoption of HST while complexity had a significant negative influence on the same. But contrary to the hypothesis, compatibility had no significant effect on the speed of adoption of HST. Among the attributes that had significant influence, the relative advantage had the highest and complexity had the lowest influence. The farmers who perceived HST seeder to be relatively advantageous compared to the conventional method of wheat sowing had high hazards of early adoption. By one unit increase in perception regarding the relative advantage of HST, hazards for the adoption speed was increased by about 3.5 times. In the case of observability, one unit increase in the observability increased the hazards of the speed of adoption by about 2.5 times. Further, it was found that with one unit increase in trialability, hazards of adoption increased by about 2.25 times. Complexity was found to have a significant negative influence on the speed of adoption of HST. The findings illustrated that favorable perceptions of farmers regarding relative advantage, observability, and trialability of HST significantly increase the speed of adoption. In contrast, a favorable perception regarding the complexity of HST reduces the adoption speed. Thus, policymakers, researchers, and extension workers should emphasize changing farmers' perceptions regarding HST based on these very attributes.

Table 1 Estimates of duration model for happy seeder technology

Parameter	Parameter estimate	Standard error	*p* value	Hazard ratio
Attributes				
Relative advantage	1.236**	0.412	0.003	3.44
Compatibility	0.379	0.275	0.168	1.46
Complexity	–0.809**	0.366	0.027	0.45
Trialability	0.800**	0.390	0.040	2.23
Observability	0.927*	0.523	0.077	2.53
Farmer and farm characteristics				
Age at adoption	0.016	0.009	0.089	1.02
Education	0.040	0.025	0.113	1.04
Farm size	–0.002	0.003	0.582	1.00
Extension contacts	–0.072	0.235	0.759	0.93
Mass media exposure	0.352	0.219	0.108	1.42
Innovativeness	0.229	0.170	0.177	1.26
Risk orientation	0.052	0.173	0.764	1.05
Environment consciousness	0.275	0.198	0.165	1.32

**Significant at $p \leq 0.05$ *Significant at $p \leq 0.10$

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26. Realising Sustainability

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Introduction

2020 was meant to mark a "super-year" for biodiversity, with multiple environmental conventions scheduled to revaluate our relationship with global biodiversity, and to reconcile our actions to secure a brighter future for global biodiversity. Except, rather than these planned environmental meetings, we faced a global pandemic which changed every aspect of our lives. A pandemic, which is likely to be the consequences of a further symptom of environmental mismanagement and unsustainable action, and a pandemic, which, if we do not learn how to be better environmental stewards may be only one of a number of pandemics we see in coming decades. Yet, rather than treating the pandemic like the call to action it should have been, many countries actively delegislated environmental legislation in order to aid economic recovery; despite the known risks of doing so.Here we consider how we can reconcile both past actions and to mainstream environmental and sustainability policy, andallow environmental recovery.

Understanding the impacts of consumption

Whilst some scholars still stubbornly cling on to the notion that population is responsible for environmental losses, data incontrovertibly shows that how and what we consume, rather than how many consume is undoubtedly responsible for the majority of global biodiversity loss. Embodied impacts on biodiversity through the import of goods (primarily food, cattle food or biofuels) is driving the majority of deforestation across most of the global tropics, but particularly in Brazil and Indonesia, with soy and oil-palm the largest drivers of primary losses of forest. Furthermore, even middle-income economies, like China have exported their footprint and now import the majority of their soy. Economies in the "developed" world routinely importing over 60% of their food, and without adequate policies in place to reduce the impact of this, deforestation is accelerating across many parts of the global tropics. Remedying these trends requires two fundamental steps. Firstly, the footprint of meat is many times higher than that of a plant-based diet, transitioning to a more plant-based diet not only requires a fraction of the land required for meat production, but the health benefits of such a diet means that economically countries would benefit from facilitating such a transition. This transition could be facilitated both by strategic taxes and levies to make plant-based food cheaper relative to meat-based food, and through in investing in industries working to create alternatives, as has been done in China. China has already shown marked progress in reducing meat consumption through the production of alternatives, though the motivation for this switch was actually that reaching any form of climate goal was impossible unless diet was included as part of the strategy. It should also be recognised that many parts of the world are still showing increases in meat consumption (as is common as economies become more economically powerful), and thus developed nations must redouble their efforts to redress consumption in their own countries a well as helping developing economies provide more sustainable nutrition to their populations through the transfer of technology. In addition, we must manage landscapes to maintain healthy wild populations, the loss of habitats will cause interactions between wildlife, humans and domestic animals, thus providing the potential for spillovers, especially when wild populations are stressed through loss of key habitats. Managing these landscapes to reduce interactions will likely prove key to reducing the risk of spillover of zoonoses into the future.

The second process requires the tracking of supplychains to reduce and ultimately remove deforestation from supplychains. As imported footprint is still a major driver of losses of biodiversity across the planet, providing financially viable systems to ensure that developing nations have appropriate markets for sustainably sourced products and that mechanisms are in place to both pay fairly and to ensure the impacts of these products are as stated. Such pledges have been made at various high-level events by a number of heads of state, such as president Macron at the start of the IUCN meeting. However further actions are needed to ensure that these tools are implemented, as unless developed nations take responsibility for their imported footprint, it will be impossible for developing economies to ever reach future targets.

To this end, and thinking more about food systems it is very clear that developing targets which only consider "intact" or "wilderness" areas, we can never hope to maintain the majority of global biodiversity. Targets must consider all elements of the landscape and thus setting targets for sustainable agriculture, including preventing the loss of further primary habitat, maintaining habitat fragments within agriculture (such as a buffer of intact habitat around agricultural fields to maximise the permeability of agricultural matrices) and moderating the use of agrochemicals. Techniques which maximise the use of natural enemies to deal with pests, and ensured continued provision of ecosystem services must be looked at and implemented across landscapes to minimise the impacts of food-systems on biodiversity. Likewise, intercropping and other mechanisms to maximise diversity in agricultural areas should be considered further.

Consumption is also not limited to food products, but includes all forms of timber (which also requires certification processes to ensure it is sustainable) and wildlife for food, fashion, medicine and pets. Studies demonstrate that for frequently neglected groups, such as the reptiles upto around 36% of all species are in trade, with around 50% of individuals coming directly from the wild, and upto 70% for groups like the lizards. Obviously the legal, but unsustainable use of wildlife needs much greater consideration to ensure that it does not threaten the long-term their long-term survival. This will require better monitoring and databasing of animals being exported, and clear monitoring of source populations. This includes for the pet trade, but also supply chains for fish, where the bluefish certification should be implemented far more widely to prevent declines of marine fish populations.

Developing better

Much of the planet still has major infrastructural needs to provide for their populations. These projects have undeniable impacts on biodiversity, however, what these impacts are can be minimised. Even major infrastructure projects, such as the belt and road initiative have extensive "science plans" which aim to both build capacity in host

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countries, and collate huge volumes of remotely sensed data to facilitate better analysis of potential impacts to enable them to be circumvented. Actively analysing the potential impacts of planned routes, and working to minimise the loss and fragmentation of intact habitat can dramatically decrease the impacts of potential routes. Where fragmentation cannot be completely avoided then creating under or overpasses to maintain ecosystem connectivity is essential. This is particularly important in areas where there are large numbers of migratory species, such as across Central Asia and much of Africa. Central Asia has been subject to an extended campaign to remove fences and barriers which acted as barriers to various migratory ungulates in these regions. Planned developments need to factor these plans in from the outset. Furthermore, infrastructure impacts transcends that of just direct development. In addition to planning routes to mimimise impacts on biodiversity, work is needed to ensure sustainable sourcing of raw materials, and policies should be in place to ensure that supportive infrastructure (particularly for power and water) is also considered. Dams, and other forms of power infrastructure can vastly increase the impacts of development, and thus having buffer-zones which prevent development may be crucial to minimise impacts. Similar approaches were used with several new road developments in Costa Rica, where protected areas were outlined either side of roads so that they did not cause accelerated deforestation, or habitat loss.

Development is also not limited to terrestrial areas, coastal areas are often particularly vulnerable to development as port areas represent intersections between oceanic and landareas and thus key areas for ports and storage. However these areas are key habitats for millions of migratory bird species, for example the East Asian-Australasian flyway is used by 50 million birds every year, yet many of these species have shown population losses of over 70% over recent decades. Land reclamation and port-development, coupled with rising sea-levels mean that many coastal habitats are shrinking, meaning migratory birds lose crucial habitats, or stop-over sites which may prevent them from successfully completing migration, or to lose condition in the process ultimately reducing their viability. Thus any form of development needs a rigorous EIA, clear oversight to ensure that there is independence, and standard criteria for evaluation and cross-checking. Furthermore financial mechanisms are needed to enforce these regulations, as finance will be key to preventing unsustainable development.

Power considerations are also a major component of sustainable development. Power is obviously needed, yet the impacts of power needs careful consideration. Whilst fossil fuels have clear implications in terms of climate change, "green" power is often much more damaging than frequently realised. Dams for example inundate vast areas of forest, and cause fragmentation of contiguous forest areas. However the impact of dams on freshwater ecosystems is even more damaging, as the fragmentation of rivers, combined with reduced oxygen content from dams can dramatically reduce the ability of fish to survive and migrate in these systems. The planned dams on the greater Mekong Subregion for example are projected to cause a loss of upto 80% of migratory fish biomass, dramatically reducing diversity in these systems and consequently also impacting on rural livelihoods and access to protein. Considerations are needed for both large dams, and smaller hydropower constructions which are placed on smaller streams and rivers, and may impact on local small range endemic species. Furthermore, the loss of native species may cause the release of potentially invasive non-native species to makeup for the loss of native species, and thus causing further causes to the ecosystem. Thus hydropower, as well as irrigation needs particular consideration, in addition to the consideration of downstream rivers which may experience drought following the construction of upstream dams. Other forms of power-infrastructure, frequently regarded as "green" often have neglected consequences for biodiversity, in the case of wind power, turbines have been found to cause considerable mortality in bats and birds, particularly if they are situated on migratory routes, and the growth of turbines across Asia thus presents a major potential risk, especially as there is very little knowledge of the migratory routes of many species (particularly bats) across this region. Biofuels are another example of a power source looked upon as "green" which have considerable implications for biodiversity. The EU biofuel initiative is an example of this, which fuelled major deforestation within Europe to provide for the biofuels, and the growth of soybeans in many tropical areas is also to fuel deforestation.

Moving forwards

Ultimately we need to reconsider our relationship with the natural world. Continuation on the status quo has inherent risks, such as the loss of key ecosystem services, and the risk of future pandemics. Mainstreaming of sustainability is possible, but it requires the reform of agricultural systems as well as financial systems. We also need a better alignment between different environmental conventions. For example, whilst clear complementarities between biodiversity (CBD) and climate (UNFCCC) conventions provide a perfect opportunity to maximise benefits. Yet many climate policies, even under the guise of "nature-based solutions" my actively harm the environment through the lack of the integration of ecological indicators. For example, the billion tree tsunami in Pakistan is planned to largely be Eucalyptus, which will not support local biodiversity, may cause the water table to drop, and may not survive into the longer-term. Similarly the great green wall of Africa in the Sahel risks replacing native savannah and desert ecosystems with trees, which again may not survive. Similar initiatives such as the great green wall in China used only three tree species, and the majority died during drought periods. The drive to afforest, whilst neglecting continued deforestation in old-growth forests across the world highlights a need to prioritise protecting biodiversity, especially where it also sits above peat, which would release carbon if burnt. Nature based solutions clearly have great potential, but should represent genuinely ecosystem based approaches to ensure that they effect positive outcomes for biodiversity.

The next generation will rely on healthy ecosystems, the provision of key ecosystem services, from pollination to support agriculture, to clean water, and of course to reduce the risk of zoonotic outbreaks. Sustainability is possible, but it will require actions at all levels, sustainable supply chains instituted at a national level, education of business and citizens to ensure that these are financially viable, and monitored sufficiently to ensure they are effective. Clear mechanisms to green finance and agricultural sectors, and to ensure planning is genuinely holistic and includes long-term risks. New approaches and technologies mean that these processes are viable, and with technology transfer, capacity building and financial support could allow such approaches to be mainstreamed across society whilst maintaining, and enhancing quality of life across the planet.

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123.	Dr. Vikas Sharma	Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha-Jammu, J&K, India
124.	Dr. Virender Kaul	Formerly at Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha-Jammu, J&K, India
125.	Dr. Virendra Pal Singh	Former Regional Representative for ICRAF- South Asia, World Agroforestry Centre, CGIAR
126.	Dr. Zeyaur R. Khan	International Centre of Insect Physiology and Ecology, Nairobi, Kenya

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This is a timely and internationally-important conference addressing the triple challenge of creating a transition towards agricultural and food systems that are more productive, have positive impacts on nature and ecosystem services, and play a significant role in reversing the climate crisis.

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Identifying the synergies and trade-offs among the sustainable development goals related to agri-food systems is one of the greatest challenges of our time. The "Sustainable Agricultural Innovations for Resilient Agri-Food Systems" conference will bring together an impressive diversity of knowledge, disciplines, and viewpoints to build a more holistic approach to food systems.

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Dr. Menale Kassie, International Centre of Insect Physiology and Ecology, Nairobi

It is incredibly meaningful and important that we are having a discussion about sustainable agriculture being held by an ecological society.

Dr. Shannon Olsson, Global Director, the echo network

This international conference on sustainable agricultural innovations for resilient agri-food systems organized by the Indian Ecological Society is very timely.

Dr. Muni Muniappan, IPM Innovation Lab, Virginia Tech, Virginia, USA

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