



Proceedings National Conference on

Sustainable and Climate Resilient Agroecosystems: Innovations and Policy Framework

(April, 28-30, 2026 | SKUAST-Jammu, Chatha)

Editors

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Organizers

Indian Ecological Society, Jammu & Kashmir Chapters



Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu (SKUAST-Jammu) and



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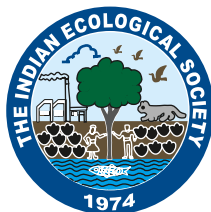
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on

**Sustainable and Climate Resilient Agroecosystems:
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Vice-Chancellor

Foreward

It gives me great pleasure to present the proceedings of the **IES National Conference on “Sustainable and Climate Resilient Agroecosystems: Innovations and Policy Framework”**, focusing on one of the most critical challenges facing agriculture today- climate change. I am pleased to note the overwhelming response from across India, with more than 260 research papers contributed by scientists, academicians, and students, reflecting strong national commitment towards climate-resilient agriculture.

The conference is structured around eight thematic areas covering climate-smart production systems, natural resource management, livestock and allied sectors, agro-biodiversity, digital agriculture and AI, indigenous knowledge systems, policy frameworks, and agri-entrepreneurship. A key highlight is the organization of three special sessions in collaboration with CIMMYT-BISA, IRRI and ICAR-IGFRI, Jhansi, bringing valuable global and national perspectives.

I am confident that this proceedings volume will serve as a valuable resource for advancing scientific knowledge, policy support, and practical solutions for resilient and sustainable agroecosystems. I congratulate the publication team for their commendable efforts and extend my best wishes for the success of this important initiative.

(B.N. Tripathi)

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"An institute for sustainable agriculture for food and nutritional security"

Preface

Agriculture today stands at a critical crossroads, confronted by the unprecedented challenges of climate change, resource degradation, biodiversity loss and increasing demand for food and nutritional security. The urgency to transform conventional production systems into resilient, sustainable and climate-smart agroecosystems has never been greater. Against this backdrop, the IES-National Conference on “**Sustainable and Climate Resilient Agroecosystems: Innovations and Policy Framework**” was conceived as a forward-looking initiative to foster dialogue, innovation, and actionable pathways for strengthening agricultural resilience.

This proceedings volume represents a comprehensive synthesis of scientific advancements, policy perspectives and field-level innovations presented during the conference. It brings together distinguished lead and invited lectures by globally and nationally renowned experts, alongside a large body of peer-reviewed research contributions spanning diverse agroecological regions and production systems. The deliberations encapsulated herein address key dimensions of climate-resilient agriculture, including soil health restoration, climate change adaptation and mitigation, precision and digital agriculture, emerging pest and disease dynamics, and sustainable intensification of cropping systems.

The thematic sections of the volume reflect an integrated and interdisciplinary approach, covering climate-smart breeding and production technologies, soil, water, and natural resource management, livestock and allied sectors, agrobiodiversity and ecosystem services, artificial intelligence and digital innovations, indigenous knowledge systems, and policy, institutional, and market-driven interventions. Special sessions led by premier national and international organizations further enrich this compilation by highlighting scalable solutions such as conservation agriculture, climate-resilient bio-systems, participatory varietal selection, and sustainable intensification pathways across South Asia.

A defining feature of this compendium is its emphasis on convergence-of science with policy, innovation with tradition, and local realities with global frameworks. The contributions underscore the importance of harnessing advanced tools such as genomics, remote sensing, modeling, and nanotechnology, while simultaneously valuing indigenous knowledge and community-led practices. Particular attention has been given to ecologically sensitive regions, including the Himalayan agroecosystems, where climate variability poses unique challenges and demands context-specific adaptation strategies.

This volume is not merely a documentation of scientific outputs; it is a reflection of collective commitment towards reimagining agricultural futures. It aims to serve as a valuable resource for researchers, academicians, policymakers, development agencies, and practitioners, providing both conceptual insights and practical pathways for advancing climate-resilient agriculture.

We place on record our deep appreciation to all authors, reviewers, session conveners, and collaborating institutions for their invaluable contributions. It is our earnest hope that this compilation will stimulate further research, strengthen policy discourse, and catalyze transformative actions towards sustainable, resilient, and inclusive agroecosystems.

Editors



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Lead / Invited lectures



Managing Soil Health for Climate Resilient Agro-Ecosystems

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ABSTRACT

India's agriculture since 1960s is a global success story. With land area of only 2.4% and water resources of only 4%, India is home to 18% of the world's population (~1.48B in 2026) and 31% of the world's livestock (~0.54B in 2026). Major characteristics of India's agriculture, indicative of the success story include: net sown area of 141 M ha but gross sown area of 200 M ha indicating land use intensity of 142%, net irrigated area of 75.5 M ha, and total fertilizer use of 30 million (M) Mg. Between 1947 And 2024, India's population increased from 330M to 1451M (by a factor of 4.39) but food grain production from 50 Mg to 340 Mg (by a factor of 6.8). Yet, the technical potential of food grain production in India is ~550M Mg/yr.

Keywords: Climate-Smart Agriculture Regenerative Agriculture, Soil Health Restoration, Carbon Farming, Sustainable Agro-ecosystems

Input-Intensive Green Revolution

Increase in agriculture production by adoption of Green Revolution technologies is due to adoption of improved varieties, increased rate of fertilization from 0.5 kg/yr in 1950 to 178 kg/ha in 2022 and of pesticide from 0.20 to 0.25 kg/ha, and increase in land area equipped for irrigation from 15 M ha to 75 M ha. In addition to depletion and pollution of water resources, the input-intensive agriculture has also strong adverse impacts on quality of water and air, loss of natural habitat and biodiversity, and degradation of soil on land area of 114 to 147 M ha. Land area prone to accelerated soil erosion is estimated at 64 M ha by water and 9 M ha by wind. In addition to waterlogging (14.3 M ha), salinity/alkalinity (6.7 M ha), acidity (16 M ha), there are several other soil degradation processes which are not accounted for. Important among these are depletion of soil organic matter (SOM) content and plant available nutrients in the root zone, decline in soil structure leading to severe problems of crusting, compaction, removal of topsoil for brickmaking and other industrial uses, and rapid/ad hoc urban encroachment. Furthermore, the Green Revolution has been cereal-centric with focus on three crops (wheat, rice, corn), driven by subsidies and procurements, neglect of traditional food crops (sorghum, millets, pulses and other minor grains), and decline in nutritional quality (contents of micronutrients and protein) of food grains. These adverse environmental effects are attributed to over/unbalanced fertilization, indiscriminate use of pesticides, excessive and flood-based irrigation, uncontrolled and excessive grazing, excessive plowing, in-field burning of crop residues, and use of simple crop rotations with disconnect between crops on the one hand and trees and livestock on the other. Among major limitations of the present food system are: inadequate supply of nutritious and safe food, degraded soils, depleted and polluted waters, contaminated air, dwindled biodiversity, denuded landscape, aggravated emission of greenhouse gases (GHGs), and increase in malnutrition.

The Soil-Centric Green Revolution

There is a strong need for transformation of agro-ecosystems and adoption of those practices which restore natural resources in general and specifically soil and biophysical environments in

particular, conserve and purify water, improve air quality, restore biodiversity, and create emission-negative and nutrition-sensitive agriculture. Furthermore, improved agro-ecosystems must limit global warming to 2° by harnessing the potential of land-based C sink. The increase in food grain production has made India food self-sufficient and even a net exporter of the food. However, there is a need to improve the nutritional quality of food to alleviate hidden hunger. It is also important to reduce food waste (30 to 50% at present), increase access and distribution of food, enhance use of pulses, and adopt the approach of eco-intensification and regenerative agriculture to enhance soil health.

Regenerative Agriculture

Intensive and indiscriminate use of chemicals must be replaced by adoption of soil/environmental restorative approach. In this context, use of the principles of agro-ecology and transformation to regenerative agriculture (RA) is critical to reversing the degradative trends. Any RA inspired by eco-innovation, powered by non-carbon (non-fossil fuel) energy, driven by a circular economy, and supported by re-carbonization of the terrestrial biosphere (soil and trees), especially soil organic carbon (SOC). This is nature-positive agriculture and is based on enhancing eco-efficiency of inputs. The overall strategy is to “produce more from less” inputs (e.g., fertilizers, pesticides, irrigation) and adopt complex farming systems based on integration of crops with trees and livestock. The goal of transformation agriculture is to replace 5 Ds (deplete, degrade, destroy, discard, and dominate) by 5 Rs (reduce, reuse, recycle, regenerate, and restore). Indeed, RA can produce safe and nutritious food while restoring degraded soils and environment. This is the environment-friendly agriculture whereby people live in harmony with nature.

Carbon Farming

An important component of RA is “Carbon Farming”. It implies management of C pools, flows and GHG fluxes at farm level to make agriculture a net sink of atmospheric CO₂ while creating another income stream for land managers. Thus, sequestering atmospheric CO₂ in land-based sinks is similarly to growing C as a new crop or commodity. Land managers should be rewarded for C sequestration at the social value or C at US \$50/credit (1 metric ton of CO₂eq). The social value of C may differ among biophysical and socioeconomic environments. Notable practices of carbon farming (CF) include a system-based conservation agriculture, C-based fertilization (C NPK rather than NPK), and complex farming systems involving integration of crops with trees and livestock. Any supplemental need for nutrients and water must be met by use of drip-fertigation method. Adoption of C-farming practices can increase in total terrestrial C stock comprising of SOC, soil inorganic C (SIC), and tree carbon. The rate of SOC sequestration in soil of Indo-Gangetic Plants of India may range from 0.3 to 0.5 Mg C/ha.

Cooperation with the Private Sector

Implementation of CF approach needs close cooperation between private sector, policy makers, land managers, and academicians. Private sector can play a critical role in translating science into action by: Promoting nature-positive agriculture, increasing access to inputs, and Improving investment in agricultural research, education, and development.

Policy Interventions

Researchers should work with farmers, private sector, and policy makers to identify policies which can promote adoption of RA and CF. Therefore, environmental-friendly acts must be established in relation to: Pure water, Clean air, and Healthy soil. The trinity of acts should have the provision to reward farmers for strengthening of critical ecosystem services. This would imply replacement of subsidies by payments for ecosystem services. To simplify the process, payments

can be based on adoption of recommended management practices (as verified by remote sensing) rather than detailed measurements of soil, water, and air quality parameters.

Need for a Paradigm Shift

It is the right time for bringing about a paradigm shift to make agriculture a solution to environmental issues. This would imply empowering land managers to “produce more from less” by reducing waste, enhancing eco-efficiency, restoring degraded soils, afforesting denuded landscapes, strengthening the landscape biodiversity, and improving the overall empowerment. Furthermore, transformative agriculture is important to not only eliminate hunger and poverty but also to keep global temperatures at safe levels. This requires transformation in a way by which food is produced, consumed, and wastage recycled. The goal is of sustainable management of soil, water and other natural resources for generations to come.

Climate Change Adaptation and Mitigation Strategies in India

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ABSTRACT

India is highly vulnerable to climate change owing to its diverse agro-ecological regions, heavy reliance on climate-sensitive sectors, and increasing demographic and developmental pressures. Rising temperatures, erratic rainfall, frequent extreme weather events, water scarcity, and land degradation are already impacting agricultural productivity, food security, and rural livelihoods. Addressing these challenges necessitates an integrated framework that simultaneously advances climate change adaptation and mitigation. This abstract highlights key adaptation strategies adopted in India, including the development and deployment of climate-resilient crop varieties, diversification of farming systems, conservation agriculture, improved water-use efficiency, agroforestry, and climate-informed risk management advisories. Central to these strategies is the enhancement of soil health, ecosystem services, and adaptive capacity of small and marginal farmers.

Mitigation strategies emphasize reducing greenhouse gas emissions through sustainable land and nutrient management, soil carbon sequestration, efficient use of inputs, renewable energy integration in agriculture, and promotion of low-emission and resource-efficient farming practices. National missions, climate-smart agriculture initiatives, and supportive institutional and policy frameworks play a pivotal role in scaling these interventions. The abstract underscores the critical importance of science-policy integration, institutional strengthening, capacity building, and multi-stakeholder participation for effective implementation. Advancing research, innovation, and policy coherence will be essential to achieve climate-resilient agriculture and sustainable development goals in India.

Keywords: Climate change; Adaptation; Mitigation; Climate-resilient agriculture; Soil health; Climate-smart practices; Sustainable development

Leveraging AI and Sensing for Precision Agriculture

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ABSTRACT

Artificial Intelligence (AI) is characterized as machine intelligence designed to emulate human-like functioning. It serves as a cognitive engine, facilitating analysis and decision-making based on data acquired from various sources. AI processes this acquired information to derive meaningful insights. Thus, AI is renowned for its prowess in big data analysis and pattern recognition and is revolutionizing numerous domains including agriculture and agricultural research. As the world faces increasing pressures from population growth, climate change and food security concerns, AI has emerged as one of the pivotal tools for driving innovations in agricultural research from reactive farming to data-driven precision agriculture for improving productivity and sustainability. The global market for AI in agriculture, valued at approximately US\$1.5 Billion in 2023, is projected to reach US\$10.2 Billion by 2032. This rapid expansion highlights AI's transformative potential in the agricultural sector.

The rapid proliferation of proximal sensors, IoT-based soil and weather stations, unmanned aerial vehicles (UAVs), and satellite platforms has resulted in the generation of high-dimensional and multi-temporal datasets. Traditional statistical approaches often struggle to capture nonlinear relationships and spatial-temporal variability inherent in these datasets. AI techniques, particularly machine learning (ML) and deep learning (DL), are capable of extracting meaningful patterns from such data and uncover complex relationships between environmental factors, crop growth dynamics, and soil health parameters—insights that are often beyond human perception. Artificial Intelligence (AI) has emerged as a transformative enabler for precision agriculture, offering capabilities in data integration, pattern discovery, prediction, optimization, and automation. Recent advances in next-generation AI, including foundation models, generative AI, agentic AI, causal inference, reinforcement learning, and multi-agent systems, offer unprecedented opportunities to model complex agro-ecosystem processes, derive actionable insights, and enable autonomous decision-making. Generative AI (Gen-AI), Deep Convolutional Generative Adversarial Networks (DCGANs), Predictive and Prescriptive AI are emerging as pivotal tools in advancing scalable and intelligent agricultural systems.

Some of the potential applications of AI and Sensor technologies for Precision Agriculture are assessing crop stresses (mainly pests, diseases, nutrients, water, heat etc), forewarning and early detection of pests and diseases, non-invasive rapid estimation of soil fertility, digital soil fertility mapping, predicting yield, high throughput plant phenotyping for developing climate resilient cultivars, AI-powered decision support systems (DSS) integrate information from multiple sources, including weather data, soil conditions, and crop growth stages, to guide automated decision-making and precision interventions. Such systems enhance farmers' capacity to respond proactively to changing field conditions, improve input-use efficiency, and reduce operational costs. In addition, AI-driven robotics and automation are transforming field management by enabling autonomous machinery capable of planting, weeding, and harvesting with high precision. Automated cameras, acoustic sensors, and water quality probes optimize feeding, track behaviour

and biomass, and maintain optimal environmental conditions. Post-harvest, machine vision and sensor-based grading systems ensure consistent quality, enhancing market value and supporting sustainable, high-efficiency aquaculture operations. Precision Livestock Farming (PLF) integrates sensors, IoT, wireless sensor networks, and AI to enable real-time, data-driven livestock management.

Despite the widespread recognition of AI in agriculture and agricultural research, several critical barriers limit its effective adoption. These include the digital divide, limited access to high-quality data, lack of reliable, context-specific data for AI model training and/or interoperability, lack of awareness and technical skills among farmers, high upfront costs for AI technologies and infrastructure, data privacy concerns, regulatory uncertainty etc.

Looking forward, AI is positioned to enable climate-smart, resource-efficient, and sustainable agriculture aligned with national priorities for Viksit Bharat mission. However, We need to work for transparent, explainable, and auditable AI outputs to enhance trust, accountability, and regulatory acceptance of AI-driven interventions. Furthermore, the translational research framework will bridge the gap between innovation and adoption by embedding AI solutions within existing extension systems, policy mechanisms, and agri-service delivery models, thereby ensuring long-term socio-economic impact, farmer empowerment, and strategic value for national agricultural transformation.

The chapter highlights key applications, including soil health assessment using spectroscopy and machine learning, crop monitoring through UAV-based hyperspectral imaging, pest and disease detection using spectral analytics, and AI-enabled drone-based variable rate input application. Emerging approaches such as high-resolution sun-induced fluorescence (SIF) generation and smartphone-based seed phenotyping demonstrate the expanding scope of AI in agricultural research and practice. These innovations have shown measurable benefits, including improved nutrient-use efficiency, reduced input consumption, enhanced productivity, and better environmental sustainability. Despite these advancements, several challenges persist, including data scarcity, limited model transferability, lack of interpretability, infrastructure constraints, and socio-economic barriers to adoption. The chapter emphasizes the need for standardized datasets, physics-informed and explainable AI models, and stronger integration of AI with geospatial and sensing technologies. Looking forward, AI is positioned to enable climate-smart, resource-efficient, and sustainable agriculture aligned with national priorities on Viksit Bharat mission. Achieving this potential will require interdisciplinary collaboration, capacity building, robust policy support, and inclusive technology deployment to ensure benefits reach diverse farming systems across India.

Keywords: Artificial Intelligence, Precision Agriculture, Machine Learning, Climate-Smart Agriculture, Decision Support Systems (DSS)

L4

Impact of Climate Change on the Emergence and Re-emergence of Crop Pests and Diseases

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ABSTRACT

Climate change and the most significant associated change in the form of global warming in recent decades are of overwhelming concern to agriculture worldwide. The global temperatures have been gradually rising since the 1980s. We have just experienced a stretch of the 11 hottest years on record (2015-2025) ^[1]. Even more alarming is the forecast that the trend may continue with a significant impact on agricultural production, especially in India. Climatic changes can influence the emergence and re-emergence of pests and diseases by expanding their geographic distribution and accelerating the metabolism, reproduction, and survival of pests and pathogens, resulting in more generations per year and increased vector-borne disease transmission. We have witnessed, massive outbreaks (2019–2021) of locusts in East Africa, Middle East, South Asia linked to unusual rainfall cycles resulting in devastation of crops within hours; emergence of new virulent strains of wheat rust complex specially UG 19, spreading across Africa, Middle East, Asia threatening global wheat security; spread of whitefly transmitted begomoviruses in new geographical areas devastating a variety of crops. These are just indicative of the ominous threat to global food security. It is time to revive the enthusiasm and energy that ushered the Green Revolution and take urgent steps to plan and establish a robust system for integrated pest management supported by real-time monitoring of climate and pest and pathogens, and development of prediction tools, to save food production system from devastating consequences of the emerging pest and disease challenges and ensuring food security for the growing population for the next 50 years when the world population will peak and then stabilize.

Keywords: Climate change; Global warming; Emerging pests and diseases; Integrated pest management; Food security; Pest surveillance.

Temperate Horticulture and Climate Change: India Perspectives

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ABSTRACT

Temperate horticulture, a vital component of the agrarian economy in high-altitude regions, is increasingly susceptible to the multifaceted pressures of global climate change. Over the last century, global average surface temperatures have risen by approximately 1.3°C relative to the pre-industrial baseline (1861–1890), with much of this warming concentrated in the last five decades. Parallel to this thermal shift, atmospheric carbon dioxide (CO₂) levels have surged from roughly 300 ppm in the early 20th century to a record 422.8 ppm in 2024, as documented by the National Oceanic and Atmospheric Administration (NOAA). While elevated CO₂ can theoretically enhance photosynthetic rates, these benefits are frequently negated by the deleterious effects of "terminal heat stress" and erratic precipitation patterns. In India, peer-reviewed studies and government reports from the Ministry of Earth Sciences indicate that the Himalayan regions are warming at rates higher than the national average, leading to a significant reduction in cumulative snowfall and a shortening of the winter season, both of which are critical for the phenological cycle of temperate crops. The impact on apple cultivation, the cornerstone of India's temperate fruit industry, has been particularly profound. Apples require specific chilling hours (typically between 800 to 1,200 hours below 7°C to break dormancy and ensure uniform flowering. Data from the Indian Council of Agricultural Research (ICAR) and the National Innovations in Climate Resilient Agriculture (NICRA) reveal a consistent decline in chilling units in traditional growing belts like Himachal Pradesh and Jammu & Kashmir. This has forced a documented altitudinal shift; in the Shimla district, apple orchards below 1,500 meters have seen productivity drops of 40-50%, leading farmers to replace traditional 'Royal Delicious' cultivars with low-chilling varieties or alternative crops like pomegranate and kiwi. Furthermore, the increased frequency of extreme weather events, such as hailstorms during the fruit-setting stage and heatwaves during maturation, has led to physiological disorders including fruit cracking, sunburn, and poor color development, significantly reducing the market value of the produce.

Beyond apples, other temperate fruits such as pears, peaches, plums, and apricots are facing similar climatic bottlenecks. Research highlights that warmer springs are triggering premature blooming, making these crops highly vulnerable to sudden late-season frosts that can destroy an entire season's yield. The data show that while the total area under horticulture in India has expanded, the productivity of temperate fruits has struggled to keep pace with this expansion due to these abiotic stressors. Mitigation strategies now focus on the development of climate-resilient genotypes and the adoption of precision technologies like anti-hail nets and micro-irrigation to combat moisture stress. However, the long-term sustainability of temperate horticulture in India remains contingent upon localized adaptation strategies that account for the rapid 1.5-2.0 ppm annual increase in CO₂ and the persistent upward trajectory of global temperatures, which threaten to render current mid-hill production zones unviable by the end of the 21st century.

Keywords: Climate change, Chilling hours, Apple cultivation, Heat stress

Changing Himalayan Landscapes and Options for Sustainable Natural Resource Management

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ABSTRACT

In biologically rich and topographically complex Himalayas sustainably managed mountain landscapes are key to confronting and overcoming the challenges posed by ever increasing human population, urbanization and land sealing driving the demand for increased food, water, energy, economy and livelihoods requirements in the upstream and downstream of the Himalayas. Climate extreme events have only unfolded different types of disasters (e.g., droughts, cloud bursts) that are challenging the existing land use practices. Climate Change scenarios, exacerbation of infrastructure and other multi-sectoral investments in to Himalayan landscape where geopolitical tensions are high are expected to further intensify impacts since the region is already affected by unplanned urbanization, mass tourism, infrastructure expansion and degraded forest and rangelands. Shift from traditional to input-intensive agriculture and horticulture have only contributed to land degradation and resource depletion. However, simply adopting sustainable field practices and new technologies is usually insufficient to provide the full complement of socio-ecological and economic benefits required from rural landscapes. A broader, spatially explicit landscape perspective is needed so as to address the dynamics, linkages, synergies, and trade-offs among multiple objectives, lands units, and stakeholder interests, as well as to manage or overcome conflicts. To sustain these services, these landscapes need to be managed as a mosaic of integrated socio-ecological systems, linking upstream and downstream conservation actions with local level adaptation strategies. A coherent institutional response that provides highest level of coordination at national, state and local level among various actors and sectors will be needed to realize the vision of sustainable natural resource management. Ongoing strategic planning, mountain specific policy-practice communication and coherence among the mountain states, knowledge management, and linkage with national ministries/programs and private sector are recommended.

Keywords: Himalayan landscapes; Sustainable resource management; Climate change; Mountain ecosystems; Integrated landscape management.

Advancing Sub-Seasonal Monsoon Prediction for Agriculture: Integrating Extended Range Forecasts with Crop Insurance Frameworks

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ABSTRACT

The Southwest (SW) monsoon season (June to September) accounts for the major share of annual rainfall over India and plays a decisive role in agricultural production, water availability, and rural livelihoods. Despite improvements in seasonal forecasting, the pronounced intra-seasonal variability of the monsoon ranging from fortnight to a few months - reflected in fluctuations in onset, active-break cycles, and uneven spatial distribution—continues to induce significant uncertainty in agricultural decision-making at policy to farm level. These variations often coincide with sensitive crop growth stages, thereby increasing the risk of yield loss, particularly in rainfed regions. Timely distribution of input resources viz. seed, fertilizer etc is also affected adversely. In this context, Extended Range Forecasts (ERF), which provide weather outlooks at lead times of about 2–4 weeks, have emerged as a useful intermediate tool bridging the gap between short-range forecasts and seasonal predictions.

The present study proposes an integrated framework for the application of ERF in agriculture, with particular emphasis on its linkage to crop risk management and insurance applications. The approach is based on a hybrid strategy combining dynamical model outputs with data-driven techniques. The dynamical component utilizes a suite of coupled General Circulation Models (GCMs) commonly used in extended range prediction systems. These include models such as the Climate Forecast System version 2 (CFSv2), multiple configurations of the GFDL coupled models, COLA-RSMAS-CCSM4, and Canadian modelling systems including CanCM4i, CanSIPS, and GEM-NEMO. These models represent fully coupled atmosphere–ocean–land systems (with some anomaly-coupled configurations) and operate at horizontal resolutions ranging from about T42 (~250 km) to T126 (~100 km), with ensemble sizes typically varying between 10 and 24 members.

For instance, the CFSv2 system, widely used in operational forecasting, employs a spectral resolution of T126 with 64 vertical levels and includes multiple ensemble initializations generated at frequent intervals. Similarly, GFDL model variants operate at T42 resolution but differ in ocean coupling configurations and ensemble sizes, while systems such as CanCM4i and GEM-NEMO incorporate higher vertical resolution and coupled sea-ice processes. These models generate forecasts up to monthly and seasonal lead times, but their outputs are adapted here for sub-seasonal applications using weekly initialization cycles. The availability of long-term hindcast datasets, typically spanning 20–30 years, allows for robust estimation of model climatology and systematic biases. Rather than relying on a simple ensemble mean, a skill-based Multi-Model Ensemble (MME) approach is adopted.

In this framework, model outputs are combined using both deterministic and statistical techniques, including weighted ensemble averaging and regression-based methods. Techniques such as singular value decomposition (SVD)-based multiple regression, supervised principal component regression (Sup-PCR), and canonical correlation analysis (CCA) are used to extract dominant modes of variability and improve forecast skill. These approaches allow the incorporation

of predictor–predictand relationships and help reduce systematic errors associated with individual models. These methods are trained using a combination of model reforecasts, observed rainfall datasets, and large-scale climate indices, enabling better representation of non-linear interactions and temporal dependencies in rainfall variability. Observed gridded rainfall data at $0.25^\circ \times 0.25^\circ$ resolution are used as the reference dataset for both model calibration and verification. Since GCM outputs are inherently coarse in spatial resolution, a series of post-processing steps are applied to make them suitable for agricultural applications. Bias correction techniques, particularly quantile mapping, are used to align model outputs with observed climatology. Subsequently, statistical downscaling is performed to derive finer-scale forecasts at district and block levels (of the order of 5–10 km resolution). The downscaled forecasts are then aggregated into weekly and fortnightly time scales and converted into agriculturally relevant indicators such as dry spell probability, wet spell persistence, and indicative soil moisture stress conditions.

An important component of this study is the integration of ERF outputs with crop insurance frameworks. Existing insurance approaches largely depend on historical yield data or end-of-season assessments, which may not adequately capture evolving weather risks during the crop season. The use of ERF introduces a more dynamic perspective, enabling early identification of potential stress conditions such as rainfall deficits during sowing or excess rainfall during critical growth phases. This information can support both farmers and insurance agencies in making more informed decisions. The integration of ERF into crop insurance systems also provides scope for improving risk assessment and reducing uncertainties in loss estimation. Sub-seasonal forecasts can contribute to more realistic risk zonation but dynamic in time, refinement of weather-based index thresholds, and improved alignment between observed crop losses and insurance payouts. In addition, coupling ERF outputs with crop simulation models can provide indicative in-season yield estimates, complementing traditional/ smart approaches such as Crop Cutting Experiments.

The performance of the framework is evaluated using a combination of statistical and application-oriented verification metrics, including root mean square error, correlation coefficients, bias, and probabilistic measures such as Brier score. Categorical verification using contingency tables is also carried out to assess the ability of forecasts to capture extreme events such as prolonged dry spells and heavy rainfall episodes. Particular attention is given to forecast performance during agriculturally sensitive periods. The results suggest that the combined use of multi-model ensembles, statistical techniques, and machine learning approaches improves the representation of intra-seasonal rainfall variability, especially at weekly to fortnightly time scales. These improvements enhance the usefulness of forecasts for agricultural planning and risk management. When linked with crop insurance applications, the improved forecasts provide more reliable inputs for assessing potential losses and supporting timely interventions.

In summary, the study highlights the potential of extended range forecasting as an operational tool for strengthening climate resilience in Indian agriculture. By linking forecast outputs with crop insurance mechanisms such as PMFBY, the approach moves toward a more integrated system where weather information supports both advisory services and financial risk management. With further refinement and operational adoption, such frameworks can contribute to reducing uncertainty, improving decision-making, and enhancing the overall stability of the agricultural sector under a variable monsoon regime

Keywords: Extended Range Forecast, Monsoon Variability, Agriculture, Crop Insurance, Climate Resilience.

Recent Developments and Technological Innovations in Weed Management for Climate-Resilient Agriculture

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ABSTRACT

Weed management is a crucial component of sustainable crop production systems. Globally, weeds account for an estimated 37–45% yield losses when left unmanaged, severely constraining food security and economic stability (Gharde *et al.*, 2018; Rao and Nagamani, 2010). In India, where more than 55% of agriculture is rainfed, the challenge is intensified due to climate change, limited mechanization, and labor shortages. Furthermore, the climate change fundamentally altering the weed-crop dynamics. Elevated CO₂ levels, fluctuating temperature regimes, and erratic rainfall patterns have shifted weed phenology, weed seed dormancy, expanded the geographical range of invasive species, and reduced the efficacy of conventional herbicides through physiological adaptations. In this context, achieving climate-resilient agriculture requires a paradigm shift from reactive chemical control to proactive, technology-driven Integrated Weed Management.

Recent innovations spanning nano-formulations, automation, artificial intelligence, robotics, and biological suppression have redefined global and Indian weed science. Nanotechnology has become a cornerstone of next-generation herbicide delivery, offering controlled release, enhanced selectivity, and reduced ecological footprint. Encapsulated and nano-enabled formulations of diclosulam, metolachlor, sulfentrazone, and pendimethalin demonstrate prolonged weed suppression with minimal residue. Emergence of "Smart Weeding" technologies that leverages the Artificial Intelligence and Machine Learning. Deep learning algorithms, trained on vast libraries of spectral images, now enable real-time, species-specific identification. This precision allows for the deployment of Site-Specific Weed Management via autonomous ground vehicles and Unmanned Aerial Vehicles. These platforms reduce herbicide use by up to 90% through targeted micro-dosing or "see-and-spray" systems, mitigating the environmental footprint and slowing the evolution of herbicide resistance. Parallel developments in automation and robotics through UAVs, AI-based sensors, and laser or electrothermal weeders enable site-specific mechanical and chemical interventions. Biological and allelopathic strategies utilizing fungal pathogens, microbial bioherbicides, and allelochemical-rich crops such as sorghum and sunflower are gaining momentum as chemical-free alternatives. Integrated Weed Management frameworks now merge chemical, biological, mechanical, and digital methods to sustain efficacy and prevent herbicide resistance. Climate-smart and conservation agriculture practices mulching, residue retention, and competitive cultivars further enhance resilience in agroecosystems.

Keywords: Climate Resilience, Controlled Release Herbicide Efficacy, Integrated Weed Management, Nano-herbicides, Nanotechnology, Precision Agriculture, Smart Weeding

Climate-Resilient Agricultural Practices for Enhancing Productivity, Profitability, and Sustainability in Smallholder Cropping Systems

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ABSTRACT

Climate change poses a serious threat to agricultural sustainability, particularly in smallholder farming systems characterized by limited resources and high climate vulnerability. Increasing temperature, erratic rainfall, frequent extreme weather events, and declining natural resource quality are adversely affecting crop productivity, profitability, and food security. Climate-resilient agriculture (CRA) integrates adaptive and mitigation strategies to enhance system resilience while ensuring efficient resource utilization and environmental sustainability. The Climate Resilient Agriculture Programme implemented in Bihar promotes a participatory approach through Krishi Vigyan Kendras to demonstrate climate-smart technologies at village level. Key interventions include precision seed sowing, direct seeded rice, zero tillage, conservation agriculture practices, site-specific nutrient management, nano and biofertilizers, laser land levelling, efficient irrigation methods such as alternate wetting and drying, and water harvesting techniques. Adoption of smart tools like Leaf Colour Chart, SPAD meter, Nutrient Expert decision support system, and drone-based crop management improved input-use efficiency and reduced production costs. Resource conservation practices enhanced soil health, water productivity, and reduced greenhouse gas emissions. Climate-resilient crop varieties, diversified cropping systems, and crop intensification significantly improved farm productivity and profitability compared to conventional practices. The programme demonstrated that integrated climate-smart interventions not only strengthen farmers' adaptive capacity but also promote sustainable intensification and long-term agricultural resilience. These approaches provide a scalable pathway for transforming smallholder agriculture under changing climatic conditions while safeguarding natural resources and ensuring livelihood security.

Keywords: Climate-resilient agriculture; Smallholder farming systems; Conservation agriculture; Resource-use efficiency; Precision nutrient management; Sustainable crop productivity.

Bridging tradition and innovation for resilient farming systems

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ABSTRACT

Climate change poses significant challenges to agricultural sustainability, particularly in ecologically fragile and resource-constrained regions. In this context, the integration of indigenous knowledge systems with innovative agricultural extension services offers a promising pathway toward building climate-resilient farming systems. Indigenous knowledge, developed over generations through close interaction with local environments, encompasses practices such as mixed cropping, seed conservation, organic soil management and traditional water harvesting. These practices are inherently context-specific, cost-effective and environmentally sustainable, contributing significantly to resilience against climatic variability. However, the increasing complexity of climate risks, emergence of new pests and diseases, and market-driven demands necessitate the integration of traditional wisdom with modern scientific approaches. Innovative extension services play a crucial role as a bridge between these two knowledge systems, facilitating knowledge exchange, validation, and dissemination. Approaches such as participatory extension models, digital advisory platforms, climate-smart services and community-based institutions enable the co-creation and scaling of locally relevant solutions. The study highlights the importance of systematically documenting, validating, refining and disseminating indigenous practices through modern extension frameworks. Special emphasis is placed on the Himalayan and Jammu & Kashmir region, where traditional practices like terrace farming, organic nutrient management and local irrigation systems remain vital for sustainable agriculture. Integrating these with advancements such as weather-based advisories, protected cultivation and precision agriculture can significantly enhance productivity and resilience.

Furthermore, the study underscores the need for inclusive and participatory approaches involving women, youth and smallholder farmers, supported by enabling policies and institutional frameworks. The future pathway necessitates the systematic development of digital repositories for indigenous knowledge, the promotion of climate-smart village approaches and the strengthening of last-mile extension delivery mechanisms to ensure effective knowledge dissemination and adoption. Ultimately, the synergistic integration of indigenous knowledge systems with modern extension frameworks has the potential to enhance agricultural sustainability, promote inclusive and equitable rural development and build long-term adaptive capacity and climate resilience within farming systems.

Keywords: Indigenous Knowledge Systems, Agricultural Extension, Climate-Resilient Farming, Climate-Smart Agriculture, Participatory Extension, Sustainable Agriculture

Conservation of Biodiversity in Nepal: Status, Progress and Problems

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ABSTRACT

Nepal, a signatory to the Convention on Biological Diversity since 1994, has developed a robust policy and institutional framework for biodiversity conservation, including the National Biodiversity Strategy (2002), NBSAP (2014–2020), and the recently updated NBSAP (2024–2030) aligned with the Kunming-Montreal Global Biodiversity Framework. The country harbors 30,391 species 12,102 flora and 16,887 fauna-representing 2.7% of global biodiversity across 118 ecosystems and 69 vegetation types. Protected areas cover 23.3% of the national territory, complemented by community-based forest management regimes that now govern over 42% of forestlands through 23,682 community forest user groups, benefiting 2.92 million households.

Conservation achievements include significant recovery of flagship species: tiger populations increased from 120 in 2010 to 355 in 2022, rhinoceros from 544 to 752, and vulture populations rebounded following the 2006 diclofenac ban. Despite these gains, biodiversity remains under pressure from direct drivers—land-use change, climate change (0.056–0.072°C/year warming), invasive alien species (30 species), forest fires (32,898 fires, 2013–2024), overexploitation (50–80% of medicinal plants harvested from wild sources), and human–wildlife conflict (10,426 incidents in 2022–2023). Indirect drivers—weak institutional coordination, policy implementation gaps, erosion of traditional knowledge, and inadequate incentives—have contributed to the loss of over 50% of local crop landraces and the listing of 237 taxa under IUCN Red List categories.

Key recommendations include: expanding community-based management with equitable benefit sharing; integrating indigenous knowledge into climate adaptation planning; accelerating geographical indication registration for unique products; and enforcing sustainable harvest protocols for medicinal plants. Translating existing policies into effective, locally adapted actions remains the central challenge for securing Nepal's biodiversity heritage.

Keywords: Biodiversity Conservation, Community based Management, Climate Change Impacts

Climate-Resilient Legumes: Driving a New Agricultural Revolution for Food and Nutritional Security

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ABSTRACT

Global food systems are facing a unique set of threats that are getting worse due to climate change, soil degradation, and rising nutritional deficiencies that are affecting billions of people around the world. Under this scenario, legumes become fundamental crops that can support a new agricultural revolution that is both adaptable to climate change and transformative for nutrition. Cowpea (*Vigna unguiculata*), soybean (*Glycine max*), mungbean (*Vigna radiata*), and common bean (*Phaseolus vulgaris*) are four most important legumes grown under temperate agro-climatic conditions. Soybean, the most widely grown legume, produces more protein and oil than any other plant. Mungbean and cowpea, a valuable short duration crop, grows quickly and can handle moderate drought. It is a good source of dietary protein and micronutrients, especially iron and folate. Common bean is a staple food in J&K, but it is vulnerable to rising temperatures and irregular rainfall. However, climate-smart varieties have been developed which can tolerate drought up to 17 days and possess wide range of adaptability. These four legumes work together to fix nitrogen in the soil, which makes it more fertile and lessens the need for synthetic fertilisers. Adding them to cropping systems increases agrobiodiversity, protects against yield instability, and directly addresses protein-energy malnutrition and micronutrient deficiencies. Genomics, speed breeding, and climate modelling are all making it easier to create stress-tolerant, high-yielding, and biofortified plants. It is important to have policy frameworks that put legume research, seed system development, and value chain strengthening first. In SKUAST Kashmir a modern breeding and genomic approach led to the development of bio-fortified climate resilient varieties in legumes that give higher yields and survive under changing climatic conditions; which include Shalimar Cowpea 2 and 3, Shalimar Soybean 2 and 3, Shalimar Rajmash 3, 4, 5, 6 and 7; and Shalimar Moong 2 and 3. Climate-resilient legumes are potential tools for achieving food sovereignty, which help to develop a wider range of food products and by-products that can sustain agricultural change in the changing climatic scenario.

Keywords: Legumes, Climate Resilience, Food security, Nutritional Security, Biofortification

Conversion of Agro-Residues into Valuable aromatic biochemical by Bioelectrochemical System

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ABSTRACT

Agricultural residues represent one of the largest renewable biomass resources on Earth, yet a significant fraction remains underutilized and is often disposed of through open-field burning or uncontrolled degradation. These practices contribute to greenhouse gas emissions, particulate pollution, and loss of potentially valuable carbon resources. Lignocellulosic agro-residues such as rice husk, rice straw, wheat straw, and corn stover contain substantial quantities of lignin, cellulose, and hemicellulose, which can serve as feedstocks for producing high-value chemicals. Among these, lignin is an abundant aromatic polymer that can be transformed into value-added compounds such as vanillin, phenolic acids, and other aromatic intermediates. However, conventional chemical depolymerization routes require harsh conditions, high energy input, and generate secondary pollutants. Bioelectrochemical systems (BES), including microbial electrochemical cells (MECs) and microbial peroxide-producing cells (MPPCs), have emerged as promising technologies that integrate microbial catalysis with electrochemical processes to enable sustainable biomass valorization. These systems utilize electroactive microorganisms to convert organic substrates into electrons and protons while simultaneously enabling the in situ generation of oxidants such as hydrogen peroxide (H_2O_2). The generated oxidants can facilitate oxidative depolymerization of lignin into valuable aromatic chemicals. This article discusses the potential of bioelectrochemical systems for converting agro-residues into valuable biochemicals, focusing on lignin valorization through microbial electro-Fenton processes, hydrogen peroxide generation, and integrated wastewater treatment. Recent studies demonstrating the conversion of rice husk lignin into vanillin and other aromatic compounds using microbial electrochemical platforms are highlighted. The integration of biomass conversion, pollutant degradation, and resource recovery in a single system offers significant opportunities for advancing circular bioeconomy and sustainable biorefinery development.

Keywords: Agro-residue Valorization, Lignin Depolymerization, Bioelectrochemical Systems, Microbial Electro-Fenton Process, Circular Bioeconomy, Sustainable Biorefinery.

Development of Climate-Smart Maize: Novel and Innovative Approaches

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ABSTRACT

Climate variability, particularly the increasing frequency and intensity of drought, poses a major constraint to maize productivity worldwide. Developing climate-smart maize varieties with enhanced tolerance to water stress is essential for sustaining yields under rainfed and limited irrigation conditions. This study aimed to evaluate maize genotypes under controlled and field conditions to identify reliable traits and superior genotypes for drought tolerance. A set of maize genotypes was screened under greenhouse conditions with two treatments: water deficit (stress) and well-irrigated (control). Key physiological and morphological traits, including normalized difference vegetation index (NDVI), plant height (PH), and root depth (RD), were assessed to understand plant responses under contrasting moisture regimes. The same genotypes were further evaluated under rainfed field conditions to validate their performance under natural drought stress. Comparative analysis was carried out to assess genotypic variability and interaction effects between genotypes and water regimes. Significant variation was observed among the genotypes in response to drought stress. NDVI emerged as a reliable indicator of drought tolerance, and its combination with plant height and root depth proved effective for predicting stress performance. Several genotypes, including DTPYC-9, ZL-132258, V-357, HKI-488, and ZL-19291, exhibited stable performance with non-significant interactions across treatments, indicating their adaptability under both stress and non-stress conditions. These genotypes also maintained consistent agronomic performance under rainfed conditions. The study highlights the importance of integrating controlled environment screening with field validation for accurate selection of drought-tolerant genotypes. The identified traits and stable genotypes provide valuable resources for breeding programs aimed at improving maize resilience to water stress and ensuring sustainable production under changing climatic conditions.

Keywords: Drought, Maize, NDVI, Phenotyping, Root, Water stress

Genomics-informed Breeding of Temperate Rice: The Convergence of Disease Resistance and Adaptive Allelic Landscapes

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ABSTRACT

Global rice production is increasingly destabilized by the convergence of stochastic abiotic stressors like drought, cold, submergence and the pervasive biotic threat of diseases like rice blast. Climate-driven co-occurrence of drought, cold, submergence and blast disease threaten global rice production, yet breeding for multi-stress tolerance remains constrained by polygenic complexity and trade-offs. While the molecular ontogeny of individual stress responses is well-documented, the synergistic genetic orchestration required for cross-tolerance remains a critical frontier in plant biotechnology. We carried out the comprehensive studies on Rice Genome Panel of SKUAST-K comprising core set of 270 germplasm lines. Based on detailed phenotyping over multiple locations and through controlled chamber assays, alongside Genome-Wide Association Studies (GWAS), genomics/ transcriptomics approaches, we identified seven candidate genotypes that exhibited superior multi-stress resilience profiles. Combined omics and field level experiments revealed that these genotypes leverage distinct adaptive modules. Drought tolerance is primarily driven by the DRO1-mediated deep-rooting architecture and OsbZIP23-regulated osmotic homeostasis. Under cold stress, cellular integrity is maintained through OsICE1-CBF/DREB1 signaling hubs and OsFAD2/3-mediated lipid remodeling to preserve membrane fluidity. Allele mining of important loci revealed significant SNPs and InDels conferring adaptability under cold stress. Submergence resilience in these lines is governed by the SUB1A quiescence sub-program, which suppresses gibberellin-mediated elongation to conserve carbohydrate reserves via OsTPP7 and OsCIPK15 energy-sensing modules. Furthermore, broad-spectrum resistance to *M. oryzae* is conferred by the strategic pyramiding of NLR receptors, including *Pi54*, *Pi9*, and *Pita*, which trigger hypersensitive response upon effector recognition. Major and additional minor QTLs confirmed a polygenic nature of resistance. Our findings as regards blast system suggested the genes that encode NBS-LRR, CC-NBS-LRR proteins. Despite these advancements, a prolific gap in knowledge exists regarding the hierarchical crosstalk between ABA-dependent abiotic pathways and SA/JA-mediated biotic defense networks, which often resulting in deleterious pleiotropic trade-offs. Current breeding efforts are frequently bottlenecked by the "linkage drag" associated with traditional QTL introgression. Integrated GWAS and multi-omics frameworks helped us to delineate high-resolution quantitative trait nucleotides (QTNs). Our approach shift from single-stress to systems-level breeding helped us to dissect the synergistic tolerance mechanisms in elite germplasm lines, which can be further used in breeding programmes and functional genomics studies.

Keywords: Rice, Drought, Cold stress, Submergence, Rice blast, GWAS, multi-stress tolerance

Changing Dry Spell Regimes and Agricultural Risk in India

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ABSTRACT

Indian agriculture, long sustained by the seasonal rhythm of the Indian Monsoon, is increasingly facing new forms of climatic uncertainty. While total seasonal rainfall often receives primary attention, the intra-seasonal distribution of rainfall, particularly the occurrence of dry spells has emerged as a critical determinant of agricultural outcomes. Changing dry spell regimes, characterized by shifts in frequency, duration, and timing, are posing significant risks to crop productivity, especially in rainfed regions that constitute a substantial portion of India's cultivated landscape.

A dry spell is typically defined as a sequence of consecutive days receiving negligible or no rainfall during the cropping season. Even within an otherwise normal monsoon year, prolonged breaks in rainfall can induce moisture stress, disrupt crop phenology, and ultimately reduce yields. Recent studies suggest that the variability in rainfall distribution is increasing, with a tendency toward fewer rainy days but more intense precipitation events. This implies longer dry intervals between rainfall episodes, exacerbating the vulnerability of crops during critical growth stages. The dynamics of dry spells are closely linked to fluctuations in Monsoon circulation and large-scale climate drivers such as the El Niño–Southern Oscillation. During El Niño years, for instance, weakened monsoon circulation often results in reduced rainfall and more frequent dry spells over large parts of India. Additionally, rising temperatures associated with global climate change are intensifying atmospheric moisture demand, often expressed as higher vapor pressure deficit (VPD). This leads to faster depletion of soil moisture, making crops more susceptible to even short-duration dry spells.

The agricultural implications of changing dry spell regimes are profound. Crop growth is highly sensitive to water availability during specific phenological stages such as germination, flowering, and grain filling. A dry spell occurring during these stages can lead to irreversible yield losses. In crops like rice, which dominate the kharif season, water stress during the reproductive phase can drastically reduce grain formation. Similarly, maize, pulses, and oilseeds exhibit significant yield declines under intermittent moisture stress conditions. In rainfed systems, where irrigation support is minimal or absent, the impact is even more pronounced. Spatially, the vulnerability to dry spells varies across regions. Semi-arid and sub-humid zones of central and peninsular India, such as parts of Maharashtra, Karnataka, Telangana, and Odisha, are particularly susceptible due to their dependence on erratic monsoon rainfall. Even traditionally high-rainfall regions are not immune, as changes in rainfall distribution can lead to unexpected dry periods. The risk is compounded in areas with poor soil water-holding capacity, where moisture reserves are quickly exhausted.

Understanding and quantifying dry spell dynamics is essential for developing effective adaptation strategies. Several indices and metrics are employed for this purpose, including the Dry Spell Index (DSI). These indices provide insights into the temporal characteristics of rainfall gaps and help identify periods of heightened agricultural risk. Complementary tools such as the

Standardized Precipitation Index (SPI) are also used to assess meteorological drought conditions at different time scales. Integrating these indices with crop models can enhance the prediction of yield responses under varying dry spell scenarios. Addressing the challenges posed by changing dry spell regimes requires a multi-pronged approach. At the farm level, agronomic interventions such as adjusting sowing dates to align with rainfall onset, adopting short-duration and drought-tolerant crop varieties, and practicing mulching and conservation tillage can significantly reduce vulnerability. Soil and water conservation measures, including farm ponds, check dams, and rainwater harvesting structures, can provide critical supplemental irrigation during dry spells.

Weather-based agro-advisory services play a pivotal role in mitigating dry spell impacts. Institutions like the India Meteorological Department, through initiatives such as Gramin Krishi Mausam Sewa, disseminate location-specific forecasts and advisories that enable farmers to make informed decisions. Timely information on expected dry spells can guide irrigation scheduling, fertilizer application, and pest management practices, thereby enhancing resilience. At the policy level, strengthening crop insurance schemes and promoting climate-resilient agricultural practices are crucial. Programs that support diversification of cropping systems, integration of livestock, and adoption of agroforestry can buffer farmers against climatic shocks. Furthermore, investments in climate research, particularly in high-resolution modelling of intra-seasonal rainfall variability, are essential for improving the predictability of dry spells. Emerging research is also highlighting the compound nature of climate risks, where dry spells often coincide with heat waves, amplifying stress on crops. The interaction between high temperature and moisture deficit can accelerate crop senescence and reduce water use efficiency. Understanding these interactions is critical for designing robust adaptation strategies in the face of climate change.

In conclusion, changing dry spell regimes represent a subtle yet significant dimension of climate variability that has far-reaching implications for Indian agriculture. Moving beyond a sole focus on total rainfall to a more nuanced understanding of its temporal distribution is imperative. By integrating scientific insights, technological innovations, and policy support, it is possible to enhance the resilience of agricultural systems and safeguard food security in an era of increasing climatic uncertainty.

Keywords: Dry spells; Monsoon variability; Rainfed agriculture; Climate resilience; Soil moisture stress; Agro-advisory services.

Biocultural Landscape of the Himalaya: Agriculture, Biodiversity and Sustainable Future

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ABSTRACT

The Himalaya represents a globally significant biocultural landscape where long-standing interactions between human societies and diverse ecological systems have shaped multifunctional agricultural mosaics that sustain both biodiversity and livelihoods. Traditional farming systems such as large Cardamom-based agroforestry, farm-based agroforestry, Mandarin Orange-based agroforestry, subsistence farming, terrace rice cultivation, and agropastoral practices are adapted to the climatic and physiographic conditions, and managed by indigenous communities through their instinctive wisdom. These traditional ecosystems harbour substantial biodiversity and contribute to ecosystem functioning through services such as pest control, pollination, and nutrient cycling. Across the region, different biodiversity components (such as birds, butterflies, odonates) exhibit strong responses to landscape heterogeneity, seasonal dynamics, and cropping practices, with higher diversity often associated with mixed cropping systems, increased tree cover, and structurally complex habitats. Evidence from Himalayan and broader Asian agricultural landscapes indicates that natural and semi-natural elements embedded within farmlands enhance species richness and community stability, while monoculture intensification and expanding human settlements negatively impact biodiversity. Traditional agroecosystems, particularly diverse agroforestry systems, can equate or even exceed adjacent natural forests in maintaining taxonomic, functional, and evolutionary dimensions of biodiversity, while also supporting rare and habitat-specialist species. At the same time, climate change and rapid socio-economic transformations in the Hindu Kush Himalaya threaten these systems by accelerating biodiversity loss and disrupting ecosystem services. Addressing these challenges requires integrated approaches that recognize the ecological and cultural value of traditional land-use systems, maintain habitat heterogeneity, and incorporate multi-dimensional biodiversity assessments into land-use planning. Strengthening biocultural landscapes through policy support, community engagement, and adaptive management is essential for fostering resilient agroecosystems that balance conservation and production. Such approaches are critical for ensuring a sustainable future in the Himalaya, where biodiversity conservation and human well-being are deeply interconnected.

Keywords: Biocultural landscapes; Agroforestry; Biodiversity; Traditional farming; Ecosystem services; Climate resilience.

L18

From Wilderness to Food Systems: Some Novel Additions and Wild Edible Mushrooms as Sustainable Nutritional Resources in Trans-Himalayan Region of Ladakh

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ABSTRACT

Macrofungi exhibit remarkable ecological adaptability, yet their diversity in high-altitude cold desert ecosystems remains poorly documented. This study investigates the diversity, phenology, substrate associations, and adaptive strategies of wild mushrooms in the Trans-Himalayan region of Ladakh. Field observations revealed diverse macrofungal taxa with distinct phenological patterns and substrate specificity, reflecting ecological specialization. Eco-morphological traits such as compact fruiting bodies, thick-walled hyphae, and protective pigmentation indicate adaptations to desiccation and radiation stress. Biochemical analyses further revealed the accumulation of antioxidants and protective metabolites, supporting survival under extreme conditions. Several novel species, including *Lactarius drassinus*, *Lactarius indoevosmus*, *Pleurotus shentelii*, *Hebeloma himalayense*, *Melanoleuca drassina*, *Laetiporus* spp. etc., were documented. Additionally, selected taxa showed high levels of phenols, flavonoids, and carotenoids, indicating strong antioxidant potential. These findings highlight the resilience and ecological importance of macrofungi in nutrient cycling and ecosystem stability, while emphasizing their potential for biotechnological and therapeutic applications.

Keywords: Trans-Himalaya; Ladakh; Cold desert ecosystems; Mushroom diversity; Antioxidant potential.

Transforming Agroecosystems under Climate Change: From Vulnerability to Resilience *Bridging Science, Policy, and Practice through Adaptive and Nature-Based Solutions*

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ABSTRACT

Climate change is fundamentally reshaping agroecosystem structure and function, intensifying biophysical stresses through increased temperature variability, shifting precipitation regimes, and a higher frequency of extreme climatic events. These disturbances disrupt ecological processes, diminish resource-use efficiency, and destabilize productivity, exposing the inherent vulnerabilities of input-intensive, homogeneous agricultural systems particularly in smallholder-dominated landscapes. Transitioning from vulnerability to resilience necessitates the development of adaptive agroecosystems characterized by ecological complexity, functional diversity, and strengthened feedback mechanisms. Agroecological strategies such as crop diversification, crop-livestock integration, conservation agriculture, and precision nutrient and water management enhance soil carbon sequestration, nutrient cycling, and hydrological regulation, thereby improving both resistance and recovery under climatic stress while sustaining long-term productivity. Nature-based solutions further reinforce resilience by harnessing ecosystem services intrinsic to agricultural landscapes. Agroforestry, landscape heterogeneity, biodiversity-mediated pest and disease regulation, and soil-centric interventions including organic matter augmentation and reduced disturbance contribute to microclimate stabilization, carbon sequestration, improved soil structure, and enhanced microbial functionality. These synergistic interactions between biotic and abiotic components strengthen system adaptability and reduce climate-induced risks. Effective transformation, however, depends on the integration of scientific innovation with enabling policy environments and context-specific management practices. Institutional frameworks that support climate-informed decision-making, incentivize sustainable intensification, and promote knowledge exchange are essential for scaling adaptive strategies across regions and production systems. Within smallholder agroecosystems, resilience emerges from the dynamic integration of indigenous knowledge systems and contemporary scientific approaches, fostering locally adapted, resource-efficient, and risk-buffering strategies. Strengthening adaptive capacity in these systems enhances livelihood security while contributing to broader ecological sustainability and development goals. A systemic shift toward diversified, ecology-driven agroecosystems increases functional redundancy, stabilizes ecosystem processes, and enhances overall system resilience. Integrating adaptive management, nature-based solutions, and multi-scalar policy support provides a robust pathway for sustaining productivity, ecological integrity, and resilience in agroecosystems under accelerating climate change.

Keywords: Climate change; Agroecosystem resilience; Agroecology; Nature-based solutions; Crop diversification; Soil carbon sequestration; Ecosystem services; Sustainable intensification; Smallholder agriculture; Adaptive management

Future scenario of Hydroponics and vertical farming in Jammu and Kashmir

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ABSTRACT

The Union Territory of Jammu and Kashmir, with its diverse agro-climatic zones and limited cultivable land, faces unique challenges in ensuring sustainable and high-quality agricultural production. Traditional soil-based farming systems are increasingly constrained by factors such as land fragmentation, erratic rainfall, declining soil fertility, and changing climate patterns. In this context, hydroponics, a soilless cultivation technique that offers a transformative opportunity to enhance productivity, resource-use efficiency, and crop quality. Presently, hydroponic farming in Jammu and Kashmir is at a nascent stage, with pilot-scale units primarily focusing on high-value crops such as lettuce, tomato, cucumber, and exotic herbs, fruits and salads. Supported by academic and research institutions like SKUAST-Jammu and various government initiatives under the Holistic Agriculture Development Programme (HADP), hydroponics is gaining attention as a climate-resilient farming model. Hydroponic systems can be particularly advantageous in regions like Jammu, which experience high temperatures and water scarcity, as well as in Kashmir, where cold winters limit field cultivation. The integration of protected cultivation, automated nutrient delivery, and renewable energy sources further enhances system sustainability. Future prospects lie in scaling hydroponics through public-private partnerships, youth-led agri-startups, and research on region-specific nutrient formulations. Moreover, coupling hydroponics with aquaponics and algal bio-production systems can create circular, low-waste models aligned with the principles of climate-resilient and carbon-neutral agriculture. Therefore, hydroponics represents a forward-looking paradigm for Jammu and Kashmir's agricultural transformation offering a pathway toward higher productivity, reduced environmental footprint, and enhanced livelihood opportunities for future generations.

Keywords: *Climate-resilient agriculture, soilless cultivation, sustainable farming, protected cultivation*

Reimagining Agricultural Futures: Strengthening Market Linkages, Agri-Entrepreneurship, and Startups for Sustainable Food Systems

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ABSTRACT

Agriculture remains central to global food security, rural livelihoods, and economic development, particularly in emerging economies such as India. The sector contributes significantly to national income and sustains nearly half of the country's population. Despite its socio-economic importance, agriculture continues to face persistent structural challenges including fragmented landholdings, inefficient supply chains, inadequate market access, limited value addition, and vulnerability to climate change. These constraints reduce farm profitability and limit the ability of agricultural systems to transition toward sustainability and resilience. In this context, strengthening market linkages, fostering agri-entrepreneurship, and promoting startup ecosystems have emerged as transformative pathways for reimagining agricultural futures and building sustainable food systems.

Market linkages form the backbone of modern agri-food systems by connecting farmers with input suppliers, processors, retailers, and consumers across local, national, and global markets. Efficient market integration improves price discovery, reduces dependence on intermediaries, minimizes post-harvest losses, and enhances income stability for farmers. However, agricultural markets in many developing regions remain characterized by information asymmetry, inadequate infrastructure, and weak institutional support. Smallholder farmers, who constitute the majority of producers in India, often lack access to organized markets and reliable logistics systems, resulting in reduced bargaining power and low price realization. Strengthening physical and digital market infrastructure is therefore essential for ensuring inclusive agricultural growth.

In recent years, agri-entrepreneurship and startups have emerged as key drivers of innovation within agricultural systems. Technology-enabled enterprises are leveraging digital platforms, artificial intelligence, data analytics, mobile advisory systems, and supply-chain innovations to bridge longstanding gaps in agricultural value chains. These startups facilitate direct farmer-to-market linkages, improve transparency, optimize input use, and enable efficient logistics management. By addressing inefficiencies in input delivery, extension services, market access, and financial inclusion, agri-entrepreneurs contribute to productivity enhancement and risk reduction. Nevertheless, the agri-startup ecosystem remains at an early stage of development and faces constraints related to scalability, access to finance, regulatory complexity, and uneven digital literacy among rural populations.

The evolving discourse on sustainable food systems further emphasizes the need to integrate economic efficiency with environmental stewardship and social equity. Increasing climate variability, resource degradation, biodiversity loss, and rising global food demand necessitate a shift toward resilient and climate-smart agricultural models. Sustainable food systems aim to

enhance productivity while minimizing ecological footprints through resource-efficient technologies, precision agriculture, circular economy approaches, and climate-smart practices. Improved market incentives can encourage farmers to adopt sustainable production methods by linking environmental performance with economic rewards.

The intersection of market linkages, agri-entrepreneurship, startups, and sustainability represents a paradigm shift from subsistence-oriented agriculture to innovation-driven, market-responsive agri-food systems. Entrepreneurs play a crucial role in identifying market opportunities, enabling value addition, and developing inclusive business models. Digital technologies such as blockchain, satellite analytics, and mobile platforms enhance traceability, provide real-time market intelligence, and strengthen transparency across value chains. These innovations not only improve farm incomes but also support sustainable production practices by optimizing resource use and reducing waste.

Despite significant progress, several structural barriers continue to limit the effectiveness of this transformation. Limited access to affordable finance constrains both farmers and startups from investing in technology and infrastructure. Inadequate rural infrastructure—including transportation networks, storage facilities, and cold chains—raises transaction costs and contributes to post-harvest losses. Policy fragmentation, regulatory uncertainties, and insufficient institutional coordination further impede innovation adoption. Additionally, the digital divide restricts participation of smallholders in technology-driven agricultural ecosystems. Addressing these challenges requires coordinated policy interventions and multi-stakeholder collaboration.

The paper proposes a strategic reform framework to strengthen sustainable agri-food systems. Key interventions include expanding digital agricultural marketplaces to enhance price transparency and farmer participation; promoting Farmer Producer Organizations (FPOs) to aggregate smallholders and improve bargaining power; improving access to finance through blended funding models and startup incubation ecosystems; and investing in rural infrastructure such as warehouses, logistics networks, and cold storage facilities. Building agri-innovation ecosystems through incubators, accelerators, and public–private partnerships can further stimulate technological adoption and entrepreneurial growth.

Climate-smart agriculture emerges as a central pillar of sustainable transformation. Technologies such as satellite-based advisories, precision irrigation systems, climate-resilient crop varieties, and sustainable input management practices can enhance adaptive capacity while reducing environmental impacts. Strengthening agricultural data ecosystems through artificial intelligence, Internet of Things (IoT), and interoperable digital platforms can support data-driven decision-making and improve risk management at farm and system levels. Equally important is human capital development through capacity building, digital literacy programs, and entrepreneurship training to empower farmers and rural youth.

Public–private partnerships play a critical role in scaling agricultural innovations by combining public institutional support with private sector efficiency and investment capacity. Policy and regulatory reforms aimed at simplifying compliance procedures, improving ease of doing business, and fostering innovation-friendly environments are essential for accelerating agri-entrepreneurship and market integration. Inclusive policy frameworks must ensure that the benefits of technological and market transformation reach smallholders, women farmers, and marginalized communities.

In conclusion, reimagining agricultural futures requires an integrated approach that aligns market efficiency, entrepreneurship, technological innovation, and sustainability objectives. Strengthened market systems can enhance farmer incomes and reduce inefficiencies, while startups and agri-entrepreneurs can drive innovation and value creation. When supported by enabling policies, infrastructure investments, digital ecosystems, and climate-smart practices, this convergence can lead to resilient, inclusive, and environmentally sustainable agri-food systems. The transition toward such systems is essential not only for ensuring long-term food security but also for fostering economic growth, rural transformation, and ecological balance in an increasingly uncertain global environment.

Keywords: Market Linkages, Agri-Entrepreneurship, Agri-Startups, Sustainable Food Systems, Climate-Smart Agriculture, Agricultural Innovation

Climate Resilient Small Ruminant Production: Key Challenges and Strategic Interventions

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ABSTRACT

Climate change has emerged as one of the most significant challenges affecting global agriculture and livestock production systems. Small ruminants, particularly sheep and goats, form the backbone of livelihood security in agro-pastoral regions of India and are highly vulnerable to climatic variability due to their dependence on natural grazing resources. Climate change impacts small ruminant production both directly through heat stress and indirectly through reduced pasture productivity, water scarcity, and altered disease dynamics. At the same time, livestock production contributes to climate change through greenhouse gas (GHG) emissions, primarily methane from enteric fermentation, creating a two-way interaction between livestock systems and climate.

Heat stress disrupts physiological, metabolic, and reproductive functions in small ruminants, leading to reduced feed intake, poor growth performance, impaired fertility, and increased susceptibility to diseases. Rising temperature and humidity also favor vectors such as ticks, flies, and mosquitoes, thereby modifying disease transmission patterns. Nutritional stress resulting from declining forage availability further aggravates production losses under changing climatic conditions.

Climate-resilient small ruminant production requires a dual strategy involving adaptation to climate stress and mitigation of livestock-related emissions. Key mitigation approaches include genetic selection for low methane-emitting animals, improved feeding strategies using high-quality forages, strategic supplementation, grassland management, dietary manipulation, rumen microbial interventions, and emerging biotechnological tools aimed at reducing enteric methane emissions.

Adaptive interventions focus on minimizing heat stress through low-cost housing modifications, provision of shade using locally available materials, adequate hydration, and improved grazing management during cooler periods of the day. Nutritional strategies such as feeding high-quality and low-fiber diets, incorporation of bypass fat, buffers, antioxidants, and silage feeding enhance dry matter intake, stabilize rumen function, and improve metabolic resilience under thermal stress. Genetic improvement programs emphasizing thermotolerant breeds and cellular heat-shock resistance mechanisms further strengthen long-term adaptation.

Developing climate-resilient small ruminant production systems is essential for sustaining rural livelihoods, enhancing livestock productivity, and reducing environmental footprints. Integrated management combining genetics, nutrition, housing, pasture management, and technological innovation offers a sustainable pathway to ensure resilient and environmentally responsible small ruminant production under changing climatic scenarios.

Keywords: Climate Change, Small Ruminant Production, Heat Stress Adaptation, Methane

Roots of Climate-Resilient Agriculture: Tradition Meets Science

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ABSTRACT

The amalgamation of Indigenous Technical Knowledge (ITK) and Western scientific knowledge offers a comprehensive and sustainable approach to climate-resilient agriculture. In the year 2025, about 195 indigenous knowledge practices from 18 agro-ecological zones across India were systematically collected and documented from 36 villages, reflecting the diversity and richness of traditional farming wisdom prevailing under varied climatic and ecological conditions. Developed over generations through farmers' observation and experience, this knowledge provides location-specific, eco-friendly, and cost-effective practices related to seed selection, nursery management, soil fertility enhancement, natural pest and disease control, water conservation, and post-harvest handling. These time-tested practices are well adapted to local agro-climatic conditions and significantly contribute to sustainable crop management. Western scientific knowledge complements these traditional systems through validated technologies, improved crop varieties, precision nutrient management, advanced irrigation methods, and modern plant protection strategies. The integration of these two knowledge systems enhances productivity, resource-use efficiency, and climate resilience while preserving cultural heritage and traditional wisdom. Such a synergistic approach reduces dependency on chemical inputs, promotes environmental sustainability, and strengthens farmers' adaptive capacity to changing climatic conditions, thereby supporting resilient livelihoods and sustainable agricultural development.

Keywords: *Indigenous Knowledge, Climate-Resilient Agriculture, Knowledge Integration, Sustainability, Traditional Wisdom*

Understanding the impact of climate change on the Glacial Reservoir Health of Chenab River System, Indus Basin, North-West Himalayas, India

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ABSTRACT

Due to the change in the precipitation pattern and the temperature rise, glaciers in the Himalayan region have lost significant mass which has significantly imbalanced the Asian Water Tower. As per the recent report of United Nations our Planet earth has entered into the period of “Great Water Crisis”. After the year 1990, 50% of the large lakes of the world have shown water depletion. 70% of the aquifer systems of world have shown progressive decline, since the same period. Nearly one-fifth of the Earth's accessible freshwater is stored in the densely-populated, alluvial floodplains of the Brahmaputra, Ganges, Indus, Irrawaddy and Meghna River Basins in the Himalayan region. The Indus River is a trans-boundary river system that flows through several countries – India, China, Afghanistan and Pakistan. The Indus River Basin covers a land area of ~1 million km² and encompasses various proportions of the total area of Pakistan (65%), India (14%), China (1%) and Afghanistan (11%). Major tributaries that contribute to this river system river emerge from Indian Western Himalayas are Jhelum, Chenab, Ravi, and Sutlej Rivers, from the Indian states of Jammu, Kashmir and Himachal Pradesh. Chenab river is one of the important components of Indus water basin and is the largest glacierized basin of Indian NW Himalayas. The Chenab river basin is has an area of ~18824 km² of which ~14.5% is occupied by glaciers. The river system is formed by the confluence of the Chandra and the Bhaga in Himachal Pradesh; after travelling 144 km, it enters Jammu and Kashmir state and flows southwest to Akhnoor, then it enters Pakistan through Sialkot district. The basin is significantly influenced by the Indian summer monsoon during summer and the westerlies during winter. Studies have revealed that the glaciers of the lower Chenab basin in the State of Jammu and Kashmir (UT) have experienced a significant amount of area loss (Kulkarni *et al.*, 2007) with a total glacial area reduction of 58.55 km² during the timeline of 2000-2020 which accounts for 7.52% of deglaciation. Importantly during 2000-2009 the amount of area loss is seen to be less at 24.39 km² as compared to the subsequent decade of 2010-2020 which is at 34.16km². The glacier area change rate in the regions appears to be at the rate of 2.44 km²/year during 2000-2009 and rate of 3.10 km²/year during 2009-2020 with an average area change rate of 2.79 km²/year during the period of 2000-2020 (Rai *et al* 2024). Concomitant to the recession it has been observed that modifications and formation of the peri-glacial geomorphology has become vigorous (Dhar *et al.*, 2010) resulting in the development of high altitude moraine dammed lakes. Identified moraine dammed lakes in the upstream region can be a potential threat to the Pakal Dul Dam and Bursar Dam sites which are planned to be constructed on the tributaries of these lakes/glaciers (Dhar *et al.*, 2024, Rai *et al.*, 2024). Glaciers in the region are showing recession, where smaller glaciers are more prone to disappearing in the upcoming years. The studies have also revealed that the change in precipitation phase (snow to rain transition) is one of the governing factors which control the glacier's health. The recession and loss of glaciers in the region will affect the water availability and energy generation for this part of the region and also have trans-boundary implications linked to the Indus Water Treaty (IWT).

Keywords: Himalayan Glacier Retreat; Asian Water Tower Imbalance; Indus River Basin Hydrology; Climate-Driven Water Crisis; Transboundary Water Security

Sustainable Fruit-Based Agroecosystems under Climate Change: Integrating Innovation, Adaptation, and Policy Support

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ABSTRACT

Climate change poses unprecedented challenges to fruit-based agroecosystems through rising temperatures, erratic precipitation, increased frequency of extreme weather events, and emerging pest and disease dynamics. These stresses threaten productivity, fruit quality, and the livelihoods of growers, particularly in ecologically fragile and rainfed regions. Sustainable fruit-based agroecosystems offer a viable pathway to enhance resilience by integrating ecological principles with advanced technologies and supportive policy frameworks.

This paper explores a holistic approach to developing climate-resilient fruit production systems by combining innovation, adaptation, and policy support. Technological innovations such as high-density planting, precision irrigation, protected cultivation, climate-resilient rootstocks and varieties, and digital decision-support tools are transforming traditional orcharding into efficient and resource-smart systems. Concurrently, adaptation strategies including diversification of fruit crops, integrated farming systems, soil and water conservation practices, and adoption of organic and natural farming approaches strengthen system stability and ecological balance.

The role of institutions and policy interventions is equally critical in scaling these innovations. The supportive policies for climate-smart agriculture, capacity building, market linkages, risk mitigation (crop insurance), and incentives for sustainable practices are essential to ensure widespread adoption. The experiences from subtropical regions, including varietal development, orchard rejuvenation, and water-use efficiency improvements, highlight the potential of integrated approaches in enhancing productivity, profitability, and environmental sustainability.

The convergence of science-based innovations, location-specific adaptation strategies, and enabling policy environments can significantly transform fruit-based agroecosystems into resilient, sustainable, and economically viable systems. Such integrated frameworks are crucial for ensuring nutritional security, enhancing farmer incomes, and achieving long-term sustainability under changing climatic scenarios.

Keywords: Climate change, Sustainable fruit production, Integrated nutrient management, Varietal development



BISA-CIMMYT & IRRI Special Session-1



SS1.1

Climate-Resilient Agri-Food Ecosystem for South Asia: Creative Innovation Through Improved Agronomic Practices

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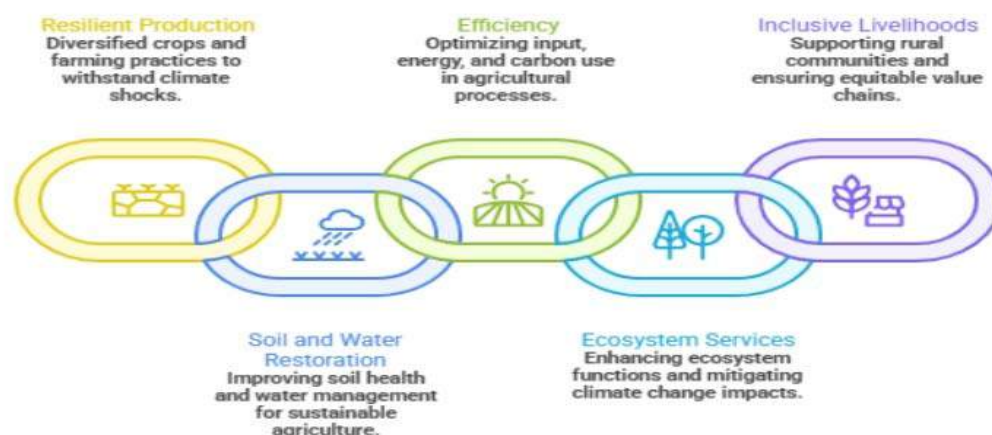
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ABSTRACT

South Asia's agri-food systems face pressure from climate variability, resource degradation, and growing food demands. Past intensification brought self-sufficiency but also groundwater and soil depletion, nutrient imbalances, poor agronomic efficiencies, biodiversity loss, residue burning, and higher greenhouse gas emissions. Addressing these trade-offs requires shifting from input-intensive models to climate-resilient, resource-efficient, and regenerative agri-food ecosystems that sustain productivity amid uncertainty. The Climate-Resilient Agri-Food Ecosystem for South Asia offers a systems-based framework that integrates production, restores ecosystems, adapts to climate change, improves efficiency, and supports inclusive rural livelihoods. It broadens resilience to include soil health, water and energy security, carbon balance, biodiversity, and socio-economic adaptability. The framework encourages moving from isolated crop interventions to system redesign at the landscape level. Long-term research in India shows that climate-resilient strategies such as conservation agriculture, crop diversification, reduced tillage, residue retention, precision nutrient and water management, and tailored appropriate mechanization deliver significant gains in productivity, profitability, and sustainability. These practices improve resource efficiency, soil health, and energy use, while reducing residue burning, irrigation needs, input dependence, and greenhouse gas emissions. Their strong performance under climate stress underscores their importance in developing adaptive, resilient production systems.

Framework for Climate-Resilient Agri-Food Ecosystem



The proposed framework is built on five pillars: resilient, diversified production; soil and water restoration and efficiency; input, energy, and carbon-use efficiency; ecosystem services and climate mitigation; and inclusive livelihoods, institutions, and value chains. Collectively, these pillars advance sustainable intensification and align with national goals such as Aatmanirbhar Bharat and Viksit Bharat @2047.

Transitioning to climate-resilient agri-food ecosystems requires agroecology-focused innovation, long-term trials, comprehensive impact assessment, digital decision tools, and stronger links between research, policy, and extension. This approach seeks to make Indian agriculture more productive, adaptive, low-emission, and regenerative, supporting long-term food, ecological, and livelihood security.

Keywords: Climate-resilient agriculture, Agri-food systems, Sustainable intensification, Resource-use efficiency, Agroecology, Climate adaptation

SS1.2

Digital Agriculture and Climate-Resilient Practices: A Farm-Level Assessment of Productivity and Technology Adoption in Bihar

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Keywords: Digital agriculture, Climate resilience, Yield variability, Farmer adoption, Bihar

1. Background

Climate variability and resource-use inefficiencies continue to constrain agricultural productivity in eastern India, particularly in smallholder-dominated systems. Increasing frequency of erratic rainfall, temperature fluctuations, and soil degradation has intensified production risks and widened yield gaps across agroecological regions. Digital agriculture offers a promising pathway to enhance adaptive capacity by enabling timely access to weather forecasts, market intelligence, and site-specific agronomic advisories. These technologies have the potential to improve input-use efficiency, optimize resource management, and strengthen climate resilience. However, despite growing availability of digital tools, their field-level effectiveness and adoption dynamics remain inadequately quantified, especially under diverse socio-economic and agroecological conditions. Variability in access, digital literacy, and infrastructural support further complicates their integration into farming systems. In this context, the present study evaluates the interaction between digital tool adoption, farm characteristics, and productivity outcomes in smallholder systems of Bihar, with a focus on understanding the extent to which digital interventions contribute to improved resilience and yield performance.

2. Materials and Methods

A structured survey was conducted among more than 300 farmers across agroecological regions of Bihar. Data on socio-economic characteristics, soil type, irrigation access, cropping systems, and digital tool awareness and usage were collected. Farmers were categorized based on digital adoption levels and usage intensity. Descriptive and comparative statistical analyses were performed to assess variability in yield and identify associations between digital adoption and productivity.

3. Results and Conclusion

The analysis revealed substantial heterogeneity in crop productivity, with yields ranging from approximately 800 to 3000 kg acre⁻¹, indicating a yield differential of more than threefold across farms. Irrigation access emerged as a critical determinant of yield stability, with irrigated farms consistently exhibiting lower variability and relatively higher productivity levels. Soil type also influenced yield outcomes, with loam soils demonstrating comparatively better performance than sandy and clayey soils, reflecting improved moisture retention and nutrient availability. Digital agriculture adoption exhibited a positive but non-linear association with productivity. Farmers with moderate to high digital engagement demonstrated relatively higher yields, with an estimated improvement in the range of 10–15% compared to low-adoption farmers, suggesting enhanced decision-making and resource-use efficiency. However, despite widespread awareness, actual utilization remained limited, indicating a significant adoption gap. The relationship between digital access and productivity was mediated by usage intensity, implying that mere availability of tools

does not translate into improved outcomes unless supported by effective and regular use. Constraint analysis highlighted key barriers including language limitations, inadequate digital literacy, connectivity issues, and cost-related constraints, which collectively restricted the effective integration of digital tools into farming systems. These findings suggest that digital agriculture currently functions as a supplementary support mechanism rather than a fully embedded component of farm management. From a systems perspective, the results emphasize that while digital tools have the potential to reduce yield variability and improve climate resilience, their impact is contingent upon integration with localized agronomic practices and user-centric delivery systems. Future research should focus on developing context-specific digital advisory platforms, integrating real-time soil and climate data, and strengthening capacity-building frameworks to bridge the gap between awareness and effective adoption.

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Climate-Resilient Bioformulations (CRBs): Omics-Based Discovery of Nitrification Inhibition Traits

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Keywords: Biological nitrification inhibition, maize husk extract, metabolomics, metagenomics, nitrogen cycling

1. Background

Nitrogen losses through nitrification, leaching, and gaseous emissions significantly reduce fertilizer use efficiency and contribute to environmental degradation, particularly in intensive agricultural systems. It is estimated that a substantial proportion of applied nitrogen is lost from soils, leading to reduced agronomic efficiency and increased risks of groundwater contamination and greenhouse gas emissions. Nitrification inhibition (NI) has therefore emerged as a promising strategy to mitigate such losses by slowing the microbial conversion of ammonium to nitrate, thereby improving nitrogen retention within the soil–plant system. Traditionally, NI has been associated with plant root exudates and synthetic inhibitors; however, these approaches are often constrained by variability in effectiveness, cost, and environmental persistence. In this context, there is a growing need to explore alternative, sustainable sources of NI-active compounds. Crop residue–derived products, conceptualized as Climate-Resilient Bioformulations (CRBs), represent an emerging and underexplored avenue for enhancing nutrient-use efficiency while promoting circular bioeconomy principles. Maize husk, an abundant and underutilized agricultural residue, is rich in secondary metabolites and organic compounds that may influence microbial processes in soil. Its transformation into bioactive formulations offers a dual opportunity for waste valorization and functional nutrient management. Despite this potential, the biochemical and microbial mechanisms underlying residue-derived NI remain poorly understood. In this study, we investigate maize husk extract (MHE) and its micronutrient-incubated derivative (MHEM) as potential sources of nitrification inhibition traits using integrated multi-omics approaches. By combining metabolomic and metagenomic analyses, the study aims to elucidate the chemical diversity, microbial interactions, and functional pathways associated with NI activity, thereby providing a novel framework for developing climate-resilient, resource-efficient bioformulations.

2. Materials and Methods

Maize husk samples were collected from different agroecological zones and processed to prepare aqueous maize husk extract (MHE). A micronutrient-incubated formulation (MHEM) was developed by incubating MHE with Fe–Zn solution under controlled conditions. Untargeted metabolomic profiling was conducted using LC-MS to identify bioactive compounds, while metagenomic sequencing was performed to analyze microbial community composition and functional pathways. Diversity indices and pathway enrichment analysis were used to evaluate nitrogen cycling potential. Integrated multi-omics analysis was performed to establish metabolite–microbe–function relationships.

3. Results and Conclusion

Metabolomic profiling revealed a high degree of chemical diversity in maize husk extract (MHE), with ~1,900 detected peaks corresponding to over 900 annotated metabolites, confirming its intrinsic biochemical richness. Key compounds such as coumarin, umbelliferone, and allantoin were among the dominant metabolites, all of which are reported to influence microbial nitrogen transformations and are associated with nitrification inhibition potential. Micronutrient incubation further amplified this diversity, with the micronutrient-incubated derivative (MHEM) exhibiting >3,100 detected peaks and ~1,100 annotated metabolites, including the emergence of functionally relevant compounds such as valine, cerulenin, and bromacil. Notably, a substantial fraction of metabolites (~400+) were unique to MHEM, indicating that incubation not only preserves but significantly transforms the biochemical profile of the extract. Microbial community analysis demonstrated a distinct shift in community structure following incubation. While MHE was relatively enriched with Actinobacteria and genera such as *Streptomyces*, MHEM showed a pronounced increase in Proteobacteria (~45–50%), along with enrichment of functionally important genera including *Bacillus* and *Rhizobium*. Diversity indices indicated enhanced microbial richness and evenness in MHEM (e.g., higher Shannon and Chao1 indices), while beta diversity analysis confirmed clear separation between MHE and MHEM communities, reflecting strong incubation-driven restructuring.

Functional pathway analysis further supported these shifts, with MHEM exhibiting enrichment of nitrogen cycling pathways, including ammonia oxidation (*amoA*), hydroxylamine oxidation (*hao*), nitrate reduction, and nitrite reduction processes, suggesting a reconfiguration of microbial functional potential toward nitrogen transformation dynamics. The integrated metabolomic–metagenomic evidence indicates that metabolite diversification and microbial restructuring act synergistically to enhance the nitrification inhibition potential of the formulation. These findings confirm that Climate-Resilient Bioformulations (CRBs) derived from maize husk possess intrinsic biological nitrification inhibition capacity, which is significantly enhanced through micronutrient incubation. The study demonstrates a novel residue valorization pathway, where agricultural waste is transformed into a dual-function bioformulation capable of both micronutrient delivery and modulation of nitrogen cycling processes. This approach offers a promising strategy for improving nitrogen use efficiency, reducing environmental nitrogen losses, and advancing climate-resilient, resource-efficient agroecosystems.

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UAV-Based Weed Management in Rice-wheat Systems for Enhancing Sustainability and Climate Mitigation under Conservation Agriculture

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Keywords: Conservation agriculture, precision agriculture, UAV, climate change mitigation, zero-tillage, weed control efficiency

1. Background

The rice-wheat system is vital to global food security, but traditional agricultural practices, including transplanted rice and conventional tillage, are associated with soil degradation, greenhouse gas emissions, diminished climate resilience and economics. These practices exacerbate the impacts of climate change, contributing to methane emissions and carbon depletion. Conservation agriculture (CA), particularly Zero-Tillage Direct Seeded Rice (ZT-DSR) and Zero-Tillage Wheat (ZT-Wheat), has been identified as a sustainable alternative, enhancing soil fertility, improving water use efficiency, attaining food security and reducing GHG emissions. However, effective weed management remains a significant challenge in CA, as traditional herbicide application methods are labour-intensive, costly, and environmentally harmful.

This study aims to evaluate the potential of unmanned aerial vehicle (UAV)-based herbicide applications as a precision agriculture technology for improving weed control efficiency, reducing herbicide usage, and enhancing climate change mitigation in rice-wheat systems under conservation agriculture. Specifically, it investigates how UAV-based spraying can improve resource efficiency, reduce environmental impact, and increase farm profitability in zero-tillage direct-seeded rice (ZT-DSR) and zero-tillage wheat (ZT-Wheat) systems.

2. Material and Methods

Field experiments were conducted over two consecutive growing seasons of *kharif* and *rabi* (2022–2023 and 2023–2024) at the Borlaug Institute for South Asia (BISA) in Bihar, India. Three herbicide concentrations (75%, 100%, and 125% of the recommended dose) were applied at three UAV altitudes (2.5, 3.5, and 4.5 meters). The primary outcomes measured included weed control efficiency, crop yield, herbicide use, and economic viability.

3. Results & Conclusion

UAV spraying at 3.5 meters achieved the highest weed control efficiency (97.16%), resulting in significant yield increases of 48% in wheat and 38% in rice compared to untreated plots. Applying 75% of the recommended herbicide dose reduced herbicide costs by 25%, while maintaining a yield advantage of up to 57% over the weedy check and 16% over conventional backpack spraying. Economic analysis demonstrated that UAV-based herbicide application generated 38.04% higher net returns than the untreated control and 16.22% higher net returns than traditional spraying methods.

This study demonstrates that UAV-based herbicide applications are a viable and efficient tool for weed management in Zero-Tillage Direct Seeded Rice (ZT-DSR) and Zero-Tillage Wheat (ZT-Wheat) systems under Conservation agriculture. UAV spraying not only improves weed control

but also reduces input costs, minimizes environmental impact, and enhances crop productivity. By reducing herbicide use and optimizing resource application, UAV technology contributes significantly to climate change mitigation by lowering emissions and improving soil health. The findings suggest that UAV-based herbicide applications, as a form of precision agriculture, can play a crucial role in enhancing the sustainability of conservation agriculture systems. By improving resource efficiency, reducing chemical inputs, and mitigating environmental damage, UAV spraying represents a scalable solution for addressing climate change in agriculture. The integration of this technology into Zero-Tillage Direct Seeded Rice (ZT-DSR) and Zero-Tillage Wheat (ZT-Wheat) systems provides a pathway for more climate-resilient farming practices, ultimately contributing to global efforts to reduce agriculture's carbon footprint and increase food production sustainability.

Unravelling the Genetic Basis of Early Flowering in Rice under Optimized Speed Breeding Conditions

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Keywords: Speed breeding, Speed Flower, GWAS, Early flowering, Superior Haplotypes, Rice

1. Background

Rice (*Oryza sativa* L.) is a staple food for more than half of the global population, yet current yield gains are insufficient to meet future food demands. Conventional breeding approaches are constrained by long generation times, seasonal limitations, and variable flowering behaviour. Speed breeding has emerged as a promising approach to accelerate genetic gain by manipulating environmental factors such as light spectrum, intensity, photoperiod, temperature and hormones. Optimizing these parameters can significantly reduce flowering time and enable multiple generations per year. However, the genetic basis of early flowering under controlled speed breeding conditions remains poorly understood. Therefore, the present study aimed to develop an optimized speed breeding protocol in rice and identify genetic factors controlling flowering time using genome-wide association studies (GWAS).

2. Materials and Methods

To accelerate breeding cycles and overcome limitations of long generation time in rice, a speed breeding approach was adopted under controlled environmental conditions. Accordingly, SpeedFlower protocol optimization was carried out by fine-tuning key parameters such as light spectrum, light intensity, temperature, and humidity using representative rice genotypes comprising early, medium, and late maturing varieties belonging to indica, japonica, and landraces (Kabade *et al.*, 2023). Three major experiments were performed for optimization. First, light optimization was conducted by evaluating different light spectrum combinations (2R>1B, 2B>1R, and R=B) at two intensities (400 and 800 $\mu\text{mol m}^{-2} \text{s}^{-1}$) under a 10-hour photoperiod to determine conditions favourable for early flowering. Second, photoperiod optimization involved the application of extended photoperiods (20, 22, and 24 hours) for 6–15 days during early plant growth, followed by a shift to a 10-hour short-day photoperiod to induce flowering. Third, seed maturity acceleration was achieved by harvesting immature seeds at 9–15 days after anthesis and treating them with different concentrations of gibberellic acid (GA_3) ranging from 20 to 80 ppm to reduce generation time. Based on these experiments, a robust speed breeding protocol, termed SpeedFlower, was developed.

Subsequently, phenotyping was carried out using the optimized SpeedFlower protocol on a subset of 412 rice accessions from the 3K-RGP, representing indica, japonica, aus, aromatic, and admixture groups. Multi-locus genome-wide association studies (GWAS) were conducted to identify marker–trait associations (MTAs) and superior haplotypes associated with flowering time.

3. Results and Conclusion

The optimized SpeedFlower protocol enabled early and synchronized flowering within 52–60

days, facilitating 4–5 generations per year in rice under controlled conditions.

GWAS analysis identified 60 significant MTAs associated with flowering time, 6 of the identified candidate genes in our study were directly associated with flowering-time genes, including *Ghd7.1/DTH7*, *Hd5*, *OsCTR2*, *OsPLC1*, *OsFLZ2*, and *Hd18*. Among these, 8 MTAs were consistent across multiple models, indicating their robustness. A total of 699 candidate genes were identified, involved in flowering regulation, light response, hormone signaling, and stress pathways.

To identify superior haplotypes associated with early flowering, we conducted haplo-pheno analysis along with Duncan's test on 699 candidate genes.

The focus was on early flowering, specifically within the range of 48 to 60 days to flowering (DTF), which is considered the optimal period for early flowering under speed breeding irrespective of early, medium and late duration entries of rice. Among the 53 superior haplotypes identified from the 699 candidate genes, one haplotype (H107; LOC_Os02g32610) was detected in the flowering time-controlling gene *OsCTR2*, located on chromosome 2. The entries carrying the superior haplotype consistently recorded days to flowering below 60 days. These findings demonstrate that manipulation of environmental conditions combined with genetic analysis can significantly accelerate breeding cycles.

In conclusion, the SpeedFlower protocol offers a powerful platform to enhance genetic gain in rice breeding programs, while identified MTAs and haplotypes provide valuable targets for developing climate-resilient and early maturing rice varieties.

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Productivity and System Performance of Conservation Agriculture-Based Diversified Cropping Systems in the Eastern Indo-Gangetic Plains

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Keywords: Conservation Agriculture, Zero Tillage, Permanent Bed, Rice Equivalent Yield

1. Background

Agriculture in the Eastern Indo-Gangetic Plains (EIGP) is primarily based on cereal cropping systems, especially rice–wheat, which have been vital for food security. However, these systems face declining productivity, higher production costs, delayed crop establishment, soil degradation, residue management challenges, and inefficient use of water, nutrients, and energy. Conventional tillage, though common, often increases soil disturbance and resource depletion, reducing system resilience under changing climate and socio-economic conditions.

Conservation agriculture (CA) practices, including zero tillage (ZT) and permanent bed planting (PB), are emerging as effective alternatives to conventional tillage. These methods enable timely sowing, reduce fuel and labour needs, improve soil conditions, enhance residue retention, and increase resource-use efficiency. Additionally, diversifying crops beyond rice and wheat, by including maize, soybean, and lentil, is recognised as a key strategy to improve productivity, profitability, and sustainability.

2. Material and Methods

A long-term field experiment was conducted from 2013–14 to 2018–19 at Bihar Agricultural University, Bihar, India (87°02'42" E, 25°15'40" N; 37 m above sea level). The split-plot design assigned crop establishment and tillage practices to main plots and cropping systems to subplots. Three crop establishment methods—zero tillage (ZT), permanent bed (PB), and conventional tillage (CT)—were tested with six cropping systems: rice–wheat (RW), rice–maize (RM), rice–lentil (RL), soybean–maize (SM), maize–wheat (MW), and maize–maize (MM). Productivity was assessed by total biomass, crop yield, harvest index (HI), rice equivalent yield (REY), and system rice equivalent yield (SREY).

3. Results and Conclusion

Significant differences were observed among cropping systems and tillage treatments each year. Although weather variations influenced specific values, the relative performance of each system remained stable. During the kharif season, maize–maize (MM) and maize–wheat (MW) consistently produced the highest biomass (MM: 10.4–12.8 t ha⁻¹; MW: 10.2–12.8 t ha⁻¹), grain yield (MM: 4.7–5.6 t ha⁻¹; MW: 4.6–5.6 t ha⁻¹), and rice equivalent yield (REY) (MM: 4.50–6.43 t ha⁻¹; MW: 4.37–6.30 t ha⁻¹). In contrast, soybean–maize (SM) had lower biomass (2.4–3.3 t ha⁻¹), grain yield (0.8–1.2 t ha⁻¹), and REY (1.43–2.60 t ha⁻¹). Among rice-based systems, rice–maize (RM) achieved higher kharif REY (4.01–4.53 t ha⁻¹) than rice–wheat (RW; 3.60–4.48 t ha⁻¹) and rice–lentil (RL; 4.13–4.47 t ha⁻¹), with rankings consistent across years. These results confirm the

reliability of system performance trends. During the rabi season, maize-based systems (RM, SM, and MM) consistently outperformed non-maize systems (RW and RL). Maize–maize (MM) recorded the highest total biomass (15.9–21.9 t ha⁻¹), grain yield (7.77–10.77 t ha⁻¹), and REY (7.4–12.2 t ha⁻¹). Rice–maize (RM) and soybean–maize (SM) also performed well, with RM producing 14.7–18.5 t ha⁻¹ biomass, 7.37–9.90 t ha⁻¹ grain yield, and 7.4–9.6 t ha⁻¹ REY, and SM producing 14.9–22.1 t ha⁻¹ biomass, 7.37–10.47 t ha⁻¹ grain yield, and 7.5–10.0 t ha⁻¹ REY. Rice–lentil (RL) had the lowest productivity, with 2.8–3.3 t ha⁻¹ biomass, 1.43–1.67 t ha⁻¹ grain yield, and 3.2–4.9 t ha⁻¹ REY. These results show that maize-based systems outperformed non-maize systems across all key metrics. The harvest index also confirmed this, with maize-based systems demonstrating higher partitioning efficiency (HI of 0.49–0.55, especially in RM and SM).

System-wide, conservation tillage combined with crop diversification produced higher productivity than conventional tillage. Zero tillage maize–maize (ZT-MM) achieved the highest system rice equivalent yield (SREY), rising from 12.4 t ha⁻¹ in 2013–14 to 18.5 t ha⁻¹ in 2018–19. Permanent bed maize–maize (PB-MM; 12.0–18.5 t ha⁻¹) and zero tillage rice–maize (ZT-RM; 11.6–13.9 t ha⁻¹) also performed well, while permanent bed rice–maize (PB-RM) recorded SREY values of 11.5–13.9 t ha⁻¹. Among diversified systems, permanent bed soybean–maize (PB-SM) and zero tillage soybean–maize (ZT-SM) showed moderate productivity (9.0–12.3 and 9.1–12.5 t ha⁻¹, respectively). Conventional tillage systems, such as rice–wheat (CT-RW) and rice–lentil (CT-RL), were least productive, with SREY typically between 7.5–9.0 and 7.8–8.6 t ha⁻¹. (Ten years of conservation agriculture in a rice–maize rotation of Eastern Gangetic Plains of India: Yield trends, water productivity and economic profitability, 2019, pp. 1-12) These results show that zero tillage and permanent bed planting matched or exceeded conventional tillage, especially in maize–maize, rice–maize, and soybean–maize systems. (Rashid *et al.*, 2019, pp. 683-710)

Overall, conservation tillage combined with crop diversification significantly improves crop productivity and system performance in the eastern Indo-Gangetic Plains. Of all systems tested, zero tillage and permanent bed maize–maize, rice–maize, and soybean–maize offered the greatest potential for sustainable growth and higher yields.

While this study focused on the eastern Indo-Gangetic Plains, the principles of conservation tillage and crop diversification may benefit other regions with similar climates, soils, and cropping patterns. However, local factors such as soil type, rainfall, crop selection, and available resources should be considered before applying these results elsewhere. Additional research and field trials in diverse settings are recommended to assess the broader applicability of these findings.

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SS1.7

Scaling Climate-Resilient Rice Varieties through Participatory Demonstrations and Seed System Strengthening in Odisha, India

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Keywords: Rice, Resilient varieties, Participatory breeding

1. Background

Agriculture in many parts of India is increasingly threatened by climate variability, including rising temperatures, erratic rainfall, droughts, floods, and emerging pests and diseases. These challenges significantly affect the productivity and livelihoods of smallholder farmers who depend heavily on rice-based farming systems. Climate-smart breeding and production systems have therefore emerged as critical strategies to enhance resilience, sustain productivity, and ensure food and nutritional security. The International Rice Research Institute (IRRI) has been at the forefront of developing and promoting climate-resilient rice varieties and production technologies. Climate-smart breeding focuses on developing rice varieties that can withstand multiple environmental stresses while maintaining high productivity and grain quality. IRRI's breeding programs emphasize key traits such as drought tolerance, submergence tolerance, heat resilience, and resistance to major pests and diseases. The identification of distinct trait combinations is crucial for effective varietal development. Advanced breeding approaches, including participatory varietal selection, help accelerate the development, evaluation, and dissemination of resilient rice varieties suited to local agro-ecologies.

2. Material & Methods

In Odisha, IRRI implemented a research and demonstration program in four districts, establishing eight varietal cafeterias over two years. These on-farm exhibitions showcased the comparative performance of newly developed, ecology-suitable, and market-demanded rice germplasm with a special focus on drought-tolerant varieties. At crop maturity, various stakeholders from the seed value chain including farmers, KVK scientists, input dealers, millers, SHG members, seed certification agencies, Department of Agriculture officials, and policymakers to observe and rank the varieties based on parameters such as yield potential, grain quality, marketability, special traits, and cooking quality.

A key component of IRRI's approach is the active engagement of farmers, government agencies, and development partners in the co-design and scaling of climate-smart innovations. On-farm trials, dealer demonstration plots, and farmer field schools support quality seed production, participatory validation, and the adoption of improved varieties and agronomic practices. IRRI collaborates closely with the Department of Agriculture, Odisha State Seed Corporation, private seed growers, private companies, and Farmer Producer Companies (FPCs) to scale up stress-tolerant rice varieties through systematic seed production and distribution.

3. Results & Conclusion

As a result, breeder seed indent for varieties such as Swarna Shreya and Swarna Shakti has increased significantly over the past three years. In contrast, the indent for the previously popular

variety MTU-1010 has declined sharply and became almost nil during 2022–2025. Farmers increasingly prefer varieties like Swarna Shreya because they combine drought tolerance, higher yield potential, and preferred grain quality.

Overall, climate-smart adaptive production and seed systems offers a transformative pathway for building resilient rice-based farming systems and ensuring sustainable agricultural development under changing climate conditions.

References

Seed Net India Portal, <https://seednet.gov.in/> BS Indent by different states

Gender-Responsive Participatory Selection of Varieties for An Accelerated Varietal Replacement in Eastern India

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Keywords: Gender-responsive breeding; Participatory varietal selection; Varietal replacement; Women farmers; Rice adoption.

1. Background

Selection and adoption of a variety is guided by a host of complex factors including farmers' gender. Women and men evaluate varieties differently for a set of parameters concerning market and consumer preferences. The intelligence of such gender-specific distinct trait choices is crucial for variety breeding programs. However, the current extension and research mechanism in India doesn't consider the gender element adequately and they remain gender blind. Consequently, the specific needs of women in a variety are largely overlooked.

Intervention

2. Material & Methods

IRRI conducted a research program in eastern India where it established 10 varietal cafeterias (on-farm exhibition) to showcase the comparative performance of new ecology-suitable and market-demanded germplasm. Upon crop maturity, we invited a total of 100 women and 100 men farmers to observe, assess and rank the varieties based on several parameters including marketability, special characters, and cooking qualities. While 84% of men farmers ranked yield as the first preferred trait, 78% of women placed cooking quality as the first ranked characteristic. It has been observed while women consider long slender, fine grain, cooking quality, mild aroma, and fitment for value addition like beaten rice, idli along with potential yield, men strongly look for yield and market acceptance of the varieties for adoption decision. Based on the experiment, five such new varieties were selected by women for further promotion and scaling. Subsequently, the evaluator-women were given one Minikit of those varieties in the following season for on-farm validation and further adoption.

3. Results & Conclusion

It has been observed, of those 100 women farmers, 87 registered sustained the adoption of those varieties and kept farm-saved seeds for cultivation in the next seasons. 86% of participating women think these varieties identified and selected through varietal expo followed by mini kits and demonstration have met specific needs which were earlier not addressed by existing varieties. A whopping 91% of women farmers believe that this whole experiment was helpful in terms of learning about new varieties and making informed adoption decisions. The experiment strongly suggests varietal evaluation should be gender segregated and in order for an accelerated adoption, women should be included in the varietal extension process throughout.

Climate-resilient and nutrition-sensitive farming: Conservation agriculture-based diversification for smallholders in the Eastern Gangetic Plains

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ABSTRACT

The conventional rice–wheat (RW) cropping system in eastern India is increasingly constrained by declining productivity, inefficient water and energy use, and deteriorating soil health. Although this system remains central to regional food security, its long-term sustainability is under significant threat. It is hypothesized that conservation agriculture (CA)-based crop diversification can enhance system productivity, resource-use efficiency, farm profitability, and nutritional outcomes for smallholder farmers.

An on-farm study was conducted over three cropping cycles (2016–2019) across three villages in two districts (Vaishali and Samastipur) of Bihar, India. Five cropping systems with different establishment practices were evaluated: (i) conventionally tilled rice–wheat (CT–RW), (ii) conservation agriculture-based rice–wheat (CA–RW), (iii) conventional rice followed by CA-based mustard and mungbean (partial CA–RMuMb), (iv) CA-based maize–wheat (CA–MW), and (v) CA-based maize–mustard–mungbean (CA–MMuMb). Key performance indicators included system productivity, irrigation water productivity, energy-use efficiency, economic returns, and nutritional yields (protein, fat, iron, and zinc).

The CA–MMuMb system recorded the highest performance, achieving 52.6% greater system productivity (15.01 t ha⁻¹) and 63.2% higher net returns (USD 2,046 ha⁻¹) compared to the conventional CT–RW system (9.83 t ha⁻¹ and USD 1,253 ha⁻¹, respectively). Irrigation water productivity and energy productivity were significantly improved under CA MMuMb, reaching 6.06 kg grain m⁻³ and 0.68 kg grain MJ⁻¹, respectively approximately 4.0 and 2.4 times higher than CT–RW (1.5 kg grain m⁻³ and 0.28 kg grain MJ⁻¹). Additionally, the CA–MMuMb system substantially enhanced nutritional yields, with increases of 30.9% (protein), 112.5% (fat), 119% (iron), and 26.5% (zinc) relative to CT RW. The CA MW system also demonstrated comparable gains in productivity and nutritional output.

These findings highlight the potential of CA-based diversified cropping systems to improve productivity, resource-use efficiency, profitability, and nutritional security. The CA–MMuMb system, in particular, offers a scalable and sustainable solution for intensifying agriculture in the Eastern Gangetic Plains, with broader applicability to similar irrigated agro-ecologies across South Asia.

Keywords: Conservation agriculture; crop diversification; resource-use efficiency; nutritional security; water productivity; Eastern Gangetic Plains

SS1.10

Diversified Long-Term Conservation Agriculture Improved Soil Microbial Diversity and Soil Biological Index in the Indo-Gangetic Plain of India

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ABSTRACT

Intensive cereal-based systems often degrade soil due to poor agronomic practices, leading to reduced soil organic carbon, nutrient availability, and microbial activity. Conservation agriculture (CA) and diversified cropping systems can restore soil health while meeting food and feed demands. This study evaluated seven contrasting production scenarios along with conservation agricultural practices. The findings indicated that diversified conservation agriculture (CA) systems markedly enhanced soil quality compared to the conventional rice–wheat system (Sc1). Among the treatments, rice–wheat–mungbean (Sc3) and maize–mustard–mungbean (Sc4) performed best, showing higher soil organic carbon, nutrient availability, microbial biomass (MBC, MBN), and enzyme activities (DHA and phosphatases), whereas Sc1 recorded the lowest values. Relative to Sc1, diversified systems increased SOC, available N, P, and K by 42%, 16%, 33%, and 24%, respectively. Microbial groups such as nitrogen fixers, *Azotobacter*, *Actinomycetes*, and *Thiobacillus* were also more abundant. Functional diversity indices, including AWCD, Shannon index, and substrate utilization, reflected enhanced microbial activity. Principal component analysis identified key indicators contributing to the Soil Biological Index (SBI), which was highest in Sc3 and lowest in Sc1. A strong positive correlation between SBI and rice equivalent yield highlighted the close association between soil biological health and system productivity. Overall, diversified systems following conservation agriculture practices significantly enhanced soil health, biological activity and microbial functional diversity, emphasizing their potential for restoring soil quality while sustaining productivity in intensively managed agroecosystems.

Keywords: Conservation agriculture, Microbial diversity, Residue, Soil biological index

Assessment of Climate Risks and their adaptation options for Groundnut, Mustard and Soybean in South Asia

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ABSTRACT

South Asian oilseed crops principally groundnut mustard and soybean are increasingly threatened by thermally and hydrologically driven climate hazards that affect agronomic productivity, edible oil self-sufficiency, and smallholder farm viability. Conventional impact assessments have largely relied on aggregated climatic indicators and generalized crop response functions, limiting their capacity to resolve crop-specific physiological sensitivities and inform targeted field-level adaptation. This study presents a physiology-anchored, adaptation-oriented framework that explicitly maps biologically meaningful stressor thresholds onto adaptation interventions across present and future climate scenarios. Crop-specific thermal and hydrometeorological hazards were quantified against established physiological cardinal thresholds, assessed across both the full growing season and discrete phenologically sensitive windows. Hazard intensity and frequency were characterized under observed historical baselines and ensemble CMIP6 projections for the 2050s and 2080s across shared socioeconomic pathways (SSPs). A structured, expert-reviewed heuristic framework subsequently evaluated the agronomic feasibility and expected efficacy of genetic improvement, crop management, soil nutrient optimization, and financial risk-transfer mechanisms under changing stress regimes. Results demonstrate that reproductive-phase heat stress is projected to increase predominantly in exceedance frequency, intensifying episodic thermal damage during yield-critical stages, while full-cycle heat accumulation is projected to intensify substantially. Crop water deficit indices are projected to worsen across major oilseed-producing agro-ecological zones. Rainfall-associated hazards exhibit spatially heterogeneous trajectories, reflecting inter-model uncertainty in regional precipitation dynamics. The study further delineates adaptation suitability, identifying the most robust and scalable interventions across crops, geographies, and emission trajectories. Taken together, these findings underscore need for agronomic strategies enabling resilient oilseed production systems under rapidly intensifying climate stress.

Keywords: South Asian oilseeds, climate stress, adaptation

SS1.12

Conservation Agriculture Practices Enhances Productivity, Resource use Efficiency in North-Western India

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ABSTRACT

The conventional agricultural practices in rice-wheat-cropping system (RWCS) leads to resource degradation, including deterioration of soil, air, and water, while exacerbating global challenges such as climate change, biodiversity loss, and inefficient energy use. Conservation agriculture (CA), offers a sustainable path forward for enhancing productivity, resource use efficiency, and environmental sustainability in this productive but resource-fragile region of NW India. This study evaluates productivity, sustainability, and environmental footprints (energy, water, and carbon) to foster environmental stewardship through conservation agriculture-based climate-smart agriculture. Six scenarios (Sc) were analyzed: conventional till (CT) rice-wheat (CT-RW, Sc1); CT rice-zero till (ZT) wheat-ZT mungbean (CTR-ZTWM, Sc 2); ZT direct-seeded rice-ZTWM (ZTRWM, Sc3); ZT maize-ZTWM (ZTMWM, Sc 4); Sc3 with subsurface drip (SSD) irrigation (ZTRWM-SSD, Sc5); and Sc4 with SSD (ZTMWM-SSD, Sc6). Among the evaluated scenarios, Sc6 (ZTMWM-SSD) recorded the highest performance across productivity, resource-use efficiency, and sustainability indicators. It achieved the maximum rice equivalent yield of 8.25 t ha⁻¹, representing a 22.2% increase over Sc1. Wheat yield under Sc6 reached 6.34 t ha⁻¹, showing a 22.1% improvement compared to Sc1, and resulting in a total system yield of 16.73 t ha⁻¹, which was 35.6% higher than the baseline. In terms of nutrient efficiency, system-wide partial factor productivity of nitrogen significantly improved under climate-smart agricultural practices (CSAPs). Sc5 recorded a 51.4% increase, while Sc6 achieved the highest gain of 69.7%, indicating superior nitrogen use efficiency. Energy analysis further confirmed that Sc6 was the most efficient system. Overall, the findings demonstrate that CSAPs, particularly ZTMWM-SSD, can enhance crop productivity, resource-use efficiency, and profitability while reducing environmental impacts. This highlights their critical role in addressing water scarcity, improving soil health, and supporting climate-resilient agriculture in north-western India.

Keywords: Conservation agriculture, productivity, Rice-wheat, Resource use efficiency





ICAR-Indian Grassland & Fodder Research Centre, Jhansi Special Session-2



SS2.1

New Vistas in Forage Research in India

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ABSTRACT

India with only 2.29% of land area of the world, is maintaining nearly 18 % of world human population and 11 % of livestock (more than 540 million heads) creating a huge pressure on land, water and other resources. Besides, the livestock sector, one of the largest globally, is constrained by a persistent deficit of quality fodder, estimated at 11 per cent for green fodder and higher for dry (23 %) and concentrate feeds (33), impacting productivity, profitability, and sustainability. This gap underscores the urgent need to reposition forage research from a peripheral activity to a central pillar of national agricultural policy and planning. There is a need to highlight emerging vistas in forage research with a clear focus on policy integration, institutional convergence, and sustainable intensification. Contemporary advances in forage science-spanning climate-resilient cultivar development, genomics-enabled breeding, and precision resource management- offer unprecedented opportunities to enhance fodder productivity and nutritional quality. Recent advances in forage breeding focus on the development of high-yielding, climate-resilient, and nutritionally superior cultivars, including multi-cut varieties and dual-purpose crops. The integration of biotechnological tools, such as molecular markers, genomic selection, and gene editing, is accelerating the development of stress-tolerant and quality-enhanced forage species. The integration of digital agriculture tools, including remote sensing, GIS, and AI-driven analytics, is enabling dynamic assessment of fodder resources, early warning systems for feed deficits, and evidence-based decision-making for rangeland management. However, technological innovations alone are insufficient without enabling policy frameworks. Integrated approaches such as hortipastoral and silvipastoral systems demonstrate strong potential for improving land-use efficiency, enhancing carbon sequestration, and supporting smallholder and pastoral livelihoods. Innovations in fodder conservation technologies, such as silage enrichment using agro-industrial by-products, are addressing seasonal feed gaps. Furthermore, rangeland restoration and sustainable grazing management are gaining prominence, especially in fragile ecosystems like the Himalayan and arid regions, particularly in ecologically fragile regions like the Himalayas and arid zones. The on-going International Year of Rangelands and Pastoralists 2026 provides a strategic window to reposition rangelands within national and global policy agendas. ICAR Institutions such as ICAR-Indian Grassland and Fodder Research Institute and AICRP-Forage Crops have a pivotal role in driving translational research, developing region-specific models, and facilitating multi-stakeholder platforms that connect science, policy, and practice. On behalf of ICAR-IGFRI, I reiterate for a “3P-5P framework”-linking *Places, Plants, People* with *Policy and Partnerships*-to guide future interventions. Such an approach calls for targeted investments in forage seed systems, rangeland restoration, and decentralized fodder banks, alongside incentives for private sector participation and community-led management. Strengthening extension systems, digital advisory platforms, and capacity building of farmers and pastoralists will be critical to scaling innovations. India cannot achieve livestock productivity without ensuring fodder security—Forage must move from margins to the mainstream of agricultural policy

Keywords: Forage research, fodder security, livestock productivity, Fodder Innovations, IYRP 2026, ICAR-IGFRI

Climate Resilient Horti- Silvipastoral models for Restoration of Degraded land

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ABSTRACT

Livestock productivity in India is constrained by multiple factors such as poor nutrition, inferior genetic potential, and disease prevalence; however, fodder scarcity remains the most critical, contributing nearly 50% to productivity losses. The country faces significant deficits in green fodder, dry fodder, and feed concentrates, while only a limited share of agricultural land is devoted to fodder cultivation. With increasing demand projected by 2050 and shrinking land resources, conventional expansion of fodder production is not feasible. In this scenario, utilizing indigenous nutritive fodder shrubs & trees, grasses and legumes by integrating them on a same piece of land to form alternate land use system is the best option. In India, huge area is under degraded lands, wastelands, community lands, grasslands and barren lands that can be utilized efficiently for growing quality fodder for our livestock. Growing fodder trees, shrubs, grasses and legumes in these areas will not only enhance fodder availability for Indian livestock but will also reclaim these degraded lands via restoring nutrient cycling, hydrological cycles, soil fertility and will also help in mitigating climate change via creating huge terrestrial carbon dioxide sinks. Research conducted by ICAR-IGFRI demonstrates that silvipastures can produce 5–10 t dry matter (DM)/ha/year, with species-based systems such as *Morus alba*, *Acacia nilotica*, and *Leucaena leucocephala* yielding up to 11–13 t DM/ha, and advanced mulberry-based systems producing as high as 74.23 t green fodder and 20.93 t DM/ha. These systems also improve crude protein content (7–20%), enhance land carrying capacity by up to 50%, and ensure year-round fodder supply. Hortipasture systems, integrating fruit trees with grasses and legumes, further enhance productivity and resource use efficiency. Studies by ICAR-IGFRI at Jhansi, Jammu & Kashmir, and Dharwad have reported fodder yields of 6–12 t DM/ha/year under guava, aonla, bael, apple, and coconut-based systems, along with a 20–25% increase in fruit yield. These systems not only augment fodder availability but also improve soil organic carbon, moisture retention, and microbial activity, thereby restoring degraded lands. From a policy perspective, these findings underline the urgent need to mainstream integrated fodder production systems into national livestock and land-use planning frameworks. This includes promoting silvipasture and hortipasture models under watershed development programs, incentivizing farmers through subsidies and extension services, strengthening seed and planting material supply chains, and encouraging public–private partnerships for large-scale adoption. Convergence with existing schemes on afforestation, climate change mitigation, and rural livelihoods can further accelerate implementation.

Keywords: Fodder deficit, Silvipasture systems, Hortipasture systems, Restoration of degraded lands, Sustainable livestock production

SS2.3

Livestock based Integrated Farming Systems (IFS) for Enhancing Livelihood and Ecosystem Services for Small and Marginal Farmers

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ABSTRACT

Livestock-based Integrated Farming Systems (IFS) have emerged as a viable strategy for enhancing livelihood security and ecosystem services among small and marginal farmers, particularly under conditions of resource scarcity and climate variability. Livestock based IFS modules integrates crops, livestock, forages, and horticultural components to optimize resource recycling, improve productivity, and sustain agro-ecosystems. Compared to conventional monocropping or double cropping systems, livestock-centered IFS significantly enhances provisioning, regulating, supporting, and cultural ecosystem services. A smallholder dairy-based IFS model evaluated at ICAR-IGFRI integrating sorghum–wheat cropping, Bajra–Napier hybrid with legumes (cowpea–berseem), guava-based agri-horticulture, and livestock (2 buffalo + 2 crossbred cows) recorded 323% higher wheat equivalent yield ($27,358 \text{ kg ha}^{-1}$) than a groundnut–wheat system. Similarly, the model generated 82.7% higher net returns and ensured year-round income flow, thereby stabilizing farm livelihoods. Dairy-based IFS produced 418 man-days $\text{ha}^{-1} \text{ year}^{-1}$, compared to only 119 man-days under double cropping, demonstrating its role in rural livelihood enhancement. Ecosystem benefits are evident through 19% improvement in soil organic carbon and over 500% increase in carbon sequestration, along with enhanced nutrient recycling (100 kg N , 45 kg P , $80 \text{ kg K ha}^{-1} \text{ year}^{-1}$), reflecting strong regulating and supporting services. The integration of livestock plays a pivotal role in converting crop residues into high-value outputs such as milk and manure, thereby closing nutrient loops and reducing dependence on external inputs. The incorporation of perennial forages and legumes ensures round-the-year fodder availability, enhancing livestock productivity and system resilience. A three-year life cycle assessment was conducted at ICAR-IGFRI on a 3-hectare IFS comprising 30 adult cattle units and diversified components, including 45% food crops, 33.8% fodder, 17.5% vegetables, 2.5% flowers, 1.3% fruits, and allied enterprises. The system was evaluated both internally across components and in comparison with a conventional groundnut–wheat cropping system (GWCS). Results indicated that LIFS produced 80,178 kg wheat equivalent yield per hectare per year, generated net returns of US\$ 8,952, and achieved an energy output of 455,368 MJ alongside a carbon output of 33,974 kg, from inputs of 90,791 MJ energy and greenhouse gas emissions equivalent to 14,942 kg carbon. In comparison to GWCS, LIFS demonstrated 8.4 times higher productivity, 6.4 times greater profitability, 6.6 times higher employment generation, 3.0 times improved energy productivity, and 4.6 times greater net carbon gain, primarily due to enhanced crop–livestock integration and efficient resource management. Among the system components, livestock contributed the largest share to both inputs (86% of cost, 66% of energy, and 92% of carbon emissions) and outputs (77% of production, 66% of returns, and 59% of employment), underscoring its central role in system performance and sustainability. Overall, livestock-based IFS promotes diversification, risk minimization, income stability, and ecological sustainability. Strategic policy support, capacity building, and institutional interventions are essential to mainstream livestock-based IFS as a cornerstone of resilient agricultural systems.

Keywords: Integrated Farming Systems, Livestock Integration, Ecosystem Services, Smallholder Farmers, Resource Recycling, Climate Resilience

Rangelands of the North-Western Himalayas: Management for Livelihood and Sustainability

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ABSTRACT

Rangelands of the north-western Himalayas, encompassing Jammu & Kashmir, Ladakh, Uttarakhand and Himachal Pradesh, represent critical socio-ecological systems that underpin pastoral livelihoods, livestock productivity, and ecosystem stability. These fragile landscapes serve as primary grazing resources for pastoral and agro-pastoral communities such as Gujjars, Bakarwals, Gaddis, Van Gujjars, Chopans and Changpas, while also contributing significantly to biodiversity conservation, carbon sequestration, and hydrological regulation. However, increasing pressures from climate change, shrinking grazing commons, unregulated grazing, and land-use transitions have led to widespread degradation, reduced carrying capacity, and increased vulnerability of dependent communities. The absence of clear policy recognition of grasslands further aggravates their degradation, often leading to their misclassification and diversion. In regions like Jammu and Kashmir and Ladakh, where 60–80% of livestock feed requirements are met through natural grazing, the sustainability of rangelands directly determines livelihood security. Short growing seasons, harsh winters, and limited fodder reserves further exacerbate seasonal feed deficits, often reaching 30–50%. Addressing these challenges requires a paradigm shift from conventional, extractive use of rangelands to integrated, science-based management approaches that enhance productivity while conserving ecological integrity. Interventions such as reseeding with improved forage species, adaptive and regenerative grazing, silvipastoral and hortipastoral systems, and soil-moisture conservation measures have demonstrated substantial improvements in biomass productivity and system resilience. Through the introduction of improved forage species such as *Dactylis*, *Festuca*, and *Lolium* grasses, along with legumes like *Trifolium*, degraded pastures can be effectively rejuvenated, leading to substantial improvements in biomass availability. Coupled with soil and moisture conservation measures such as contour bunding, water harvesting, and organic matter enrichment and the control of invasive species, these interventions can significantly improve rangeland health and ecological balance. Notably, such restoration efforts have demonstrated the potential to increase forage production from as low as 1.5 t/ha to nearly 10 t/ha dry matter, highlighting the transformative impact of scientific management. Regulating livestock numbers based on scientifically determined carrying capacity further ensures optimal utilization of available resources without degrading the ecosystem. The integration of geospatial tools, including remote sensing and GIS, is further enabling precise assessment of rangeland health, identification of degradation hotspots, and development of early warning systems for fodder scarcity. The role of ICAR-Indian Grassland and Fodder Research Institute and its regional stations in Kashmir and Palampur have been instrumental in advancing region-specific forage technologies, grassland mapping, germplasm improvement, and capacity building, thereby strengthening the scientific foundation for sustainable rangeland management in Himalayan ecosystems. The on-going International Year of Rangelands and Pastoralists 2026 presents a unique opportunity to reposition rangelands within national and regional development priorities. It calls for mainstreaming grasslands into agricultural, livestock, and climate policies, fostering institutional convergence, and recognizing pastoral communities as custodians of these ecosystems. Keywords: Rangelands, North-Western Himalayas, pastoral livelihoods, sustainable management, climate resilience, grazing systems, forage productivity, rangeland restoration

Keywords: Rangelands, NWHs, livestock, fodder, grasslands, livelihood

Challenges and Opportunities for Grassland Development in Mid-hill Sub-temperate Regions

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ABSTRACT

The grasslands and pastures of the Indian Himalayas represent a critical ecological and economic resource, spanning sub-tropical, temperate, and alpine regions. Within this landscape, the mid-hill sub-temperate regions are specifically defined as areas situated between 1000 and 2000 meters above mean sea level. As altitude varies, so does the vegetation and the livestock rearing systems adopted by local farmers, which include migratory, sedentary, and semi-sedentary models. A significant gap currently exists between fodder demand and availability. This shortage is exacerbated by seasonal fluctuations; grass availability is high during the monsoon but drops significantly during the cold winter months. While grazing pressure is highest in the low hills, the mid-hills still face substantial demand from both local farmers and nomadic graziers like the Gaddis and Gujjars. The development of these grasslands is hindered by several formidable challenges which includes the undulated terrain, prone to natural disasters such as landslides, cloud bursts, and soil erosion; resource neglect and socio-economic factors, especially lack of awareness among farmers regarding grasses and modern technologies due to the lower financial returns of fodder compared to commercial crops. Land Degradation and conversion is another challenge, and overgrazing has led to the loss of native species and the invasion of poisonous or unpalatable weeds like *Lantana camara* and *Ageratum* sp. etc. To mitigate and adapt these issues, the document proposes a transition toward sustainable cultivation and management practices. This includes management chiefly; technical, biological and policy interventions. Grazing should be controlled through rotational grazing, which allows pastures to recover during rest periods. Protection measures, such as solar or wired fencing, are necessary to prevent over-exploitation by stray animals. Furthermore, there is a pressing need for processing and storage facilities, such as seed defluffing and silage-making units, to help farmers manage resources more efficiently. Farmers need to be encouraged to move away from monocultures and instead grow a mixture of high-yielding, locally suited fodder. Incorporating legumes (like clover or alfalfa) is highly recommended, as they enrich the soil with nitrogen through symbiotic *Rhizobium* microbes, reducing the need for chemical fertilizers. Additionally, the adoption of perennial grasses, such as ryegrass and tall fescue, is preferred over annual varieties for long-term productivity. Soil health should be maintained using organic sources like vermi-compost and poultry manure. Modern technology, including GIS, should be used to locate and restore degraded grasslands. The government provides subsidies through initiatives like the National Livestock Mission (NLM) and Rashtriya Gokul Mission (RGM) to encourage value-added products like hay bailing and fodder blocks. The Pastoralists Empowerment in Himalayan Ecosystems for Livelihood (PEHEL) scheme launched by the Himachal Pradesh in January, 2026 is an appreciable step in this regard. The creation of a dedicated Grassland Development Board, comprising pastoralists, scientists, and government officials, may be created for the long-term conservation of these vital ecosystems and the livelihoods and ecosystem services they provide. Keeping in view the challenges and opportunities for Grassland Development in mid-hill sub-temperate regions, there is an urgent need for collaborative effort, focussed on the healthy management of these grasslands.

Keywords: Grassland Development, Mid-hills, Pastoral Communities, Challenges, Opportunities

Ecosystem Services in Grassland and Alternate Land use Systems

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ABSTRACT

Grasslands are among the most extensive yet undervalued ecosystems, delivering a wide range of provisioning, regulating, supporting, and cultural ecosystem services (ES). However, increasing pressure from land-use change, particularly conversion to croplands, plantations, and other alternate land use systems, has significantly altered their structure, function, and service delivery. This keynote examines the comparative dynamics of ecosystem services in natural grasslands versus alternate land use systems, with a focus on semi-arid and sub-humid regions. Natural grasslands are highly efficient in sustaining key services such as fodder production, soil carbon sequestration, water regulation, biodiversity conservation, and resilience to climatic variability. In contrast, alternate land use systems often enhance short-term provisioning services (e.g., crop yield or timber production) but may compromise long-term regulating and supporting services, including soil health, nutrient cycling, and ecological stability. The trade-offs and synergies among these services are analysed using recent advances in remote sensing, ecological modelling, and integrated indices. There is a need to highlight emerging frameworks for quantifying and monitoring ES across land use gradients, including low-cost, spatially explicit tools that integrate vegetation, soil, and climate indicators. Case studies from semi-arid landscapes demonstrate how restoration of degraded grasslands and adoption of climate-smart alternate land use systems can optimize ecosystem service bundles while maintaining ecological integrity. The integration of ecosystem service valuation into land-use planning is essential for informed decision-making and policy formulation. Emerging tools such as remote sensing, GIS, and ecosystem modelling enable spatial quantification of services and identification of priority areas for restoration and conservation. Our team at ICAR-Indian Grassland and Fodder Research Institute have significantly studied the understanding and quantification of ecosystem services in grassland-based systems. The work has focused on carbon dynamics, soil health improvement, and productivity assessment under silvipastoral and alternate land use models across different agro-climatic zones. Notably, studies on carbon sequestration potential of grassland systems, evaluation of ecosystem service trade-offs, and development of sustainable land use models have provided critical insights for integrating ecological sustainability with livelihood enhancement. These contributions have helped establish grasslands as key components in climate change mitigation and adaptation strategies. In the context of the International Year of Rangelands and Pastoralists 2026, there is an urgent need to mainstream grasslands into national development agendas, recognize pastoral communities as ecosystem stewards, and promote incentive-based mechanisms such as payments for ecosystem services. Grasslands and alternate land use systems represent nature-based solutions that simultaneously address challenges of land degradation, climate change, and livelihood insecurity. Strengthening research-policy linkages, scaling proven models, and integrating ecosystem service frameworks into planning processes will be critical to unlocking the full potential of these systems for sustainable and resilient agriculture.

Keywords: Ecosystem services, grasslands, alternate land use systems, climate resilience, sustainable land management

SS2.7

Prevailing Interventions for the Pastoralists in the UT of Jammu & Kashmir

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ABSTRACT

Jammu & Kashmir has the world's largest ethnic migratory transhumant population with 6.12 lakhs in numbers. Gujjar, Bakerwal, Gaddi, and Sippi fall under the Scheduled Tribe category in the UT of Jammu & Kashmir. Different schemes have been implemented under the Tribal Affairs Department in Jammu & Kashmir for the welfare of tribal pastoralists. A nomadic survey was conducted for the first time in UT of Jammu & Kashmir by the Department of Tribal Affairs during the year 2021-22 to collect data on the nomadic population in Jammu & Kashmir. Few initiatives such as mobile medical units in the migratory routes of the nomadic population, transit accommodations, establishment of Mini Sheep/Goat farms and 2 Animal Dairy Units and Forest Rights Act were taken to improve the living conditions of the nomadic population in the UT of Jammu & Kashmir. The Tribal Affairs Department conducted a comprehensive survey, registering a total of 85,239 migratory families across various districts. The survey highlighted significant disparities in access to sanitation facilities, with many families lacking basic amenities. Further, the study conducted by the Centre for Pastoralism, New Delhi for the year 2024-2025 on various schemes in the Union Territory of Jammu & Kashmir helped assess the need for support services to sustain pastoral production systems in the Union Territory and other states. However, the present-day initiatives need to be refined and integrated through a multidisciplinary approach to meet the modern enabling policy requirements for pastoralists. The Centrally Sponsored Schemes (PMAAGY) ensures that the villages have a population of more than 500 and a 50% ST population approved by the Ministry of Tribal Affairs, the Govt of India, with Rs 20.38 lakh per village. It aims at mitigating gaps and providing basic infrastructure in villages with significant tribal populations in convergence with funds available under different schemes in the Central Scheduled Tribe Component. Under the UT Capex Budget, various works such as developing rural roads, providing electrification, and drinking water facilities, establishing dairy/sheep units, and establishing e-classrooms are being constructed. Milk villages and milk chilling plants have been established in tribal areas under the Special Central Assistance to Tribal Sub Scheme for the best practices in milk production. Under the UT Capex Budget, two animal dairy units have been established. The Integrated Dairy Development Scheme covers 20% of SC/ ST. Jammu & Kashmir State Livestock Breeding Policy, 2019 including Ovine and Caprine aim at the conservation of the indigenous sheep, goat, dog, and horse population of Jammu & Kashmir. The documentation and registration of the important shepherd dog "Bakerwali" at the national level will be useful for their sustainable use, improvement, and preservation. Sheep plays a significant role in the socio-economic upliftment of Chohan, Gujjar, Gaddi, and Bakerwal pastoralist communities in Jammu & Kashmir. The tribals, viz. Bakerwals and Gaddies are highly skilled in sheep and goat rearing. Gaddi and Bakerwali are the migratory sheep breeds reared by these communities. The Gaddi (White Himalayan goat) goat breed is mainly used for meat, fibre, and work by the Gaddi tribe.

Bakerwal, Kaghani, Lubdi, and Kilan goat breeds are reared by the Bakerwal tribes. Under the UT Capex Budget, mini sheep/goat farms have been established. The ongoing Holistic Agriculture Development Programme (2022-23 to 2027-28) i.e. Project 24 reflects reorienting priorities for self-sufficiency in mutton production in J&K. Thus Jammu & Kashmir is a model Union Territory in India with an already existing set of provisions for the pastoralists. Further, understanding and assessing the impact of these policies can provide a basis for making similar interventions in other states that have a decent, sizeable population of nomadic herders and pastoralists, specifically the Himalayan ranges, the Deccan plateau and the south western India. With 2026 being celebrated as the International Year of Rangelands & Pastoralists and the first Pastoralist Livestock Census (as part of 21st Livestock Census) is yet to be out soon, such research study will substantiate the redesigning of the already existing policy framework, while meeting the 17 UN Sustainable Development Goals towards 2030.

Keywords: Pastoralists, J&K, HADP, Tribal farmers

Climate Variability and Changing Mobility Patterns among pastoral herder community in the Kashmir Himalayas

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ABSTRACT

Transhumant pastoralism in the Kashmir Himalayas constitutes a highly adaptive socio-ecological system, organized around seasonal mobility across altitudinal gradients. In recent decades, however, this system has come under increasing pressure from climate variability in the Himalayan region, evidenced by rising temperatures, erratic precipitation patterns, glacier retreat, and a growing frequency of extreme weather events. These changes are progressively undermining the stability and predictability of traditional mobility regimes. This study examines the extent to which climate variability is reshaping pastoral mobility patterns across key migratory corridors of Jammu and Kashmir. It integrates primary data from household surveys, participatory mapping, and the tracking of migratory routes with secondary climate datasets to capture both spatial and temporal dynamics of change. Particular attention is given to shifts in migration timing, route selection, pasture availability, and water access. In addition, the study identifies the key drivers of these transformations, including climatic stressors, and socio-economic pressures, and analyzes the responses of herders to these changes. The study underscores that climate change is not merely altering ecological conditions but is fundamentally transforming the spatial logic, timing, and cultural continuity of transhumant pastoralism. It argues for urgent, context-specific policy interventions focused on securing migratory corridors, strengthening climate-resilient rangeland management, enhancing water security through decentralized solutions, and recognizing indigenous pastoral knowledge within adaptation frameworks.

Keywords: Climate variability, Transhumance, Pastoral mobility, Rangelands, Kashmir Himalayas

Mapping Phenotypic Diversity and Trait Associations in Red Clover (*Trifolium pratense* L.) Germplasm Using Multivariate Analysis

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ABSTRACT

Genetic diversity within germplasm collections provides a critical foundation for crop improvement and the development of resilient forage production systems. Red clover (*Trifolium pratense* L.) is an important temperate forage legume valued for its high nutritive quality and nitrogen-fixing ability. However, effective utilization of germplasm requires a clear understanding of phenotypic variability and trait associations influencing forage productivity. The present investigation evaluated 54 red clover genotypes under temperate agro-climatic conditions of the north-western Himalayas. Ten morphological, phenological, and yield-related traits were recorded to assess phenotypic variability. Multivariate statistical approaches, including principal component analysis and cluster analysis, were employed to quantify diversity and identify key contributing traits. In addition, correlation analysis and a Random Forest machine-learning model were used to examine trait relationships and determine the relative importance of traits influencing forage yield. Substantial phenotypic variability was observed among the evaluated genotypes, with higher coefficients of variation recorded for regrowth ability, green fodder yield, and dry fodder yield. Principal component analysis revealed that five components with eigenvalues greater than one explained approximately 78% of the total phenotypic variation, with the first two components accounting for 44.5%. The first principal component was largely associated with yield-related traits and regrowth ability, while the second component was influenced mainly by plant architectural traits such as plant height and leaf length. Significant positive correlations were observed between green fodder yield and dry fodder yield, indicating the contribution of vegetative growth traits to biomass production. Cluster analysis further revealed distinct phenotypic groupings among genotypes, highlighting substantial genetic diversity within the germplasm. Random Forest analysis identified regrowth ability as the most influential predictor of forage yield, emphasizing its critical role in biomass recovery and sustained productivity. The study revealed considerable phenotypic diversity among red clover genotypes and identified key traits associated with forage yield. The integration of multivariate statistics and machine-learning approaches provides valuable insights for selecting superior genotypes and developing effective breeding strategies aimed at improving forage productivity and adaptability of red clover under temperate environments.

Keywords: Red clover, phenotypic diversity, principal component analysis, forage yield, regrowth ability.

Integrated Crop Intensification and Zinc Enrichment Approaches for Sustainable Fodder Production

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ABSTRACT

Forage cultivation from cereal + legume mixed cropping systems can ensure equitable and judicious utilization of resources, increase fodder productivity, improve protein content and other quality parameters and produce highly nutritive forage. Globally, cereal-legume cropping system-based forage cultivation mitigates the impact of greenhouse gases through reduced use of inorganic nitrogen application and enhancing soil carbon stocks, reducing runoff losses, drought resilience, and improving livelihood and profitability. Fortifying forage-based cropping systems with micronutrients such as zinc not only addresses potential nutrient deficiencies but also plays a vital role in enhancing crop yields and quality. Thus, the present study was conducted to evaluate different forage based cropping systems and zinc fortification on forage yield and quality under temperate Himalayan conditions. The experiment was laid out in a Factorial Randomized Block Design with two factors and each treatment replicated thrice. Treatment combinations included five cropping systems i.e. sole maize - sole oat, maize + cowpea - sole oat, sole maize - oat + berseem, maize + cowpea - oat + berseem and sole cowpea - sole berseem and three zinc levels; Zn0= control, Zn1=5 kg Zn ha⁻¹ (basal soil application) and Zn2=5 kg Zn ha⁻¹ (basal soil application) + 0.5% ZnSO₄ spray. Digestible crude protein yield (DCPY), Dry matter intake (DMI), digestible dry matter (DDM) and relative feed value (RFV) were estimated from the measured variables according to various equations. The intensive cropping system involving Maize + cowpea in *kharif* followed by oat + berseem in *rabi* recorded highest GFY of 996 q/ha and DMY of 228 q/ha averaged over two years. The system recorded 23.38 % higher GFY and 19.76 % DMY over maize-oat system (127 % higher green fodder over maize only and 170 % higher green fodder yield over oat only). Soil + foliar Zn application enhanced total GFY by 11.27 % and DMY by 16.5 % over control. Intercropping of cereals and legumes resulted in increased protein yield over cereal and legume monocultures. Intercropped treatments significantly improved DMI, DDM and RFV over sole maize and sole oat. Zinc application increased Zn content and Zn uptake by 40 % and 65 % in *rabi* crops and 74 % and 99.17 % in *kharif* crops, respectively. Legume intercropping increased CP yield by 29 to 32 % over sole oat (*rabi*) and 39 to 41.6 % over sole maize (*kharif*). Both legume incorporation and zinc application enhanced over all forage quality (RFV > 105 %) and resulted in good quality forage. Cereal + legume intercropping resulted in higher available N, organic carbon and carbon accumulation (33.42 Mg C ha⁻¹ as against 30.07 Mg C ha⁻¹ in case of maize-oat system). Intercropping also increased carbon accumulation from the initial value of 28 Mg C ha⁻¹ in the post-harvest soil. Maize + cowpea - oat + berseem cropping system supplemented with soil and foliar zinc application resulted in highest total net returns of Rs. 1,66,333/ha. The cropping system also recorded highest B: C ratio in both *rabi* (1.69) and *kharif* (2.05) seasons (averaging 1.87). Crop intensification through cereal-legume intercropping, coupled with strategic zinc fortification, markedly improved both fodder yield and nutritive quality. Beyond productivity gains, the system contributed to improved soil health through better nutrient dynamics and biological enrichment, while also generating higher economic returns.

Keywords: Cereal-legume, Intercropping, Fodder, Livestock production, Zinc fortification

Socio-economic Characteristics and Livestock Management Practices of Pastoralists in the North-Western Himalayas: Implications for Climate-Resilient Agroecosystems

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Abstract

Pastoralism remains a crucial livelihood system in the Himalayan region, supporting communities that depend on livestock and natural rangelands for sustenance. In Jammu and Kashmir, pastoral groups such as Gujjars and Bakarwals practice seasonal transhumance, moving livestock across ecological zones in response to seasonal forage availability. These pastoral production systems contribute significantly to rural economies and ecosystem management, particularly in fragile mountain agroecosystems. However, climate variability, degradation of grazing resources, and socio-economic marginalization increasingly threaten the sustainability of pastoral livelihoods. Understanding the socio-economic conditions and livestock management practices of pastoral households is therefore essential for designing climate-resilient agroecosystem strategies. The study was conducted in three pastoral-dominated districts of Jammu and Kashmir—Rajouri, Ganderbal, and Anantnag. Using purposive sampling, 200 pastoral households were selected across multiple villages. Data were collected through structured interviews, focus group discussions, and field observations. Descriptive statistical methods were used to analyze socio-economic characteristics, herd composition, income sources, grazing practices, and feeding patterns. The pastoral community is characterized by low levels of formal education and small landholdings (mean 0.86 ha), with livestock serving as the primary livelihood source. The average herd size was 4.16 adult cattle units, consisting mainly of sheep, goats, buffalo, and cattle. Grazing on forest fringes and village commons was the predominant feeding strategy, while stall feeding was practiced mainly during winter. Seasonal availability of green fodder (March–October) and dry fodder (October–March) strongly influenced livestock feeding practices. Livestock contributed significantly to household income, though returns remained modest and increasingly supplemented by non-farm activities. These findings highlight the adaptive strategies pastoralists employ in response to ecological constraints but also reveal vulnerabilities related to fodder scarcity, land access, and climate variability. Strengthening pastoral production systems through improved fodder resources, sustainable rangeland management, and climate-adaptive livestock practices is essential for enhancing livelihood security in Himalayan agroecosystems. Integrating indigenous pastoral knowledge with policy support and extension interventions can contribute to more resilient and sustainable pastoral systems in the region.

Keywords: Agroecosystems; pastoralism; rangelands; livelihood security; livestock management



Theme 1:

Climate Smart Breeding and Production Systems for Resilient Agriculture



1.1 Synchronizing Sowing Window and Nitrogen Rates Improves Agrometeorological Efficiency and Fine-Grain Rice Productivity

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Keywords: Agrometeorology, Fine-grain rice, Nitrogen, Sowing window, Yield

1. Background

Rice (*Oryza Sativa* L.) occupies a high-value segment of global rice markets due to its superior aroma, cooking quality and consumer preference. However, its productivity in temperate Himalayan ecosystems is increasingly threatened by climate-induced variability, particularly rising temperatures and the frequent occurrence of terminal heat stress during flowering and grain filling stages. Recent assessments indicate that warming trends in temperate Asia are accelerating, resulting in shortened crop duration, impaired assimilate translocation and declining grain quality stability (IPCC, 2025). Sowing window plays a decisive role in determining the thermal and radiational environment experienced by rice during sensitive phenological stages, thereby regulating heat use efficiency, spikelet fertility and grain filling efficiency. Recent field-based evidence demonstrated that optimizing sowing windows based on thermal indices significantly improves yield stability and thermal use efficiency in temperate rice systems (Sharma *et al.*). Nitrogen availability further modulates canopy development, photosynthetic efficiency and assimilate partitioning, suggesting that synchronizing sowing window with nitrogen application may offer a climate-smart agronomic strategy for sustaining fine-grain rice productivity under rapidly changing climatic conditions.

However, limited field-level information is available on the interactive effects of sowing window and nitrogen rate on agrometeorological efficiency, grain yield and quality of newly released fine-grain rice cultivar (Shalimar Rice-7) under temperate Himalayan environments, which necessitated the present investigation.

2. Materials and Methods

A field experiment was conducted during Kharif season of 2024 at the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K), Wadura, Kashmir, India (34.20°N latitude, 74.33°E longitude; 1580 m above sea level). The experimental site represents temperate agro-climatic region of the Kashmir Valley, where crop growth is strongly influenced by sowing time and temperature conditions. The experiment was laid out in a factorial randomized complete block design with three replications. The treatments comprised three sowing dates (10 May, 19 May, 29 May) and three nitrogen levels (60, 80, 100 kg/ha). The fine-grain rice cultivar (Shalimar Rice-7) was transplanted at 30 days age. Nitrogen was applied in three splits (basal, active tillering and panicle initiation) thereby synchronizing nutrient availability with critical crop growth phases. Phosphorus and potassium were uniformly applied as basal doses across all treatments in accordance with recommended agronomic practices. Standard cultural operations, including irrigation scheduling, weed control and plant protection measures, were uniformly implemented throughout the cropping period to eliminate extraneous sources of variability. Standard agronomic practices were followed.

Daily meteorological observations, including maximum and minimum temperature and sunshine duration, were obtained from the adjacent agrometeorological observatory. Agrometeorological indices including growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU) and heat use efficiency (HUE) were computed using standard procedures to characterize crop-weather interactions. Growth parameters, yield attributes and grain yield were recorded following established experimental protocols & the experimental data were subjected to statistical analysis. The significance of treatment effects was tested at the 5% probability level ($p \leq 0.05$), and critical differences were computed wherever the treatment effects were found to be significant.

3. Results and Conclusion

Sowing dates and nitrogen levels significantly influenced agrometeorological indices, growth, yield attributes, grain yield, and quality of rice. Early sowing (10 May) recorded higher accumulation of growing degree days (GDD), photothermal units (PTU), and heliothermal units (HTU) resulting in superior heat use efficiency (HUE), whereas delayed sowing shortened crop duration and reduced effective thermal utilization. Nitrogen application significantly improved canopy growth, leaf area index, dry matter accumulation and yield attributes. The nitrogen rate (100kg/ha) produced maximum panicle density, filled grains/panicle and test weight. Synchronizing sowing window with nitrogen rate significantly enhances agrometeorological efficiency, yield and economic returns of fine-grain under temperate Himalayan conditions. Early transplanting (10 June) combined with 100 kg/ha is recommended as climate- smart agronomic strategy for sustaining rice productivity and grain quality in the region.

Table 1. Interactive effect of sowing dates and nitrogen levels on heat use efficiency and grain yield of Shalimar Rice-7

Treatments	HUE (kg/ha/°c/day)	Grain Yield (t/ha)
S ₁ (10 June)	3.51	7.90
S ₂ (19 June)	3.05	7.00
S ₃ (29 June)	2.85	6.20
SE(m)±	0.06	0.17
CD (p≤0.05)	0.18	0.52
N ₁ (60 kg ha ⁻¹)	2.76	6.50
N ₂ (80 kg ha ⁻¹)	3.26	7.14
N ₃ (100 kg ha ⁻¹)	3.39	7.45
SE(m)±	0.06	0.17
CD (p≤0.05)	0.18	0.52

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1.2 Optimization of Fertilizer Inputs via Microbial Inoculants for Enhancing Growth, Yield and Soil Health in Mustard (*Brassica juncea* L.)

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Keywords: Biofertilizers; RDF (Recommended Dose of Fertilizers); Soil fertility; Yield

1. Background

Indian mustard (*Brassica juncea* L.) is an important rabi oilseed crop in the Bundelkhand region; however, its productivity remains low due to poor soil fertility, nutrient deficiencies and inefficient nutrient management practices. Integrated nutrient management involving chemical fertilizers and biofertilizers has emerged as a sustainable approach to enhance crop productivity, soil health and profitability under dryland conditions. Therefore, the present study was undertaken to evaluate the effect of biofertilizers and different nutrient doses on growth, yield, soil properties and economics of Indian mustard under Bundelkhand conditions.

2. Materials and Methods

A field experiment was conducted during the rabi seasons of 2022–23 and 2023–24 at the Integrated Farming System Unit, Banda University of Agriculture and Technology, Banda. The experiment was laid out in a randomized block design with ten treatments and three replications. Treatments comprised different levels of the recommended dose of fertilizers (100, 75 and 50 per cent), applied alone or in combination with biofertilizers such as Azotobacter, phosphate solubilizing bacteria (PSB) and sulphur solubilizing bacteria (SSB). The Indian mustard variety ‘Giriraj’ (DRMRIJ-31) was grown following recommended agronomic practices. Observations were recorded on crop establishment, growth and physiological parameters, yield attributes, seed yield, quality parameters, nutrient uptake, post-harvest soil fertility and economics. Statistical analysis was performed to evaluate treatment effects.

3. Results and Conclusion

Growth parameters such as plant height, number of branches, dry matter accumulation and leaf area index were significantly improved under integrated nutrient management compared to the control. Physiological growth indices, including crop growth rate (CGR) and absolute growth rate (AGR), were higher under integrated treatments during the active growth phase. Yield attributes and seed yield responded positively to the combined application of fertilizers and biofertilizers. The highest growth and yield were recorded with 100 per cent recommended dose of fertilizers combined with Azotobacter, PSB and SSB, while 75 per cent recommended dose combined with PSB and SSB produced statistically comparable results. Oil content improved under treatments receiving sulphur solubilizing bacteria. Uptake of nitrogen, phosphorus, potassium and sulphur increased under integrated treatments due to enhanced biomass production. Post-harvest soil analysis revealed improved nutrient availability, slight increase in organic carbon content and enhanced soil biological activity under integrated nutrient management. Economic analysis indicated higher gross and net returns and benefit–cost ratio under integrated treatments, with 75 per cent recommended dose of fertilizers combined with biofertilizers emerging as the most cost-effective option. The study concludes that integrated application of 75 per cent recommended dose of fertilizers along with Azotobacter, phosphate solubilizing bacteria and sulphur solubilizing bacteria is an effective, economically viable and soil-supportive nutrient management strategy for Indian mustard cultivation in the Bundelkhand region.

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1.3 Future-Ready Crops: Breeding Strategies for Climate-Resilience in Pulses

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Keyword: Climate resilience, drought, cowpea, genotypes

1. Background

Climate change-driven variability in rainfall and increasing frequency of drought events pose serious challenges to pulse production, particularly in rainfed and temperate agro-ecosystems such as the Kashmir Valley. Pulses are vital for nutritional security and sustainable agriculture, yet their productivity is highly sensitive to water stress. Developing climate-resilient pulse cultivars requires a clear understanding of physiological, morphological, and root architectural traits that confer drought tolerance and translate effectively into yield stability under field conditions. The screening for drought stress requires well designed methods with judicious combination of phenotypic traits that are either known to or expected to impact yield when subjected to drought stress (Stirbet *et al.* 2020). From earlier experiments it has been observed that careful studies of root architecture and its relationship with physiological and vegetative traits and subsequent correlation and regression relationships of such traits with yield can unfold several ways of breeder's selection of superior genotypes (Lynch, 2022). However, novel traits and their relationships with yield amidst drought stress are important to be understood (Tittal *et al.* 2021). Traditional selection based solely on yield often fails to capture these complex adaptive mechanisms. Therefore, integrated phenotyping approaches that combine controlled-environment screening with field validation are essential. The present study was undertaken to evaluate drought responses in major pulse crops, particularly common bean and cowpea, with the objective of identifying drought-tolerant genotypes and robust trait-based screening indices for use in future breeding programs aimed at climate resilience.

2. Materials and Methods

The experiment was conducted at the Dryland Agricultural Research Station (DARS), Rangreth, SKUAST-Kashmir. Ten genotypes each of common bean and cowpea were evaluated using a two-phase approach. In the first phase, controlled greenhouse screening was carried out using PVC column culture under two moisture regimes: irrigated control (T₁) and residual moisture/water deficit (T₂). A comprehensive set of physiological, morphological, and root architectural traits was recorded, including chlorophyll content, NDVI, canopy temperature depression (CTD), shoot and root biomass, root depth, root length, root volume, root surface area, and root-shoot ratio. Precision phenotyping tools such as NDVI sensors, thermal measurements, and WinRHIZO root scanning were employed. In the second phase, the same genotypes were evaluated under rainfed field conditions. Key agronomic traits and grain yield were recorded to establish relationships between greenhouse-measured traits and field performance. Statistical analyses included analysis of variance, genotype × moisture interaction assessment, correlation and regression analyses, and per se performance comparisons to identify critical drought-responsive traits and tolerant genotypes.

3. Results and Conclusion

Significant genotypic variation and moisture regime effects were observed for most traits in common bean, although NDVI and dry root weight were relatively stable under drought. Several

genotypes, notably PPR-13, PPR-9, PPR-7, PPR-14, and PPR-12, showed minimal genotype $\times$ moisture interaction, indicating tolerance or reduced sensitivity to water stress. Field evaluation under rainfed conditions revealed significant differences in yield and yield components. Root depth emerged as the most important positive determinant of yield under drought, while root–shoot ratio showed a negative association. Drought-tolerant genotypes maintained or enhanced root traits despite moderate reductions in shoot growth, suggesting that root depth and percent change in root traits can serve as effective drought screening indices in common bean.

Cowpea displayed a distinctly different and more resilient drought response. Many traits, including NDVI, plant height, and root biomass, were not significantly affected by moisture stress, highlighting its inherent drought tolerance. Genotypes such as CPWFC-4, CPWFC-6, WFC-1, and WFC-7 exhibited stable performance across moisture regimes. Under field conditions, yield variability was significant, with regression analysis again identifying root depth as the strongest predictor of yield under drought. Cowpea showed pronounced increases in root depth, root length, root surface area, root branching, and root–shoot ratio under stress, coupled with minimal reductions in chlorophyll content and NDVI. The crop primarily relied on extensive lateral root proliferation, enabling efficient soil moisture exploration and sustained physiological activity.

Comparative analysis across crops revealed that common bean experienced greater reductions in biomass and physiological traits under drought, whereas cowpea was least affected. Canopy temperature depression patterns indicated superior transpiration regulation in cowpea. Overall, the study concludes that cowpea possesses superior drought resilience due to its plastic and robust root architecture, efficient water use, and conservative shoot growth. The integration of greenhouse and field phenotyping proved effective in identifying reliable drought tolerance indices and elite genotypes.

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1.4 Heat Unit Requirements of Sweet Corn under Different Planting Methods and Dates in Temperate Kashmir, India. A Climate Resilient Smart Crop

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Keywords: Sweet corn, Planting, Establishment and Phenology.

1. Background

The amount of heat that a crop accumulates during its growth is measured in heat units, commonly known as thermal time or growing degree days (GDD). Calculated using the daily maximum and minimum temperatures, they show how quickly a plant moves through its stages, from emergence to maturity. The fundamental tenet is that crops need a specific temperature (above a base threshold) in order to progress through each growth stage (Jan *et al.*, 2021; Gudadhe *et al.*, 2013). The phenology and yield of sweet corn are greatly influenced by ambient temperature in temperate regions such as Kashmir (North-Western Himalayas), as lower temperatures can impede development and postpone maturity. The present study carried out to see the effect of establishment method and planting date on phenology, yield, and agro-meteorological indices for sweet corn.

2. Material and Methods

The research was done at the Wadura campus of the Shere-Kashmir University of Agricultural Sciences and Technology of Kashmir, which is situated 1524 meters above mean sea level and is situated at 34° 17' N latitude and 74° 33' E longitude in Sopore, Kashmir. The highest temperatures for Kharif 2020 and 2021 were between 22.8 and 38.0 °C, while the weekly minimums ranged between 8.7 and 19.3 °C, according to meteorological data acquired throughout the investigation. The treatment procedure included two establishment methods (transplanting and direct sowing) and three sowing dates having an interval of 20 days (25th April, 15th May and 5th June during both the growing seasons). The hybrid of sweet corn was sown/transplanted on the same date at a spacing of 70 cm x 20 cm. Both transplanting and direct sowing methods of establishment were carried out on the same day. By spreading seeds at various times spaced 20 days apart, transplanting seedlings were nurtured in poly bags. To facilitate transplanting, the poly bags were maintained in the Low tunnel close to the main field. Regular cultural procedures including watering and weeding were also adhered to. Starting on the day of transplantation, it was noted how many days were needed to reach various phenological stages, knee height, 50% silking, 50% tasseling, and milking, for example (maturity). During harvest, the yield of green cobs, the biological yield, and the quantity of cobs per plant were all noted. Using weather data for daily maximum and minimum temperatures, sunshine hours, day length, and average relative humidity, we examined agro-meteorological indices such as growing degree days (GDD), helio-thermal units (HTU), photo-thermal units (PTU), and hydrothermal units (HyTU) at various growth stages of the crop (Garcia *et al.*, 2009; Ahmed *et al.*, 2020). By using correlation analysis, the relationship between biological yield and green cob and agrometeorological characteristics was found. Regression study of those indices against green cob and biological yield was carried out to forecast how those two variables will respond to agro-meteorological indices. A factorial randomised block design (RCBD) with three replications was employed to set up the experiment, and R software was utilised for the statistical analysis.

3. Result and Conclusion:

When specific phenological stages are attained depends much on the sowing period. The plant had reached Knee High, 50% Tassling, 50% Silking, and Milking phases on the initial date of planting, whether through transplanting or direct sowing, whereas late planting had more swiftly reached distinct phenological stages. The accumulated GDD by sweet corn at various phases and planting dates using two different establishing methods. The degree day accumulation with direct sowing was found to be considerably greater, Knee-high stages range from 359.9 to 498.4°C, and milking stages range from 1264.1 to 1415.1°C, respectively. From knee height through physiological maturity (the milking phases), the degree day accumulation under transplanting methods ranged from 318.3 to 468.6°C, and it was found to be considerably higher. However, a declining trend in the cumulative GDD for completing all phenological stages was observed in both establishment procedures with each additional delay in sowings. Due to higher ambient temperatures and longer sunshine hours, crops that were sown earlier gathered more degree days over a longer period of time. With delayed sowing, a similar decreasing trend in accumulated GDD was observed.

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1.5 Impact of Climate-Resilient Agriculture Interventions on Reducing Vulnerability in Rain-fed Areas of Jammu, India

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Keywords: Climate change, vulnerability, resilient

1. Background

Climate change is a major global challenge affecting agriculture and rural livelihoods. The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the degree to which a system is susceptible to and unable to cope with adverse climatic effects. It is determined by exposure, sensitivity and adaptive capacity. Agriculture is highly climate-sensitive, with global crop production projected to decline by 2–6 per cent per decade due to climate change. Smallholder farmers, who constitute nearly 80 per cent of global farms, are particularly vulnerable due to limited resources. India is among the most climate-vulnerable countries because of heavily dependence on agriculture. Within India, Jammu and Kashmir (J&K) is highly sensitive due to its fragile Himalayan ecosystem. The region has experienced rising temperatures and erratic rainfall, posing serious risks to agricultural productivity (Mahdi *et al.*, 2021).

2. Materials and Methods

The study was conducted in Bhalwal block of Jammu district, characterized by semi-arid conditions, erratic rainfall and soil erosion. A baseline survey of 51 villages was conducted in 2016–17 to assess climate vulnerability. Out of these, 25 villages were identified as highly vulnerable in baseline survey report, 2016–17 (vulnerability index 0.64–0.79) and were covered under the project. These 25 villages were selected for the present study. The total population comprised 1,250 beneficiary farm families (50 from each village). Using Yamane's (1967) formula at a 5 per cent significance level, a sample of 300 farmers was selected, with 12 farmers randomly chosen from each village. The vulnerability index was computed using five dimensions: climate, land, human capital, social capital and physical capital. Villages were categorized into high, moderate and low vulnerability groups using the equal interval method. A paired t-test was applied to compare vulnerability levels before (2016–17) and after (2023–24) project implementation.

3. Results and Conclusion

The overall vulnerability index declined significantly by 19 per cent, decreasing from 0.69 in 2016–17 to 0.56 in 2023–24 ($t=8.848$, $p < 0.05$). Village-level analysis of Bhalwal block showed the highest reductions in Doomi village (32.63%), Bajwan village (28.89%) and Baganitalab village (28.43%). Importantly, while 15 villages were categorized under high vulnerability in 2016–17, none remained in this category by 2023–24. Ten villages transitioned into the low vulnerability category. The reduction in vulnerability is attributed to project interventions such as promotion of climate-resilient crop varieties, livestock-based IFS, vermicomposting, improved irrigation infrastructure and capacity-building programmes. Similar findings have been reported by Deshmukh *et al.* (2024), who observed that diversification and institutional access significantly enhance resilience in climate-sensitive regions. The findings suggest that such climate-resilient initiatives should be continued and scaled up across similar rain-fed areas of Jammu and Kashmir to achieve broader climate adaptation goals and enhance agricultural sustainability.

Comparison of vulnerability index of vulnerable village's overtime

Indicator	Name of village	2016–17	2023–24	% Change
Average Vulnerability Index	Overall	0.69	0.56	19.00
Highest Reduction	Doomi	0.66	0.44	32.63
Lowest Reduction	Nargara	0.67	0.66	2.24
t-value	8.848*			

*Significant at $p \leq 0.05$;

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1.6 Effectiveness of Weather Forecasts in Supporting Agromet Advisory for Jammu Region

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Keywords: Climate variability, Weather forecast verification, Agromet advisories, Crop management, Forecast accuracy

1. Background

A significant proportion of India's population relies on agriculture for its livelihood, yet this sector remains highly vulnerable to the impacts of climate change. Among the many factors influencing agricultural productivity, weather plays the most critical role, affecting every stage of plant growth and development. The adoption of real-time contingency measures in crop management, guided by weather forecasts, can substantially reduce crop losses. The growing ability to deliver timely and reliable forecasts offers immense potential to mitigate risks associated with weather variability. Agriculturally relevant forecasts not only enhance the efficient use of farm inputs but also enable precise impact assessments. Access to timely weather information, coupled with value-added advisories such as climate-based input recommendations, crop management practices, and market intelligence, empowers farming communities to better navigate both climatic and market uncertainties.

2. Material and methods

To evaluate the accuracy of forecasts, weather predictions issued by the India Meteorological Department, Chandigarh, were compared with actual observations recorded at the Agrometeorological Observatory, Agromet Section, Chatha, Jammu, during 2024–25. The analysis divided the year into four seasonal groups: pre-monsoon (April–May), monsoon (June–September), post-monsoon (October–December), and winter (January–March). Six key weather parameters—rainfall, maximum temperature, minimum temperature, wind speed, wind direction, and cloud cover—were assessed using critical error values for each season. Forecast verification employed indices such as the H-K score, ratio score (Kothiyal, 2017), and threat score (Schafer, 1990) to evaluate rainfall predictions. Additionally, the root mean square error (RMSE) was calculated to determine the absolute difference between predicted and observed data. Over the course of the year, forecasts for 365 days were utilized to prepare crop-weather bulletins, which were issued twice weekly - on Tuesdays (53 bulletins) and Fridays (52 bulletins)- to benefit farmers across Jammu district.

3. Results and conclusion

Rainfall forecast usability varied across seasons, with highest accuracy in post-monsoon (91.41%) and winter (83.79%), but lowest in monsoon (36.84%), giving a yearly average of 71.47%; skill scores showed POD strongest in pre-monsoon (0.93) and winter (0.90), CSI and HSS best in winter (0.63, 0.68), HK highest in winter (0.82), and RS strongest in post-monsoon (94.23%) and winter (91.98%), confirming moderate overall skill and winter as most reliable. Forecast accuracy for maximum temperature was highest in post-monsoon (65.95%), followed by monsoon (57.37%), while pre-monsoon (45.31%) and winter (41.70%) were lower, with a yearly average of 52.58%, important for rabi pre-sowing. Minimum temperature forecasts peaked in post-monsoon (55.99%) and winter (52.36%), with moderate values in monsoon (46.19%) and pre-monsoon (47.50%), averaging 50.51%, critical for frost and stress management. Morning relative humidity (RH max) was most accurate in monsoon (82.14%), then winter (73.20%), with post-monsoon

(65.84%) and pre-monsoon (62.00%) moderate, yearly average 70.80%, vital for pest/disease prediction. Evening relative humidity (RH min) showed very high usability, with monsoon (91.15%), winter (76.67%), post-monsoon (74.27%), and pre-monsoon (70.75%), averaging 78.21%, valuable for disease management. Wind speed forecasts achieved perfect accuracy (100%) across all seasons, confirming robustness, while cloud cover was most accurate in post-monsoon (86.47%), followed by monsoon (76.83%), pre-monsoon (74.50%), and winter (70.91%), with a yearly average of 77.18%. Wind direction remained least dependable, ranging from 23.20% in winter to 39.86% in post-monsoon, with a yearly average of 28.43%, indicating need for refinement. In conclusion, forecast verification for Jammu district (2024–25) showed high accuracy for wind speed and relative humidity, moderate reliability for rainfall, temperature, and cloud cover, overall, forecasts were sufficiently precise to support agromet advisories for sowing, irrigation, pest and disease management, though improvements in rainfall and wind direction prediction would further strengthen resilience against climatic variability.

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1.7 Climate Smart Breeding and Production Systems for Resilient Agriculture Optimization of Callus Induction and Regeneration Protocol from Embryonic Tissues of *Japonica* Rice (*Oryza sativa* L. cv. K 332)

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Keywords: *Japonica* Rice, Tissue Culture, Callus Induction, Plant Regeneration, Growth Regulators, MS Medium

1. Background

Rice (*Oryza sativa* L.) is one of the most important staple crops worldwide and plays a crucial role in global food security. Development of an efficient *in vitro* regeneration system is essential for successful genetic transformation and crop improvement programs. Tissue culture techniques, particularly callus induction and plant regeneration from embryogenic tissues, provide a reliable platform for genetic engineering and molecular breeding approaches in rice. Several studies have reported that optimization of plant growth regulators and culture conditions significantly influences callus formation and regeneration efficiency in rice (Upadhyaya *et al.*, 2015; Khan *et al.*, 2021). Therefore, the present study aimed to optimize an efficient protocol for callus induction and plant regeneration using embryonic tissues of *Japonica* rice variety K 332.

2. Materials and Methods

The experiment was conducted using dehusked mature seeds of *Japonica* rice cv. K 332 as explants. Seeds were subjected to different surface sterilization treatments using 0.1% HgCl₂ and 8% NaOCl for durations ranging from 2–8 minutes. Among these treatments, 0.1% HgCl₂ for 8 minutes was found to be most effective, resulting in maximum explant survival (97.16%) and minimum contamination (2.77%). For callus induction, explants were cultured on Murashige and Skoog (MS) medium supplemented with different concentrations of 2,4-D (2.0–3.5 mg/l) either alone or in combination with NAA (0.25–1.0 mg/l) or BAP (0.5–1.0 mg/l). For plant regeneration, embryogenic calli were transferred to MS medium containing various combinations of BAP (1.0–2.5 mg/l) and NAA (0.25–1.0 mg/l) with or without kinetin.

3. Results and Conclusion

The results indicated that the highest callus induction frequency (95%) was obtained on MS medium supplemented with 2,4-D (2.5 mg/l) + BAP (1.0 mg/l). The induced calli were creamish-white, compact and embryogenic, which are ideal characteristics for successful plant regeneration. For shoot regeneration, the highest regeneration frequency (76%) was achieved on MS medium supplemented with BAP (1.0 mg/l) + NAA (1.0 mg/l). The regenerated shoots were successfully rooted and developed into healthy plantlets under controlled culture conditions. The optimized protocol established in this study provides a reliable and reproducible regeneration system for *Japonica* rice cv. K 332. This regeneration system can serve as an important platform for genetic transformation, genome editing and other biotechnological applications aimed at improving rice productivity and stress tolerance.

Table-1: Effect of Growth Regulators on Callus Induction and Regeneration in Rice cv. K 332

Stage	Medium Composition	Response
Surface Sterilization	0.1% HgCl ₂ (8 min)	97.16% explant survival, 2.77% contamination
Callus Induction	MS + 2,4-D (2.5 mg/l) + BAP (1.0 mg/l)	95% callus induction
Regeneration	MS + BAP (1.0 mg/l) + NAA (1.0 mg/l)	76% plant regeneration

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1.8 Impact of weather parameters on growth and yield of Basmati Rice cultivars under sub tropical condition of India

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Keywords: Basmati rice, cultivars, growth, weather, grain yield.

1. Background

Climate determines the suitability of crops in a particular region, whereas weather conditions during the crop growing season govern the growth, development, and yield potential of that crop. Rice (*Oryza sativa* L.) is a weather-sensitive crop whose growth and productivity are highly dependent on prevailing meteorological conditions. Basmati rice, a premium aromatic rice variety, is widely cultivated in the Indo-Gangetic Plains under subtropical climatic conditions. Among the various abiotic stresses, weather factors play a dominant role in influencing the growth, development, and yield of rice. When water is not a limiting factor, important weather parameters such as temperature, rainfall, solar radiation, relative humidity, and wind speed play a crucial role in determining crop growth, phenological development, and final yield. Variations in these meteorological parameters during different growth stages significantly affect physiological processes such as photosynthesis, respiration, and grain filling. In subtropical regions, seasonal variability and extreme weather events such as heat waves, erratic rainfall, and prolonged cloudy weather can adversely affect Basmati rice productivity as well as grain quality.

2. Material and Methods:

The field experiments were conducted during the kharif seasons of 2019, 2020, and 2021 at the Research Farm of the Agrometeorology Section, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J). The experimental station is geographically located at 32°40' N latitude and 74°82' E longitude, at an altitude of 293 m above mean sea level, in the sub-tropical foothills of the Shivalik range in Jammu and Kashmir. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The treatments consisted of three sowing environments, viz., 1st June (D₁), 16th June (D₂), and 1st July (D₃), and four Basmati rice varieties, namely Basmati-370 (V₁), Basmati-118 (V₂), Basmati-138 (V₃), and Basmati-123 (V₄), resulting in 12 treatment combinations.

3. Results and Conclusion

The yield-attributing characteristics, viz., number of panicles and tillers per plant, number of grains per panicle, test weight, and harvest index, differed significantly among the sowing environments and cultivars, except for the number of grains per panicle, which showed a non-significant difference among cultivars. The cultivar Basmati 123 recorded a significantly higher number of grains per panicle than the other two cultivars (Basmati138 and Basmati 370), while Basmati 123 was found to be at par with Basmati 370. The results also indicated that delayed sowing significantly affected the number of grains per panicle and tillers per plant. Test weight varied significantly with different sowing environments and cultivars. The early sown direct-seeded Basmati crop (1st June) produced significantly bolder grains (24.19 g) compared to crops sown on 16th June (22.49 g) and 1st July (20.71 g). Among the varieties, Basmati-123 produced the highest grain yield and straw yield, followed by Basmati-118, Basmati-370, and Basmati-138. These

variations may be attributed to the genetic makeup of the varieties and their adaptability to different sowing environments. The correlation analysis revealed that maximum temperature had a significant negative impact during the tillering and booting stages, while it showed a significant positive influence on crop yield during the flowering, hard dough, and physiological maturity stages. Minimum temperature showed a significant negative impact at the booting stage. Rainfall had a significant positive effect at the milking stage. Furthermore, evaporation and sunshine hours had a significantly positive impact at the physiological maturity stage, whereas evaporation showed a significant negative effect at the booting and panicle emergence stages. Morning relative humidity had a significant positive effect at the hard dough stage, while evening relative humidity showed a negative correlation at the booting stage (Table 1). It is therefore concluded that Weather parameters significantly influence the growth, development, and yield of Basmati rice cultivars under subtropical conditions. Based on the experimental results, Basmati-123 sown on 1st June under the was found to be the most suitable option for achieving higher productivity. This combination can be recommended as a profitable and economically viable option for resource-poor farmers under irrigated subtropical conditions of Jammu.

Table-1. Correlation coefficients between yield and meteorological parameters at different phenophases under direct seed sowing of basmati crop (3 Years pooled data).

Weather variables / Stages →	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	EPO (mm)	Sunshine (hrs)	Morning relative humidity (%)	Evening relative humidity (%)
P ₁	-0.490*	-0.368	0.365	0.330	-0.370	0.314	0.213
P ₂	-0.485*	-0.564*	0.122	-0.601**	-0.257	-0.321	-0.539*
P ₃	-0.111	-0.208	0.064	-0.710**	0.228	-0.090	0.105
P ₄	0.612**	0.410	0.133	0.375	-0.002	0.127	0.076
P ₅	0.165	-0.082	0.638**	-0.019	0.180	-0.047	0.237
P ₆	0.744**	0.026	0.413	0.198	-0.016	-0.406*	0.146
P ₇	0.942**	-0.008	-0.005	0.489*	0.568*	0.011	0.152
P ₁ -Tillering; P ₂ -Bootling; P ₃ -Panicle Emergence; P ₄ -Flowering; P ₅ -Milking; P ₆ -Hard dough; P ₇ -Physiological Maturity							
*Significant at 0.05, **Significant at 0.01							

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1.9 Climate-Resilient Technologies for Enhancing Agricultural Resilience in the Cold Arid Himalayas of Leh, Ladakh

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Keywords: Climate resilient agriculture, NICRA, cold arid ecosystem, mulching, protected cultivation, Ladakh

1. Background

Agriculture in the cold arid Himalayan region of Ladakh is constrained by extreme environmental conditions including low precipitation, prolonged winter cold stress, large diurnal temperature variations and a very short growing season. Annual precipitation is generally below 100 mm and the effective cropping period is limited to a few summer months. Frequent climatic stresses such as early season drought, frost injury, extreme temperature fluctuations and occasional hailstorms further reduce crop productivity and threaten farm livelihoods. Traditional agriculture in Ladakh remains largely subsistence-based and strongly influenced by the fragile mountain ecosystem and limited natural resources (Angchok *et al.*, 2009). Climate variability has intensified these constraints, increasing the vulnerability of traditional farming systems that depend on local crop varieties and conventional management practices. Studies on Himalayan agriculture indicate that climate change and weather variability pose serious risks to agricultural sustainability and livelihood security in mountain ecosystems (Tiwari and Joshi, 2015). Adoption of locally suitable climate resilient technologies is therefore essential to enhance productivity and reduce climate-induced risks. The present study evaluates the impact of these interventions implemented during 2021–2025 in improving crop productivity, livestock performance and livelihood resilience in the cold arid agro-ecosystem.

2. Material and Methods

The study was conducted in NICRA villages of Leh district, Ladakh representing the cold arid agro-ecosystem of the Trans-Himalayan region. Technology demonstrations were implemented during 2021–2024 involving NICRA farmers under different thematic modules including crop production, natural resource management and livestock management. Major climate resilient interventions included mulching in vegetable crops, introduction of an improved short-duration wheat variety (VLG-2041), deployment of quality vegetable seeds, promotion of protected cultivation structures such as greenhouses and low tunnels, introduction of Vanaraja birds under backyard poultry systems, and improved livestock health management and feeding through vaccination, dipping and dosing along with fodder conservation and silage preparation. Demonstrations were conducted in farmers' fields and compared with prevailing farmers' practices. Data on crop productivity, cost of cultivation, gross returns and livestock performance were collected from demonstration plots and farmers' fields to evaluate the effectiveness of the climate resilient technologies.

3. Results and Conclusion

The results revealed substantial improvements in crop productivity and system resilience following the adoption of climate resilient technologies. Mulching in cabbage increased productivity to approximately 34,000 kg ha⁻¹, compared to 20,000 kg ha⁻¹ under farmers' practice, reflecting nearly 70% improvement under normal conditions and over 50% advantage during stress years. Similarly, the improved wheat variety VLG-2041 recorded yield enhancements of 25–43%, while the use of improved vegetable seeds resulted in 50–57% higher vegetable productivity. Livestock-based interventions also showed considerable benefits. General health management and

Improved feeding practices through silage integration, area specific mineral mixture and fodder conservation has increased the overall milk production by about 60% compared to conventional feeding practices. The introduction of Vanaraja birds under backyard poultry systems provided an additional source of income and nutritional security for farm households, particularly benefiting women farmers. The intervention resulted in an average annual net income of Rs. 870 per bird. Overall, the findings highlight the potential of locally adapted climate resilient technologies to improve productivity, resource-use efficiency and livelihood stability in the fragile cold arid ecosystem of Ladakh. Wider dissemination and scaling up of these interventions through extension support, capacity building and institutional convergence could significantly strengthen the climate resilience of Himalayan farming systems.

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1.10 Elevated Temperature Stress and the Resilience of Rice Varieties for Sustaining Yield and Nutritional Security

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Keywords: Traditional Rice, Climate change, Nutritional security

1. Background

Rice (*Oryza sativa* L.) serves as a staple food for more than half of the global population (Fukagawa and Ziska, 2019), supplying a significant proportion of daily calories, protein, and essential micronutrients. Climate change, driven primarily by anthropogenic greenhouse gas emissions, is one of the most pressing challenges faced by global agriculture. Increased atmospheric CO₂ concentrations, rising temperatures, and erratic rainfall patterns pose a significant threat to nutritional security. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change highlights the projected impacts associated with a global average temperature rise of 1.5 °C and even higher warming levels. Prolonged exposure to elevated temperatures is generally termed heat stress. When temperatures exceed the optimal thresholds for crop growth over extended periods, particularly during critical stages of development, they lead to significant physiological, genetic, and biochemical changes. Rice is the principal crop in Tamil Nadu, occupying about one-third of the cultivated area, with a higher productivity (3,809 kg ha⁻¹) than the national average (2,705 kg ha⁻¹). Traditional rice varieties are nutritionally rich, resilient to climatic and biotic stresses, cost-effective, and often perform better than high-yielding varieties under low-input, drought, and waterlogged conditions (Manickam *et al.*, 2024). It can help address nutritional security due to its rich content of essential vitamins and minerals. Therefore, studying the impact of elevated temperature on these varieties is crucial to ensure their resilience and sustained nutritional benefits under climate change conditions.

2. Materials and Methods

The experiment was conducted in Field No. 36C at Climate Control Chamber (CCC), Agro Climate Research Centre (ACRC), Tamil Nadu Agricultural University, Coimbatore, during 2025. CCC is designed to maintain elevated temperature and humidity using polycarbonate covering, foggers, sensors, and a fan-regulated airflow system. Environmental parameters were continuously recorded at 10-minute intervals using a data logger, with temperature stress imposed during daytime, while control pots were maintained under ambient conditions. The geo-coordinates of the site are as detailed as latitude (11° N) and longitude (77° E) at an altitude of 423.7 m above the Mean Sea Level (MSL) with the annual rainfall of 673 mm. The present study assessed the impact of elevated temperature stress on two contrasting rice varieties, CO 57 (a popular high-yielding variety) and Karuppu kavuni (a traditional landrace). The treatments comprised ambient temperature conditions (control) and elevated temperature stress (+3°C above ambient), imposed at critical phenological stages, including tillering, panicle initiation, booting, flowering, milky stage, dough to maturity, and across the complete life cycle.

3. Result and Conclusion

Under heat stress, clear varietal differences were observed, with full-season stress causing the maximum reduction across all parameters. Panicle length declined by 37.0% in CO 57 and 27.0% in Karuppu Kavuni, with mean reductions of 17.1% and 7.4%, respectively. Productive tillers decreased by 39.4% in CO 57 and 24.1% in Karuppu Kavuni, with mean reductions of 21.0% and

10.3%. Spikelets were reduced by 31.6% in CO 57 and 20.5% in Karuppu Kavuni, with mean reductions of 14.0% and 7.9%, while filled grains declined by 32.1% and 22.1%, with mean reductions of 16.0% and 9.5%; notably, Karuppu Kavuni showed a slight increase of 1.9% at dough to maturity. Yield reduction was also highest under full-season stress, reaching 33.3% in CO 57 and 21.7% in Karuppu Kavuni, with mean reductions of 16.4% and 9.4%. Overall, CO 57 exhibited greater reductions across traits, whereas Karuppu Kavuni demonstrated comparatively better heat tolerance and yield stability under elevated temperature. Flowering stage heat stress reduced all nutritional parameters in both varieties, but the decline was lower in Karuppu Kavuni at about 3-4% compared to 6-7% in CO 57. Overall, Karuppu Kavuni maintained better nutritional stability, while CO 57 showed comparatively greater reductions in macronutrients, antioxidants, and mineral contents under elevated temperature stress.

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1.11 Climate-Resilient Controlled Cultivation of Lotus Stem (Nadru) *Nelumbo nucifera* for Enhanced Quality and Assured Production

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Keywords: Controlled microenvironment, Nadru, *Nelumbo nucifera*, scientific cultivation, wetland farming

1. Background

The edible rhizome of *Nelumbo nucifera* Gaertn., locally known as Nadru, is a culturally and nutritionally important aquatic vegetable in the Kashmir Himalayan region. Lotus rhizome contains many health-promoting substances viz: alkaloids, lipids, flavonols, carotenes, aporphine, nuciferine, phospholipids, flavonoids, xanthophylls, and minerals that may be consumed either cooked or raw (Li *et al.*, 2017). Traditionally, Nadru is harvested from natural wetlands and lakes, where production remains largely unmanaged, seasonal, and dependent on fluctuating environmental conditions. This reliance on natural ecosystems imposes several constraints, including poor accessibility, inconsistent productivity, variability in quality, ecological degradation of wetlands, and unstable market supply. Despite its high nutritional value and emerging nutraceutical potential, systematic scientific cultivation technologies for Lotus Stem (Nadru) are largely lacking. Therefore, there is a critical need to develop sustainable and controlled cultivation systems that can ensure consistent production, improved quality and reduced pressure on natural aquatic ecosystems. The present study focuses on developing a controlled microenvironment-based cultivation technology to transform Lotus stem (Nadru) production from an extractive practice into a scientifically managed and commercially viable system.

2. Materials and Methods

A controlled microenvironment cultivation system for Lotus Stem (Nadru) was developed through systematic optimization of key agronomic and environmental parameters. The system was designed to simulate ideal wetland conditions while enabling precise control over growth factors. The experimental setup consisted of triple-layer tanks (1000 L capacity, >4 ft height) arranged in units of six. Each tank was structured into three layers: a bottom soil layer (1.5 ft), a compost layer (1.5 ft) prepared from Dal weed, and a top water layer (1 ft). Rhizomes were planted at a density of 0.09 m² at a depth of 5–8 cm during April. Mulching was done using Dal weed biomass to maintain temperature and moisture. Water management included scheduled drainage and replenishment at 14-day intervals initially, followed by weekly replacement during peak growth stages. Fertilizer application involved urea (35 g/m²), DAP (10 g/m²), and MOP (18 g/m²), applied in split doses. The system was equipped with inlet-outlet pipes, a water reservoir, and solar-powered pumping for efficient water circulation. Hail nets were installed to protect the crop from adverse weather. Intercultural operations included manual weeding, removal of diseased leaves, and monitoring of pest incidence. Harvesting was carried out from September to December by carefully extracting mature rhizomes to avoid breakage. Selection of mature rhizomes was based on thickness, firmness, and plant indicators such as leaf senescence and post-flowering stage. The system was tested under controlled cultivation modules, and performance was evaluated based on yield, rhizome quality traits, and economic returns.

3. Results and Conclusion

The controlled microenvironment cultivation system demonstrated significant improvements in both productivity and quality of Lotus Stem (Nadru) compared to traditional wetland harvesting

systems. The controlled microenvironment significantly improved the productivity and quality of Lotus Stem (Nadru). The yield under the Triple C Technology reached approximately 10 kg/m² (100 MT/ha) compared to 3 kg/m² (30 MT/ha) under traditional lake-based cultivation, representing a threefold increase. The availability of Lotus stem (Nadru) was extended from a short seasonal window to a prolonged period (September–December), enhancing market supply. The optimized system resulted in improved crop uniformity and consistent yield due to precise regulation of growth conditions and standardized agronomic practices. Rhizomes produced under controlled conditions exhibited superior quality attributes, including enhanced crispness, uniform internode development, reduced contamination, and improved visual appeal. These traits are critical determinants of consumer preference and market value. Economic analysis of a six-tank unit demonstrated a benefit-cost ratio of 3:1, with initial establishment costs recovered within two years. Additional income was generated from by-products such as flowers and seeds. Economically, the technology demonstrates high profitability, with potential returns ranging from ₹2.16 to ₹3.75 lakh per kanal. In addition, its climate-resilient nature enhances production stability under variable environmental conditions. The controlled system also enabled the development of a scalable business model, encouraging farmer participation and entrepreneurship. Economic analysis revealed a substantial increase in profitability, indicating strong commercial potential for the technology. The system enables standardization, mechanization, and scalability, making it suitable for commercial adoption. It also provides a platform for integrating advanced approaches such as precision nutrient management, hydroponic or semi-aquatic systems, and climate-resilient cultivation strategies. Furthermore, the technology improved labor efficiency and reduced the dependency on skilled manual harvesting in deep water conditions. It also promoted sustainable practices by reducing pressure on natural wetlands and enabling cultivation in non-traditional areas. The water-based cultivation system offers inherent resilience to climatic variability, ensuring stable production under changing environmental conditions.

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1.12 Fodder Yield and Quality of Sorghum as Influenced by Planting Time and Seed Rate

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Keywords: Climate-smart agriculture, Planting time, Seed rate, Crop resilience, Forage quality

1. Background

Climate change-driven variability in temperature, rainfall distribution, and growing season length poses serious challenges to sustainable fodder production in temperate agro-ecosystems (IPCC, 2021). Developing climate-smart production systems through optimized agronomic management is essential for enhancing crop resilience, productivity, and resource-use efficiency. In the Kashmir valley, irregular precipitation patterns, shortening growing periods and declining soil fertility have intensified the need for resilient forage production strategies. Sorghum (*Sorghum bicolor* L.), owing to its inherent drought tolerance, rapid growth and wide adaptability, represents a promising climate-resilient fodder crop (Rooney *et al.*, 2007). However, its productivity and forage quality are strongly influenced by planting time and seed rate. Optimizing these climate-sensitive agronomic factors is therefore crucial for improving biomass yield, forage quality, and farm profitability under temperate Himalayan conditions. The present study was undertaken to identify climate-smart planting windows and optimal seed rate for enhancing the resilience and productivity of fodder sorghum.

2. Materials and Methods

A field experiment was conducted during the *kharif* season of 2024 at the Agronomy Research Farm, Faculty of Agriculture, Wadura, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. The experiment was laid out in a split-plot design comprising four planting times (21st, 23rd, 25th and 27th Standard Meteorological Weeks) in main plots and three seed rates (20, 25 and 30 kg ha⁻¹) in sub-plots, replicated thrice. Observations on growth parameters, yield attributes, green and dry fodder yields and forage quality parameters including crude protein, crude fibre, ash content, acid detergent fibre (ADF) and neutral detergent fibre (NDF) were recorded using standard procedures. Economic analysis was carried out based on prevailing market prices. Data were statistically analyzed using ANOVA and treatment means were compared at the 5% significance level.

3. Results and Conclusion

The results demonstrated that planting time and seed rate exerted a significant influence on crop resilience, productivity, forage quality and economic returns of fodder sorghum. Sowing during the 23rd SMW (04-10 June) resulted in superior plant growth, higher leaf area index, greater dry matter accumulation and enhanced crop growth rate, leading to significantly higher green and dry fodder yields compared to delayed sowings. Among seed rates, 30 kg ha⁻¹ recorded the highest biomass production, improved forage quality through increased crude protein content and reduced fibre fractions, and enhanced economic returns. The treatment combination of 23rd SMW planting with 30 kg ha⁻¹ seed rate proved to be the most climate-smart production strategy, achieving maximum fodder yield, net returns and benefit-cost ratio. Overall, the study concludes that

optimization of planting time and seed rate constitutes an effective climate-smart production approach for enhancing resilience, productivity and profitability of fodder sorghum under temperate Himalayan agro-ecosystems.

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1.13 Exploring Traditional Rice Consumption in the Era of Climate Change and Lifestyle Disorders: Evidence from Western Agro Climatic Zone of Tamil Nadu

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Keywords: Climate Change, Life style diseases, Traditional rice varieties, Consumption Pattern, Nutritional Security

1. Background

Climate-induced health risks disproportionately affect vulnerable populations, including women, children, the elderly, and individuals with pre-existing health conditions (Gkouliaveras *et al.*, 2025). In this context, traditional rice varieties assume significance due to their superior nutritional composition and documented ethnomedicinal properties, particularly in mitigating lifestyle-related and non-communicable diseases (Chaudhari *et al.*, 2018). The present study was undertaken to analyse the factors influencing consumer preference for the consumption of traditional rice varieties in the Western Agro Climatic Zone of Tamil Nadu.

2. Materials and Methods

A cross-sectional survey design was adopted, and primary data were collected from 100 respondents using a structured interview schedule. The data were analysed employing percentage analysis with standard error estimation, followed by Garrett's ranking technique to prioritise influencing factors. and nearness of shops (Rank IX).

3. Results and Conclusion

The results pertaining to consumption frequency of traditional rice revealed that 42 per cent of respondents consumed these products once in 3–4 months, 26 per cent consumed occasionally, 19 per cent consumed once in 1–1.5 months, and 13 per cent reported rare consumption. The relatively higher proportion of respondents consuming traditional rice at longer intervals suggests a pattern of mixed consumption, wherein traditional varieties are supplemented with conventional polished rice. With respect to purchase sources, 53 per cent of respondents procured traditional rice from supermarkets, 31 per cent from local vendors, and 16 per cent from both sources. The predominance of supermarket purchases may be attributed to higher purchasing power, better product visibility, perceived quality assurance, and availability of branded or value-added traditional rice products. Garrett ranking analysis indicated that the most influential factor affecting consumer preference was lifestyle compatibility (Rank I), followed by age (Rank II), education (Rank III), income (Rank IV), peer influence and social networks (Rank V), taste (Rank VI), availability of value-added products (Rank VII), availability of grains (Rank VIII), The findings further suggest that increasing climate variability, particularly rising temperatures and erratic rainfall patterns, may indirectly contribute to the growing prevalence of lifestyle-related health issues, thereby influencing consumer inclination towards healthier dietary alternatives such as traditional rice varieties. Higher educational attainment was associated with greater awareness of non-communicable diseases and the nutritional benefits of traditional foods, thereby positively influencing purchasing behaviour. Moreover, the fast-paced urban lifestyle has led to a preference

for convenience-oriented consumption, with value-added traditional rice products gaining traction over whole grains. Overall, the study highlights a trend of partial substitution, where consumers incorporate traditional rice varieties alongside conventional staples, primarily driven by increasing health consciousness and the rising burden of lifestyle diseases.

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1.14 Impact of Elevated Temperature on Growth, Physiology, Yield and Nutritional Quality of Horsegram (*Macrotyloma uniflorum*)

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Keywords: Horsegram, Heat stress, Elevated temperature, Physiological response

1. Background

Climate change has emerged as one of the most pressing challenges to global agriculture. Among the various climatic stressors, heat stress has been identified as a principal constraint affecting the growth, physiology and yield of crops. This study was conducted to assess the impact of elevated temperature (+3°C above ambient) on growth, physiological responses, yield and quality of two horsegram varieties (Paiyur 2 and Black Horsegram).

2. Material and Methods

The experiment was carried out at the Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, using a Temperature Gradient Tunnel during November 2024 to February 2025 under a Completely Randomised Design. The crops are grown in a standard pot and two environmental conditions were maintained inside the Temperature Gradient Tunnel which is ambient condition with normal atmospheric temperature and elevated temperature of +3°C.

3. Results and Conclusion

Early heat stress increased plant height but reduced leaf area index by 24 - 28% and dry matter production by up to 36% in Paiyur 2. Photosynthetic rate declined by ~40%, while transpiration and stomatal conductance increased by 71% and 73%, respectively, leading to reduced water use efficiency. Relative water content decreased by 18 - 19%, chlorophyll stability index by 30 - 32% and membrane stability index by 19 - 22%, indicating stress - induced cellular damage. Proline accumulation increased by 55 - 64%, suggesting osmotic adjustment under stress. Yield attributes were significantly reduced, with seed yield declining by 31 - 59% in Paiyur 2 and 12 - 38% in Black horsegram, particularly under season - long and flowering stage heat stress. Harvest index decreased from 36% under control conditions and test weight was also reduced. Quality parameters declined, with protein content decreasing by 18 - 27% and total sugars by 14 - 22%. Black horsegram exhibited relatively better heat tolerance, maintaining higher physiological stability and yield. These findings highlight the sensitivity of reproductive stages to heat stress and the need for developing heat-resilient cultivars and adaptive strategies.

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1.15 Climate Change: Concerns and Adaptation Strategies in Kashmir

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Keywords: Climate, Strategies, Temperature tolerance, Adaptation

1. Background

Agriculture plays a crucial role in food security for the majority of people in India. The extremes of climate poses serious risks in terms of widespread droughts, flash rains, cyclones and enhanced incidences of malnutrition. The climatic concerns in future are likely to further aggravate the problem. Climate change, driven primarily by anthropogenic greenhouse gas emissions, has emerged as one of the most critical global challenges of the 21st century. Rising temperatures, erratic precipitation patterns, and increasing frequency of extreme weather events pose serious threats to ecosystems, agriculture, and human livelihoods (UNEP, 2022). Regions such as South Asia are particularly vulnerable due to high population density and dependence on climate-sensitive sectors (IPCC, 2023). This study aims to experimentally assess the impact of elevated temperature and altered water availability on plant growth, and to evaluate simple adaptation strategies that can mitigate adverse effects.

2. Materials and Methods

A controlled experiment was conducted using potted plants (e.g., bean plants) under three simulated climate conditions. Control Group - ambient temperature and regular watering. Heat Stress Group - temperature elevated by ~3-4°C. Drought Stress Group – reduced watering frequency. Additionally, adaptation strategies were tested, mulching to conserve soil moisture, shade nets to reduce heat stress, plant height, leaf number, and soil moisture were measured over a 4-week period.

3. Results and Conclusion

Plants under heat stress showed a ~25% reduction in growth compared to control. Drought conditions resulted in wilting and ~40% lower biomass. Mulching improved soil moisture retention by ~15–20%. Shade nets reduced temperature stress and improved plant survival rates by ~18%. These results demonstrate that even small climatic variations can significantly affect plant productivity, but low-cost adaptation strategies can partially offset these impacts. The findings align with broader climate models, such as those from the Intergovernmental Panel on Climate Change, which predict reduced agricultural yields under warming scenarios. Adaptation strategies like water conservation, agroforestry, and climate-resilient crops are essential, especially in developing countries like India. Climate change poses significant risks to ecological and agricultural systems. However, localized, affordable adaptation measures—such as mulching and shading can enhance resilience. Scaling such strategies is crucial for sustainable development and food security.

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1.16 Thermal Sensitivity and Productivity Patterns in Popular and Traditional Fields Crops Across Tamil Nadu

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Keywords: Temperature sensitivity, rice, blackgram, sesamum productivity

1. Background

Understanding crop sensitivity to temperature variability is critical for designing climate resilient production strategies in South India, where rising maximum temperatures (Tmax) and widening diurnal ranges (DTR) increasingly threaten yield stability (Moulkar and Peddi, 2024).

2. Materials and Methods

A multilocation study across 14 TNAU research stations quantified yield responses to Tmax, minimum temperature (Tmin), and DTR for rice (ADT 39, TPS5, TKM13, CR1009 sub), blackgram (VBN 8, VBN 11, VBN 10), and sesamum (TMV 7).

3. Results and Conclusion

Rice varieties exhibited distinct thermal profiles: ADT 39 and CR1009 showed consistent negative correlations with Tmax and DTR, indicating high sensitivity to daytime heat and fluctuations, particularly during reproductive stages. TPS5 demonstrated moderate tolerance, while TKM13 and the traditional rice varieties “Mappilai Samba” and “Karunkurvai” displayed resilience, with positive associations to Tmax and DTR in several locations, suggesting suitability for irrigated inland tracts with wider diurnal ranges. Across rice, Tmin exerted less influence than Tmax, underscoring the dominance of heat stress. Blackgram revealed sharper seasonal differentiation. Kharif varieties (VBN 8, VBN 11) were sensitive to Tmax and Tmin, whereas rabi varieties (VBN 10, VBN 11) correlated positively with Tmax and DTR, highlighting robust heat tolerance and adaptability to dry season environments. Sesamum TMV 7 showed mixed responses: positive Tmin correlations suggested night temperature tolerance, while negative DTR correlations indicated vulnerability to large day–night fluctuations, except in MDU where strong DTR tolerance was observed. Overall, Tmax and DTR emerged as dominant stressors, with variety specific and location specific interactions. Tolerant genotypes TKM13 in rice, VBN 10 and VBN 11 (rabi) in blackgram, and TMV 7 in select zones offer promising options for sustaining productivity under future warming scenarios

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1.17 Creation of novel alleles in rice for grain size and yield through genome editing

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Keywords: Rice. Genome editing, grain size, yield, alleles

1. Background

Developing climate-resilient and high-yielding varieties is essential for sustainable agriculture and global food security. Grain yield in rice is a complex trait governed by grain size, grain number per panicle, and tillering ability. Grain size directly influences thousand grain weight (TGW) and market preference, while plant architecture determines yield stability and resource-use efficiency under stress conditions. Conventional breeding approaches for improving these traits are time-consuming, limited by linkage drag, and constrained by narrow allelic diversity. Genome editing technologies, particularly CRISPR/Cas9, provide a precise and efficient approach for generating targeted genetic variation. In this study, two key regulatory genes are targeted: *GS3*, a negative regulator of grain length, and *OsPIN5b*, an auxin transporter involved in plant architecture. Simultaneous editing of these genes is expected to improve both grain size and yield-related traits, contributing to climate-resilient rice production.

2. Materials and Methods

Guide RNAs targeting functional regions of *GS3* and *OsPIN5b* were designed using a tool, CRISPR-P 2.0. A multiplex genome editing construct was developed by assembling multiple gRNAs into a single tRNA–gRNA cassette in the binary vector pRGEB32, along with the Cas9 expression system. The recombinant vector was mobilized into *Agrobacterium tumefaciens* strain LBA4404 and used for transformation of immature embryos of rice cultivar CO 55. Transformed calli were selected on hygromycin-containing media and regenerated into whole plants under controlled tissue culture conditions. Putative edited plants were subjected to molecular analysis using PCR for the presence of selection markers (*hpt* and *Cas9*). Target regions encompassing the guide RNA binding sites were amplified and analyzed through Sanger sequencing to identify insertion/deletion (indel) mutations generated via non-homologous end joining.

3. Results and Conclusion

Genome editing of *GS3* is expected to generate loss-of-function alleles leading to increased grain length and higher TGW. Similarly, knockout of *OsPIN5b* is anticipated to enhance panicle length and tillering due to altered auxin homeostasis. Multiplex editing of both genes is expected to result in combined phenotypic effects, including increased grain length, higher thousand grain weight, enhanced panicle architecture and improved tillering capacity. These traits collectively contribute to improved yield potential and better adaptation to variable environmental conditions. Additionally, segregation in subsequent generations may enable the recovery of transgene-free edited lines suitable for breeding applications. This strategy provides a scalable framework for future crop improvement programs aimed at ensuring food security under changing environmental conditions.

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1.18 Unveiling Hard Seededness and Enhancing Seedling Vigor: Genotypic Response and Priming Strategies in Mung Bean (*Vigna radiata*) under Temperate Conditions

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Keywords: Hard seededness, Mung bean, Rhizobium, Seed priming, Trichoderma

1. Background

Mung bean (*Vigna radiata*) is an important pulse crop valued for its nutritional quality and adaptability to diverse agro-climatic conditions. However, hard seededness, a form of physical dormancy caused by impermeable seed coats, remains a major constraint affecting uniform germination and crop establishment (Baskin and Baskin, 2014). In temperate regions like Kashmir, this problem is further aggravated by sub-optimal environmental conditions during sowing. Seed priming, particularly with beneficial microorganisms such as Rhizobium, Trichoderma, and Pseudomonas, has emerged as a promising approach to enhance germination, seedling vigor, and stress tolerance. Understanding genotypic variability for hard seededness and optimizing priming strategies are therefore critical for improving mung bean productivity.

2. Materials and Methods

A field and laboratory study was conducted during 2023 and 2024 at the Faculty of Agriculture, Wadura, SKUAST-Kashmir. A diverse set of mung bean genotypes was evaluated for hard seededness by recording the number of hard seeds after standard germination tests. In parallel, a seed priming experiment was conducted using different microbial treatments including Rhizobium, Trichoderma, and Pseudomonas. Seeds were treated with respective inoculants and evaluated for seedling parameters such as root length, shoot length, root weight, and shoot weight under controlled conditions. Data were statistically analyzed to assess genotypic variation and treatment effects.

3. Results and Conclusion

Significant genotypic variation for hard seededness was observed across both years. In 2023, the majority of genotypes exhibited complete germination, while a smaller proportion showed varying degrees of hard seededness (1–12 seeds). In contrast, 2024 recorded increased hard seededness, with some genotypes showing up to 22 hard seeds. Genotype PKV-AKM-4 consistently exhibited the highest level of hard seededness, indicating strong genetic control and environmental interaction. The increase in hard seeds in the second year may be attributed to climatic variability influencing seed coat development, as also reported by Rolston (1978). This variability highlights the importance of selecting genotypes with low dormancy for uniform field emergence. Microbial seed priming significantly improved seedling vigor traits. Rhizobium treatment resulted in the highest root depth, root weight, and shoot weight. Trichoderma treatment promoted maximum shoot length. Pseudomonas also showed beneficial effects. Genotypes with lower hard seededness, coupled with priming treatments such as Rhizobium and Trichoderma, can significantly improve germination, early growth, and overall crop performance.

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1.19 Modelling Cotton Yield Response to Heat Waves by Integrating Remote Sensing with Process-Based Simulation and Future Projections (2023-2050)

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Keywords: Cotton, Heat wave, DSSAT- CROPGRO-cotton, NDVI, Future climate projections

1. Background

Cotton (*Gossypium hirsutum* L.) is a major fibre crop in semi-arid regions of India and a backbone of the country's textile economy. However, its productivity is increasingly threatened by the rising frequency and intensity of heat waves driven by climate change. In northwest India, particularly Punjab, heat wave events have become more frequent and severe in recent decades, causing significant stress during critical reproductive stages (Shukla et al 2022). This study integrates remote sensing indicators (MODIS-derived Normalized Difference Vegetation Index) with process-based crop simulation modelling (CROPGRO-Cotton in DSSAT v4.8) to quantify the impact of heat waves on cotton yield in Bathinda district. Using district-level observed yields (2000–2022) and CMIP6 future climate projections (2023–2050), the research evaluates historical yield responses during heat wave years and projects future risks under escalating thermal stress scenarios.

2. Material and Methods

The study was conducted in Bathinda district, south-western Punjab (30.58°N, 74.18°E, 211 m above mean sea level), characterized by semi-arid climate with average annual rainfall of 450 mm. Cotton yield data (2000–2022) were obtained from the Statistical Abstract of Punjab. Daily weather data (maximum and minimum temperature, rainfall, solar radiation) were collected from the PAU Regional Research Station, Bathinda. Future weather projections (2023–2050) were sourced from CMIP6 (IITM-ESM model). Heat waves were identified using India Meteorological Department (IMD) criteria based on daily maximum temperature deviations from the 1969–1999 normal. MODIS-derived Normalized Difference Vegetation Index (NDVI) data were acquired for cotton growing periods. The CROPGRO-Cotton model (DSSAT v4.8) was run for the Bt hybrid RCH-773 BGII using three sowing dates (30 April, 15 May, 30 May). Pre-calibrated genetic coefficients (Dhir et al 2021) were used without further calibration. Model validation was performed against district-level observed yields (2000–2022). Future cotton yields were simulated for 2023–2050 under projected climate scenarios. Model performance was evaluated using coefficient of determination (R^2), root mean square error (RMSE), and Willmott's index of agreement (d-statistic). All simulations incorporated actual crop management practices followed in the region.

3. Results and Conclusion

The CROPGRO-Cotton model (DSSAT v4.8) was validated using observed yields (2000–2022) for the Bt hybrid RCH-773 BGII under three sowing dates (30 April, 15 May, and 30 May). Validation statistics showed strong agreement between simulated and observed yields, with R^2 values of 0.68, 0.70, and 0.69 for the respective sowing dates. The corresponding RMSE values were 433.82, 411.83, and 373.47 kg ha⁻¹, while d-statistic values reached 0.83, 0.83, and 0.86, indicating good model performance across planting windows. When all three sowing dates were considered together, the overall R^2 was 0.67, RMSE was 407.14 kg ha⁻¹, and d-statistic was 0.84. When these simulated yields were examined against seasonal

Normalized Difference Vegetation Index (NDVI) values derived from MODIS during the cotton growing season, a strong linear relationship emerged ($R^2=0.78$). This confirms NDVI as a reliable early indicator of heat stress and validates the integration of remote sensing with process-based modelling. Future projections (2023–2050) using the validated model under CMIP6 scenarios revealed substantial yield variability driven by increasing heat wave frequency. Years with the highest projected heat wave days (2032, 2036, 2038, 2040, 2042, 2048, and 2050) recorded the lowest simulated yields. These results highlight the growing risk to cotton productivity in south-west Punjab and underscore the need for adaptive strategies such as adjusted sowing dates and heat-tolerant varieties.

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1.20 Breeding Strategies for Pellitorine Enhancement in *Anacyclus pyrethrum*: A Climate-Smart Approach to Medicinal Crop Improvement

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Keywords: *Anacyclus pyrethrum*, pellitorine, alkylamides, HPLC profiling, phenotypic diversity, breeding strategies, medicinal crop improvement

1. Background

Anacyclus pyrethrum (L.) DC., commonly known as Akarkara, is a medicinally significant herb with well-documented therapeutic properties, including immunomodulatory, analgesic, and insecticidal activities, primarily attributed to its bioactive alkylamide pellitorine. Despite its immense medicinal potential and adaptability to changing climatic conditions, systematic breeding efforts to enhance phytochemical yield remain largely unexplored (cite relevant reference). The present study was undertaken to evaluate inter-accession variability in morphological traits and pellitorine content, and to devise targeted breeding strategies for developing climate-resilient, phytochemically superior varieties of *Anacyclus pyrethrum*.

2. Materials and Methods

The study was conducted over three consecutive years at the CSIR-CIMAP research farm in Lucknow. Diverse accessions of *Anacyclus pyrethrum* were raised under uniform agronomic conditions and evaluated for morphological attributes and yield parameters through systematic phenotypic characterization. Pellitorine content was quantified from different plant parts across genotypes and growing seasons using HPLC profiling following standard protocols. Inter-accession variability was statistically assessed to identify elite genotypes combining high pellitorine accumulation with desirable climate-adaptive traits. Correlation analysis was performed to establish relationships between phenotypic characters and pellitorine concentration. Data were analyzed using standard analysis of variance, and mean separation was performed using appropriate post hoc tests.

3. Results and Conclusion

Significant inter-accession variability was observed in morphological attributes, yield parameters, and pellitorine concentration across the evaluated germplasm, confirming a robust breeding base for improving *Anacyclus pyrethrum*. HPLC profiling revealed differential accumulation of pellitorine across genotypes and growing seasons, suggesting both genetic and environment-mediated regulation of this key alkylamide. Elite accessions consistently exhibiting high pellitorine content alongside favorable agromorphological traits were identified as promising candidates for use in structured breeding programs. It may be concluded that integrating HPLC-based phytochemical profiling with phenotypic characterization provides an effective framework for developing high-yielding, pellitorine-rich varieties of *Anacyclus pyrethrum* suited to climate-resilient, smart agricultural production systems.

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1.21 Sulphur and Zinc Fortification as a Climate-Smart Strategy for Improving Productivity of Groundnut

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Keywords: Groundnut, Biofortification, Sulphur, Zinc, Yield

1. Background

Groundnut (*Arachis hypogea* L.) is a major oilseed crop contributing significantly to edible oil production, nutritional security and livelihood sustainability in semi-arid regions of India. India ranks second in terms of production with production of 7.56 million tonnes in area of 4.15 million ha. The crop also plays an important role in improving soil fertility through biological nitrogen fixation and is highly valued in agrarian economies, especially in semi-arid agro-ecologies of South and Southeast Asia. Despite its economic importance, productivity of upland groundnut remains sub-optimal primarily due to imbalanced fertilization and widespread deficiencies of secondary and micronutrients, particularly sulphur and zinc. Sulphur is critically involved in protein synthesis, oil formation and enzymatic regulation, whereas zinc plays a vital role in auxin metabolism, photosynthetic activity and reproductive development. Continuous nutrient mining under intensive cultivation has further aggravated these deficiencies, leading to yield stagnation and deterioration in seed quality. Agronomic biofortification through sulphur and zinc fertilization has emerged as a promising strategy to enhance crop productivity, improve oil quality and sustain soil health. Therefore, the present study was undertaken to evaluate the effect of sulphur and zinc biofortification on growth, yield, quality and economics of upland groundnut.

2. Material and Methods

A field experiment was conducted during the kharif season of 2022 at the experimental farm of Lovely Professional University, Punjab. The experiment was laid out in factorial randomized block design comprising nine treatment combinations with three replications. Treatments consisted of three levels of sulphur viz., 20 kg ha⁻¹ basal application, 40 kg ha⁻¹ basal application and 40 kg ha⁻¹ split application, and three levels of zinc viz., 3, 5 and 6 kg ha⁻¹ soil application. Standard agronomic practices were followed for crop management. Observations on growth attributes, yield components, oil content, nutrient uptake and economic returns were recorded and statistically analysed.

3. Results and Conclusion

Split application of sulphur at 40 kg ha⁻¹ resulted in significantly higher plant height (38.71 cm), enhanced vegetative growth and improved dry matter accumulation, indicating better nutrient assimilation and metabolic activity. Zinc application at 6 kg ha⁻¹ further augmented growth performance through improved physiological efficiency and reproductive development. The favourable effects of sulphur on N-metabolism and, as a result, on the vegetative development of the groundnut plant, may be the cause of the rise in plant height as reported in the experiment (Akhter *et al.*, 2013). For the Sulphur treatments, the highest kernel yield was observed in S₃ (40 kg ha⁻¹ split) treatment with a yield of 3091.07 kg ha⁻¹. It was followed by S₂ (40 kg ha⁻¹) treatment with a yield of 2818.48 kg ha⁻¹. The lowest kernel yield was observed in S₁ (20 kg ha⁻¹) treatment with a yield of 2450.43 kg ha⁻¹. It has been discussed that sulphur plays vital role in improving vegetative structure for nutrient absorption and photosynthesis, strong sink strength through

development of reproductive structure and production of assimilates to fill economically important sink. These findings are in confirmation to the earlier report of Nawange *et al.* (2011). The study clearly demonstrates that balanced application of sulphur and zinc significantly improves growth, oil productivity and profitability of upland groundnut. Split application of sulphur at 40 kg ha⁻¹ in conjunction with zinc at 6 kg ha⁻¹ proved to be an efficient nutrient management strategy for enhancing crop performance and ensuring sustainable production under semi-arid agroecosystems. Adoption of such biofortification practices can play a crucial role in improving oilseed productivity, nutrient use efficiency and farmer income under resource-constrained conditions.

Table.1 Effect of sulphur and zinc fortification on plant height and yield of groundnut

Treatment	Plant height(cm)	Kernel yield kg ha ⁻¹
Sulphur (S)		
S ₁ =20 kg/ha	30.37	2450.43
S ₂ =40 kg/ha	33.84	2818.48
S ₃ =40 kg/ha (split)	38.71	3091.07
S.E(m)	0.679	35.584
C.D	2.053	107.6
Zinc (Z)		
Zn ₁ =3 kg/ha	32.87	2619.68
Zn ₂ =5 kg/ha	33.73	2810.16
Zn ₃ =6 kg/ha	36.32	2930.15
S.E(m)	0.679	35.584
C.D	2.053	107.6
Interaction (S X Z)		
S.E(m)	1.176	61.634
C.D	NS	NS
General mean	34.3	2786.66

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1.22 Growth and Productivity of Pearl millet Hybrids and Relationship with Weather Parameters in North-west Himalayan region

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Keywords: Pearl millet, yield, weather, Relationship, Rainfed

1. Background

Pearl millet being a C₄ plant has a quite high photosynthetic efficiency and dry matter production capacity which ultimately leads to the efficient utilization of the resources even under scarce moisture availability conditions especially in the arid, semi-arid and rainfed regions (Warner and Edwards, 1988). Pearl millet crop is also having the in-built capacity for resilience to the extreme climatic and even poor or very poor soil conditions which are the most common features prevailing in the areas under study. The crop could be well grown under extreme environmental conditions, especially the inadequate moisture and miserable soil fertility conditions which are not suited and adequate for major crops (Baker, 2003). Surprisingly, pearl millet's inherent ability to withstand high temperatures, including temperatures as high as 42°C during its reproductive stage, makes it an attractive crop option for regions with hot summers, especially where access to irrigation is not possible. Therefore, in this study, an attempt has been made to develop and describe the relationship of pearl millet hybrids and their developmental stages with thermal time (growing degree days) and their suitability under rainfed conditions of low altitude plains of N-W Himalayan region in Jammu and Kashmir, India.

2. Material and Methods

Field experiments conducted at Research Farm, ACRA, under AICRP on Pearl millet (Cooperating Centre), Rakh Dhiansar, SKUAST-Jammu, during *kharif* 2019, 2020 and 2021. The experiment comprised of 20 pearl millet hybrids *viz.*, T₁: RHB 177, T₂: HHB 197, T₃: GHB 719, T₄: GHB 538, T₅: HHB 67 (Imp), T₆: HHB 299, T₇: PB 1705, T₈: XMT 1497, T₉: GHB 905, T₁₀: MPMH 17, T₁₁: RHB 173, T₁₂: HHB 223, T₁₃: GHB 744, T₁₄: GHB 732, T₁₅: KBH 108, T₁₆: 86M86, T₁₇: Kaveri Super Boss, T₁₈: MP 7792, T₁₉: Proagro 9444 and T₂₀: GHB 558; studied in RBD design and replicated thrice. Ten (10) pearl millet plants were tagged in each plot of all the three replications and the occurrence of reproductive stages *viz.*, 50% flowering and physiological maturity was estimated by visually observing the tagged plants at 2-3 days interval in the field. Different thermal indices, weather indices, heat use efficiencies of different pearl millet hybrids in a given period were developed, with detailed procedures.

3. Results and Conclusion

Hybrid GHB 732 recorded significantly higher grain and biological yields as compared to all the other hybrids under study. The values of grain and biological yields of pearl millet hybrids namely, GHB 744, HHB 223, PB 1705 and XMT 1497 were statistically similar to that of GHB 732 hybrid. Similarly, statistically significant grain and biological yield heat use efficiencies (GYHUE & BYHUE) observed in GHB 732 and followed by hybrids GHB 744, HHB 223, PB 1705 and XMT 1497 with at par GYHUE and BYHUE values. However, hybrid 86M86 recorded the lowest values of grain & biological yield and GYHUE & BYHUE values. The significant difference among various pearl millet hybrids might have been happened due to the potential

difference in the hybrids, their suitability to the newer environment, genetic makeup of various hybrids and yielding ability responsible for the expression of their higher grain and biological yields under a particular environment (Gupta *et al.*, 2021).

There was a highly significant correlation between accumulated growing degree days (AGDD) at 50% flowering stage and physiological maturity with both grain yield and total biomass of pearl millet hybrids under rainfed conditions. The correlation analysis evidently indicated significance of maximum and minimum temperature with respect to grain yield and total biomass of pearl millet hybrids in rainfed conditions under sub-tropical conditions (Gupta *et al.*, 2021a). It may be concluded that pearl millet hybrids namely, GHB 732, GHB 744, HHB 223, PB 1705 and XMT 1497 could be well grown under the rainfed conditions of Jammu region. Also these hybrids withstand the adverse climatic conditions and higher maximum or minimum temperature has no or negligible effects on the performance of these hybrids.

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1.23 Modeling Spatial Dependence of Extreme Particulate Matter 2.5 Events in Bengaluru Using Non-Stationary Max-Stable Processes

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Keywords: Extreme Value Theory, PM_{2.5}, Spatial Dependence, Generalised Pareto Distribution, Max-Stable Processes, Brown–Resnick Process, Bengaluru

1. Background

Air pollution is a critical public health concern in rapidly urbanising cities across South Asia, where industrial growth, vehicular emissions, and meteorological conditions combine to produce hazardous fine particulate matter (PM_{2.5}) episodes of alarming frequency and severity. Bengaluru, India's third-most populous metropolitan city, routinely records PM_{2.5} concentrations that far exceed national ambient air quality standards (NAAQS) during peak pollution seasons, posing significant cardiovascular and respiratory risks to its residents. While conventional air quality monitoring captures station-level mean concentrations, the spatial synchronisation of extreme pollution events and the consequent risk of a simultaneous city-wide exceedance remains poorly understood and statistically under characterised in the Indian urban context. This study aims to characterise and quantify the spatial dependence structure of hazardous PM_{2.5} episodes across four air quality monitoring stations in Bengaluru such as Silk Board, Hebbal, Kadabesanahalli, and BTM Layout using Spatial Extreme Value Theory (EVT) and non-stationary max-stable process modelling. The study addresses three core research questions: (a) whether the intensity of extreme pollution events is increasing despite stabilising long-run averages; (b) the effective decorrelation distance of urban smog episodes across the monitoring network; and (c) the probability of a simultaneous city-wide pollution failure exceeding the regulatory threshold.

2. Material and Methods

Daily PM_{2.5} concentrations ($\mu\text{g}/\text{m}^3$), wind speed (m/s), and wind direction (degrees) data were sourced from the Karnataka State Pollution Control Board (KSPCB) and the Central Pollution Control Board (CPCB) for the period 2018–2026, spanning a maximum inter-station distance of approximately 14.2 km (Hebbal, Kadabesanahalli). Missing wind speed values were imputed using ERA5 global reanalysis data. The full analytical pipeline was implemented in R and comprised five sequential steps: (i) *Declustering* a separation gap of $r=3$ days was applied to extract approximately i.i.d. cluster maxima, yielding 52–87 exceedances per station; (ii) *Threshold Selection and GPD Fitting* thresholds were set at the 90th percentile using Mean Residual Life (MRL) plots and parameter stability diagnostics, followed by fitting of stationary ($M0: \log \sigma = \beta_0$) and non-stationary ($M1: \log \sigma_i = \beta_0 + \beta_1 \cdot \text{WS}_i$) Generalised Pareto Distribution (GPD) models compared via Likelihood Ratio Tests (LRT) and AIC; (iii) *Marginal Transformation* each station's PM_{2.5} series was mapped to unit Fréchet marginals via a semiparametric probability integral transform, isolating purely spatial dependence from marginal differences in pollution intensity; (iv) *Spatial Dependence Analysis*, pairwise Fréchet scatter plots and Spearman's rank correlations were computed across all six station pairs to quantify upper-tail dependence; and (v) *Max-Stable Process Modelling* Brown–Resnick max-stable processes are being fitted to estimate city-wide joint exceedance probabilities.

3. Results and Conclusion

Preliminary analysis confirmed that all four stations record mean PM_{2.5} values within the India

NAAQS 24-hour limit of $60 \mu\text{g}/\text{m}^3$; however, extreme exceedances are frequent and severe. Log-log survival plots confirmed heavy-tailed (Fréchet domain) behaviour at all stations, validating the peaks-over-threshold approach. The LRT was non-significant at all stations ($p=0.319\text{--}0.838$) and ΔAIC was positive in all cases ($+1.70$ to $+1.96$), uniformly selecting the stationary GPD (M_0) as the optimal model. All four formal goodness-of-fit tests (Kolmogorov–Smirnov, Anderson–Darling, Cramér–von Mises, Ljung–Box) passed at the 5% significance level (all $p > 0.13$), confirming adequate model fit. Post-transformation pairwise Fréchet scatter analysis revealed statistically significant positive spatial dependence across all six station pairs (Spearman's $\rho=0.485\text{--}0.809$), with the strongest dependence between Silk Board and Hebbal ($\rho=0.809$). No station pair approached independence, providing strong statistical justification for Brown–Resnick max-stable process modelling. Detailed parameter estimates and city-wide joint exceedance probabilities are currently being finalised. This study presents compelling statistical evidence that extreme $\text{PM}_{2.5}$ episodes in Bengaluru are not isolated, station-level phenomena but are spatially coherent events synchronised across the city's entire monitoring network. The persistence of strong pairwise extremal dependence even at inter-station distances up to approximately equal to 14 km highlights a fundamental limitation of site-specific air quality management strategies and underscores the necessity of city-wide, network-informed regulatory interventions. The adoption of Brown–Resnick max-stable processes a framework well established in hydrology and climatology but rarely applied to urban particulate matter in India offers a statistically rigorous and replicable methodology for extreme pollution risk assessment in rapidly urbanising South Asian cities.

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1.24 Identification of Climate-Resilient Maize Germplasm for Cold Tolerance in the North-western Himalayas of Jammu and Kashmir

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Keywords: Cold tolerance stress, CTR, Electrolyte Leakage, Inbreds, Maize

1. Background

Maize (*Zea mays* L.) is an important crop in the hill and high-altitude regions of Jammu and Kashmir, where it plays a crucial role in food and livelihood security. However, its production is severely affected by cold stress during germination and early seedling stages. Low-temperature conditions impair physiological processes, disrupt membrane integrity, and reduce seedling vigour, resulting in poor crop establishment and yield instability. The increasing variability in climatic conditions in the north-western Himalayas has further intensified these challenges. Therefore, the identification of climate-resilient maize germplasm with enhanced cold tolerance is essential for sustaining productivity in these fragile ecosystems.

2. Materials and Methods:

A total of 164 maize inbred lines were evaluated for cold tolerance at the Mountain Crop Research Station, Larnoo, SKUAST-K at an altitude of 2280 msl. Field screening was conducted under natural low-temperature conditions using a Cold Tolerance Rating (CTR) scale ranging from 1 (highly tolerant) to 5 (highly susceptible). In parallel, controlled-environment experiments were performed to assess cell membrane stability through electrolyte leakage assays. Data were recorded for seedling vigour, survival, and membrane damage to identify tolerant genotypes.

3. Results and Conclusion:

Significant variability was observed among the inbred lines for cold tolerance traits, indicating the presence of exploitable genetic diversity. Among the evaluated germplasm, SMI-11 was identified as the most cold-tolerant genotype, followed by SMI-127 and L-17, which exhibited lower electrolyte leakage and better membrane stability. These genotypes also demonstrated superior seedling vigour and establishment under cold stress conditions. The integration of field-based phenotyping and physiological screening proved effective in identifying climate-resilient germplasm. The selected inbreds can serve as valuable donor lines for developing cold-tolerant maize cultivars adapted to high-altitude environments, thereby contributing to improved productivity and climate resilience in the region.

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1.25 Correlation Analysis of Morphological Traits Influencing Seed Yield in Chickpea

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Keywords: *Cicer arietinum*, correlation

1. Background

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops grown worldwide, particularly in semi-arid regions. It serves as a rich source of protein, carbohydrates, vitamins, and minerals, playing a vital role in human nutrition and soil fertility through biological nitrogen fixation. Seed yield in chickpea is a complex trait governed by multiple interrelated components such as plant height, number of branches, pods per plant, seeds per pod, and seed weight. Understanding the relationships among these traits is essential for effective crop improvement. Correlation studies help in determining the degree and direction of association between yield and its contributing characters. By analyzing correlation coefficients, plant breeders can identify key traits that directly or indirectly influence yield. This information is valuable for selection strategies in breeding programs aimed at developing high-yielding and stable chickpea varieties. Therefore, correlation analysis serves as an important tool in enhancing the efficiency of selection and improving genetic gain in chickpea.

2. Material and Methods

The experimental material involved 14 popular cultivars of chickpea (GNG2144, GNG 1581, GNG 1958, PBG 7, ICC-39, IPC 1570, JG 14, IPC 3919, ICC 92944, JG 16, JG 315, GNG 2171, PBG 8, PBG 10) which were sown during *rabi* 2024-25 in a Randomized Block Design at experimental farm of Pulses Research Sub Station, Samba, SKUAST, Jammu. In order to determine the relationships between examined traits and seed yield per plot, correlation analysis was performed using Opstat software.

3. Results and conclusion

The correlation analysis among different agronomic traits in chickpea revealed several important associations influencing seed yield. Days to 50% flowering exhibited a significant positive correlation with plant height ($r=0.395^{**}$) and a significant negative correlation with seeds per pod ($r=-0.346^{*}$), indicating that variation in flowering may indirectly affect seed yield. Days to 75% maturity showed a positive and significant association with plant height ($r=0.370^{*}$) and seed yield ($r=0.316^{*}$), suggesting that longer duration genotypes tend to produce taller plants and higher yield. Similar associations have also been reported by Akbar *et al.* 2024.

Plant height was strongly and positively correlated with pods per plant ($r=0.685^{**}$), reflecting that taller plants have a greater capacity for pod production. Among the seed yield contributing traits, number of branches per plant exhibited a highly significant positive correlation with seed yield ($r=0.426^{**}$), indicating its major contribution to productivity. Similarly, seeds per pod also showed a significant positive association with seed yield ($r=0.391^{*}$), highlighting its importance as a yield component. In contrast, pods per plant and seed weight did not show significant correlations with seed yield, suggesting that these traits may have a limited direct influence on yield under the present study conditions. Such non-significant associations have also been reported in some environments, indicating the influence of genotype $\times$ environment interactions.

The correlation study elucidated that seed yield has positively and significant correlation with days to maturity, no. of branches per plant and seed per pod. Similar findings for branches per plant and seeds per pods has been observed by Chopdar *et al.*, 2017 and for days to maturity and branches per plant with seed yield by Jain *et al.*, 2020. Overall, the results indicate that branches per plant, seeds per pod, and days to maturity are key traits contributing to seed yield improvement. Therefore, these characters should be given due emphasis in selection and breeding programs aimed at enhancing chickpea productivity.

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1.26 Studies on WUE and photosynthetic efficiency in Maize (*Zea mays* L.)

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Keywords: Maize, Gas exchange, Photosynthesis, Stomatal conductance, Water use efficiency, Physiological variability

1. Background

Maize (*Zea mays* L.) is a globally important cereal crop, serving as a major source of food, feed, and industrial raw material worldwide (FAO, 2021). Improving physiological efficiency is essential for enhancing crop productivity, particularly under changing climatic conditions (Flexas *et al.*, 2014). Gas exchange parameters such as photosynthetic rate, stomatal conductance, and transpiration play a crucial role in determining plant growth and yield (Lawlor and Tezara, 2009). Water use efficiency (WUE) is an important physiological trait for identifying genotypes with improved adaptation to water-limited environments (Blum, 2005). Therefore, the present study aimed to evaluate physiological variability among maize genotypes using gas exchange traits.

2. Materials and Methods

The experiment was conducted under field conditions involving five maize genotypes (BER, KDFM, NM1, NM2, and Sith) collected from different geographical regions of the Kashmir valley. Physiological traits were measured using a portable IRGA system (TARGAS-1, PP Systems). Parameters recorded included photosynthetic CO₂ assimilation (A), stomatal conductance (gs), transpiration rate (E), leaf temperature (Tleaf), vapour pressure deficit (VPD), and water use efficiency (WUE). Descriptive statistical analysis was performed to assess variability among genotypes.

3. Results and Conclusion

Significant variation was observed among the genotypes for all physiological traits. Photosynthetic rate (A): Highest in BER (10.1 $\mu\text{mol m}^{-2} \text{s}^{-1}$) followed by KDFM (6.16) and NM1 (5.4), while NM2 (2.53) recorded the lowest. Stomatal conductance (gs): Maximum in BER (1.62 $\text{mol m}^{-2} \text{s}^{-1}$) and KDFM (1.65), whereas NM2 (0.70) showed the lowest. Transpiration rate (E): Highest in BER (9.8 $\text{mmol m}^{-2} \text{s}^{-1}$) and NM1 (9.6). Water Use Efficiency (WUE): Maximum in NM1 (6.6) followed by BER (4.88) and KDFM (3.98), indicating NM1 as the most water-efficient genotype. Internal CO₂ concentration (Ci): Highest in KDFM (329.2). Leaf temperature remained relatively stable ($\sim 25\text{--}27^\circ\text{C}$), indicating uniform measurement conditions. The study revealed substantial physiological variability among maize genotypes collected from the Kashmir valley. BER exhibited superior photosynthetic performance, while NM1 showed higher water use efficiency, making it suitable for water-limited environments. KDFM demonstrated balanced physiological traits, indicating its potential as a stable genotype. These findings can be effectively utilized in maize breeding programs aimed at improving productivity and stress adaptability.

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1.27 Linkage disequilibrium mapping of Novel QTLs for Panicle Blast Resistance in rice (*Oryza sativa* L.)

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Keywords: GWAS, KASP, panicle blast, QTLs, Rice, Resistance

1. Background

Rice blast caused by the fungus *Magnaporthe oryzae* is one of the most destructive diseases affecting rice production worldwide (Kwon and Lee, 2002, Li *et al.*, 2007). Although more than 100 genes have been identified for leaf blast resistance, limited information is available on panicle blast resistance, which directly influences grain yield Ballini *et al.*, 2008; Huang *et al.*, 2010). The complex and polygenic nature of panicle blast resistance necessitates the identification of novel loci and candidate genes for effective resistance breeding. Therefore, the present study was undertaken to dissect the genetic architecture of panicle blast resistance using genome-wide association studies (GWAS) and extreme phenotype sequencing approaches.

2. Material and methods

A diverse panel of 271 rice germplasm lines of temperate background was evaluated under disease hotspot field conditions across five different seasons. Phenotyping for blast resistance was carried out following SES-IRRI (2013) standard evaluation system. The phenotypic observations were further validated using hyperspectral imaging for precise disease assessment. Genotyping of the panel was performed using 1,502 KASP (Kompetitive Allele-Specific PCR) markers. Genome-wide association analysis was conducted to identify significant marker-trait associations. Additionally, extreme phenotypes (highly resistant and highly susceptible lines) were subjected to GWAS and whole-genome resequencing using the Illumina NovaSeq X platform to identify sequence-level variations associated with resistance.

3. Results and conclusion

GWAS analysis identified 102 significant SNPs associated with panicle blast resistance, predominantly located on chromosomes 4 and 7. Whole-genome resequencing generated approximately 309 GB of high-quality data and detected more than one million SNPs. Major QTLs were identified on chromosomes 4, 5, 6, 7, 10, and 11, while additional minor loci across other chromosomes confirmed the polygenic nature of resistance. Variant analysis revealed functionally important polymorphisms, including a 21 bp deletion, a cytosine deletion, and a 3 bp insertion. The candidate genes identified encode proteins such as NBS-LRR, CC-NBS-LRR, F-box/LRR-repeat, and other stress-responsive proteins involved in pathogen recognition and defence activation. The integration of GWAS and sequencing approaches facilitated the identification of robust candidate genes and informative SNP alleles for panicle blast resistance. The identified resistant germplasm lines and associated loci can be effectively utilized in marker-assisted breeding programs for developing blast-resistant rice varieties.

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1.28 Linkage disequilibrium mapping of Novel QTLs for Panicle Blast Resistance in rice (*Oryza sativa* L.)

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Keywords: GWAS, KASP, panicle blast, QTLs, Rice, Resistance

1. Background

Rice blast caused by the fungus *Magnaporthe oryzae* is one of the most destructive diseases affecting rice production worldwide (Kwon and Lee, 2002, Li *et al.*, 2007). Although more than 100 genes have been identified for leaf blast resistance, limited information is available on panicle blast resistance, which directly influences grain yield Ballini *et al.*, 2008; Huang *et al.*, 2010). The complex and polygenic nature of panicle blast resistance necessitates the identification of novel loci and candidate genes for effective resistance breeding. Therefore, the present study was undertaken to dissect the genetic architecture of panicle blast resistance using genome-wide association studies (GWAS) and extreme phenotype sequencing approaches.

2. Material and methods

A diverse panel of 271 rice germplasm lines of temperate background was evaluated under disease hotspot field conditions across five different seasons. Phenotyping for blast resistance was carried out following SES-IRRI (2013) standard evaluation system. The phenotypic observations were further validated using hyperspectral imaging for precise disease assessment. Genotyping of the panel was performed using 1,502 KASP (Kompetitive Allele-Specific PCR) markers. Genome-wide association analysis was conducted to identify significant marker-trait associations. Additionally, extreme phenotypes (highly resistant and highly susceptible lines) were subjected to GWAS and whole-genome resequencing using the Illumina NovaSeq X platform to identify sequence-level variations associated with resistance.

3. Results and conclusion

GWAS analysis identified 102 significant SNPs associated with panicle blast resistance, predominantly located on chromosomes 4 and 7. Whole-genome resequencing generated approximately 309 GB of high-quality data and detected more than one million SNPs. Major QTLs were identified on chromosomes 4, 5, 6, 7, 10, and 11, while additional minor loci across other chromosomes confirmed the polygenic nature of resistance. Variant analysis revealed functionally important polymorphisms, including a 21 bp deletion, a cytosine deletion, and a 3 bp insertion. The candidate genes identified encode proteins such as NBS-LRR, CC-NBS-LRR, F-box/LRR-repeat, and other stress-responsive proteins involved in pathogen recognition and defence activation. The integration of GWAS and sequencing approaches facilitated the identification of robust candidate genes and informative SNP alleles for panicle blast resistance. The identified resistant germplasm lines and associated loci can be effectively utilized in marker-assisted breeding programs for developing blast-resistant rice varieties.

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1.29 High-Resolution QTL Mapping Reveals Genomic Regions Governing Panicle Blast Resistance in Rice

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Keywords: Rice, Panicle blast, RIL population, KASP markers, QTL, MAS

1. Background

Rice (*Oryza sativa* L.) is affected by more than 100 pathogens worldwide, among which rice blast caused by *Magnaporthe oryzae* is one of the most destructive diseases. The pathogen infects leaves, nodes, rachis and panicle base (neck blast), with panicle blast causing the most severe damage. The disease is particularly severe in upland and cold regions, resulting in yield losses ranging from 50 to 90 per cent. Infection at panicle stage leads to more than 70 per cent yield reduction along with deterioration in grain quality. Compared to leaf blast, relatively fewer resistance genes have been reported for panicle blast. Therefore, identification of genomic regions governing panicle blast resistance is essential for development of resistant rice cultivars.

2. Material and Methods

A recombinant inbred line (RIL) population consisting of 356 individuals was developed from a cross between K-332 (blast resistant short-grained japonica genotype) and GS-88 (medium bold susceptible line) using single seed descent (SSD) method. Genotyping of the RIL population was performed using 1502 KASP markers distributed across all 12 rice chromosomes. SNP genotyping was carried out using uniplex fluorescence-based KASP (Kompetitive allele-specific PCR) assay kit (Biosearch Technologies, U.K.). Out of 1502 markers, 221 KASP markers were polymorphic between the parents. Thirteen SNP markers showing segregation distortion based on χ^2 test were discarded. Composite interval mapping was performed using ICIMapping 4.01 software with a LOD threshold of 2.5, walking speed of 1.0 cM and 1000 permutations at probability level of 0.01.

3. Results and Conclusion

Three significant QTLs for panicle blast resistance namely *qPB4.1*, *qPB6.1* and *qPB11.1* were detected at physical positions of 5.58 Mb, 18.64 Mb and 22.79 Mb, respectively, with a maximum LOD score of 6.49 and phenotypic variance explained (PVE) of 46 per cent. These genomic regions are associated with resistance to neck blast and represent promising targets for further characterization. The sequence information within these QTL intervals will be deciphered for identification of candidate genes. The detected QTLs will be subjected to fine mapping and functional validation. The resistant parent K-332, known for its cold tolerance and resistance to leaf and panicle blast in rice growing regions of Jammu and Kashmir, can serve as a valuable donor for transferring resistance loci into elite rice cultivars through marker-assisted selection (MAS).

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1.30 Assessment of Long-Lived Carbon Storage Stocks in Forest Land-Use Systems of Kathua District (J&K) for Climate-Resilient Agroecosystems

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Keywords: Carbon sequestration, Forest land-use system, Long-lived carbon storage, Agroecosystems, Climate resilience, Kathua district

1. Background

Forests play a crucial role in climate change mitigation by functioning as long-term carbon sinks and supporting sustainable, climate-resilient agroecosystems. The sub-tropical Kandi belt of Kathua district (Jammu & Kashmir) is characterized by diverse forest land-use systems comprising tree, shrub, herb, grass, and litter components. These systems contribute significantly to carbon sequestration through long-lived biomass and soil carbon pools. Long-lived carbon storage is primarily associated with durable wood products, assumed to constitute about 42% of stem biomass with a lifespan comparable to rotation age. Assessing such carbon stocks is essential for designing sustainable land-use strategies and informing policy frameworks under climate change scenarios. The present study aims to assess species-wise long-lived carbon storage, evaluate ecosystem-level carbon stocks, and examine the role of forest biomass in energy substitution and emission reduction.

2. Material and Methods

The study was conducted in representative forest land-use systems of Kathua district. Biomass data were collected across different vegetation components including trees, shrubs, herbs, grasses, and ground litter using standard ecological sampling methods. The biomass values were extrapolated to a per hectare basis. Long-lived carbon storage was estimated based on the proportion of stem biomass allocated to durable wood products (42%). Carbon stocks were converted into CO₂ equivalents (CO₂e) to assess climate mitigation potential. Additionally, heat from biomass combustion and carbon storage from coal substitution were calculated to evaluate indirect benefits of biomass utilization in reducing fossil fuel dependence.

3. Results and Conclusion

The study revealed significant variation in long-lived carbon storage among species. *Pinus roxburghii* recorded the highest value (21.72 Mg ha⁻¹), followed by *Prosopis juliflora* (4.06 Mg ha⁻¹) and *Eucalyptus spp.* (3.59 Mg ha⁻¹), whereas the lowest was observed in *Ficus palmata* (0.09 Mg ha⁻¹). The average long-lived carbon storage across species was 2.59 Mg ha⁻¹.

In terms of CO₂ equivalents, *Pinus roxburghii* showed the highest mitigation potential (653.76 Mg ha⁻¹), while the overall average was 68.01 Mg ha⁻¹. Biomass energy potential was also substantial, with *Pinus roxburghii* contributing the highest heat value (5986.38 GJ ha⁻¹). Similarly, carbon storage through coal substitution was maximum in *Pinus roxburghii* (100.57 Mg ha⁻¹), followed by *Butea monosperma* and *Prosopis juliflora*.

The total ecosystem biomass was estimated at 46.57 Mg ha⁻¹, with a total carbon stock of 20.77 Mg ha⁻¹ and 76.24 Mg CO₂e ha⁻¹. Trees dominated the carbon pool, contributing about 89% (18.53 Mg ha⁻¹), followed by shrubs (3.91%), grasses (2.70%), herbs (2.36%), and ground litter (1.83%). Ground litter biomass contributed 0.38 Mg ha⁻¹ carbon (1.46 Mg CO₂e ha⁻¹), indicating its role in soil carbon stabilization.

The forest land-use systems of Kathua district demonstrate substantial potential for long-lived carbon storage and climate change mitigation. The dominance of tree biomass, particularly *Pinus roxburghii*, highlights its critical role as a carbon sink. These systems not only store carbon directly but also contribute indirectly through biomass energy and coal substitution. Integrating such forest components into agroecosystems can enhance resilience, sustainability, and ecosystem services. The findings underscore the need for conservation of native forests, promotion of high carbon-sequestering species, and incorporation of forest carbon stocks into climate policy frameworks.

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Theme 2:

Soil, Water, and Natural Resource Management for Sustainable Agro- ecosystems



2.1 Phyto-sociological analysis of weeds in Maize (*Zea mays* L.) agro-ecosystems in relation with different soil physicochemical profiles

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Keywords: Maize, Phytosociology, Physicochemical, Soil, Weeds

1. Background

Since the dawn of agriculture, weeds have been acknowledged as a concern, and the fight against them is an on-going one. Weed control is frequently the most expensive agronomic input for productive crop production. Since its domestication some 9,000 years ago, maize (*Zea mays* L.) has played an increasing and diverse role in global agri-food systems.

2. Materials and Methods

The research region is located in Western Uttar Pradesh's Moradabad district (28°-21 to 28°-16 north latitude and 78°-4 to 79° east longitude). A phyto-sociological study of weed was conducted in the maize agro-ecosystems of the district during year 2022-2023. We examined the flora of weed species through random sampling to gain a comprehensive understanding of their composition. A total of 80 quadrats of (1 m × 1 m) were laid out randomly for evaluating weed phytosociology in the agricultural fields. Weed species composition was evaluated by analyzing the frequency, density, abundance, and importance value index (IVI) according to Misra, (1968) and Curtis and McIntosh (1950, 1951). Based on quantitative traits including frequency, density, and dominance, IVI is a synthetic feature that is used to quantify a species' total dominance within a community. Importance Value Index (IVI)=Rel. Freq. + Rel. Den. + Rel. Dom.

We collected 80 soil samples from various sugarcane agricultural fields at different depths (0-10, 10-20, and 20-30 cm) between 2022 and 2023. Soil samples were obtained from 8 blocks and 10 soil samples from different soil depths were collected from each administrative block using the conning and quartering technique.

3. Results & Conclusion

Phyto-sociological studies can clarify the management & coexistence periods between crops and weeds. In Maize agro-ecosystems, of Moradabad district in Uttar Pradesh, during 2022-2023 the highest IVI of 7.63 was recorded for *Polygonum plebeium* and lowest 0.50 with *Bulbostylis barbata*. We reported 28 families, 130 species, and 23 dominant weed genera. Dominant family was Poaceae in monocots with 39 species and Amaranthaceae in dicots with 14 species each. Understanding the physical & chemical conditions of any soil is necessary for the appropriate application of other management strategies. pH of soil across the sampling sites ranged between 7.03 to 7.40. E.C. ranged from 0.40-0.88 d/Sm that represents the min value for seed germination in district. Available N content varied from 71.24 to 103.56 kg/ha, (0-10cm). Available P content varied from 13.66 to 23.50 kg/ha, 13.78 kg/ha (0-10cm) reported from TK-JSP-7 block & 9.45 kg/ha (20-30cm) from TK-JSP-7 & K content is 159.10 to 217.91 kg/ha, 213.95 kg/ha (0-10cm) from BT-JSP-1 block & 151.17 kg/ha (20-30cm) from TK-JSP-7 block. P ranged represents the

low soil status of the district and K content ranged show the medium status of soil. OC values fluctuated from 0.26 to 0.51 % that represents the low value status of district soil profile. W.H.C. of the different blocks was ranged from 22.85 to 54.28% and soil temperature ranged 10.1 to 25.2 °C. The measurement of soil fertility in a given location is an important part of sustainable agricultural production.

Weed infestation in crop ecosystem is a havoc aspect of ecology, ground level weed identification as per crop wise is important for the proper weed management in a sustainable point of view. Overall inference of current study at blocks levels reveals that, pH value ranged from (7.03 to 7.40) shows that neutral to little alkaline nature of the soil. In the context of electrical conductivity status of soil in different blocks, it is represented that electrical conductivity ranged from 0.40 to 0.88 d/Sm, and it is less than 1 d/Sm, not optimum for seed germination. The OC varied from 0.26 to 0.50%, indicating a low value in all the blocks except for block TK-JSP-7, which showed a medium value at 0.51%. Nitrogen ranged from 71 to 103.56 kg/ha. In the context of phosphorus status, block BT-JSP-1 represents a medium value (22.13 to 23.50 kg/ha), except all blocks are low values. K status in the soil of Moradabad represents that medium value (159.10 to 217.91 kg/ha) in all the administrative blocks of four subdivisions. The study suggests that improving soil quality through improved cropping practices and limiting chemical fertilizers, as well as using organic manure, can restore nutrient balance to Moradabad's soil.

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2.2 Integrated Biochar and Organic Manure Application for Climate-Smart Maize Production in Himalayan Agroecosystems

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Keywords: Biochar, Climate-smart agriculture, Maize productivity, Soil carbon sequestration, Soil CO₂ emissions

1. Background

Climate change poses a serious threat to the sustainability of agroecosystems through declining soil organic carbon, nutrient depletion and increasing greenhouse gas emissions. Himalayan agroecosystems are particularly vulnerable due to fragile soils, steep slopes, erratic precipitation patterns, short growing seasons and increasing dependence on external inputs. Recurrent climate extremes such as drought spells and unseasonal rainfall further aggravate soil degradation and reduce nutrient use efficiency. Maize (*Zea mays L.*), a nutrient-exhaustive crop widely cultivated in the Himalayan region, often accelerates soil carbon losses and nutrient mining under conventional management practices. Increasing soil carbon storage has been recognized as one of the most cost-effective strategies for mitigating climate change, enhancing soil fertility and improving long-term agricultural sustainability (Ellis and Paustian 2024). Biochar and organic manures have emerged as promising climate-smart soil amendments owing to their ability to improve soil structure, nutrient retention, microbial activity and carbon stabilization while reducing carbon losses from soil. The integration of these amendments is expected to create synergistic effects by combining stable carbon fractions of biochar with labile organic inputs from manures. However, systematic information on their combined effects on crop productivity, soil quality and soil CO₂ emissions under temperate Himalayan conditions remains limited. The present study was therefore undertaken to evaluate the influence of integrated biochar and organic manure application on maize productivity, soil physico-chemical properties and soil CO₂ emissions. However, limited information on the combined effects of biochar and organic manures under Himalayan conditions constrains their wider adoption as climate-smart soil management practices.

2. Material and Methods

The study was conducted during the kharif season under temperate conditions at the Agronomy Research Farm, SKUAST-Kashmir, representing typical maize-growing environments of the Himalayan region. The experiment was laid out in a factorial randomized block design with three biochar levels (0, 2.5 and 5.0 t ha⁻¹) and three organic manure treatments (control, vermicompost @ 7.5 t ha⁻¹ and farmyard manure @ 15 t ha⁻¹), along with the recommended dose of fertilizers. Biochar and organic manures were incorporated during land preparation to ensure uniform soil mixing, while fertilizers were applied as per standard agronomic recommendations

before sowing. Observations on crop growth parameters, yield attributes and grain yield were recorded at appropriate growth stages. Soil samples collected at harvest were analyzed for pH, organic carbon, available nutrients, bulk density, porosity and cation exchange capacity using standard laboratory procedures. Soil CO₂ emissions were measured at critical crop growth stages using the closed-chamber method. Data were subjected to analysis of variance and treatment means were compared at the 5% level of significance.

3. Results and Conclusion

Integrated application of biochar and organic manures significantly influenced maize productivity, soil properties and soil CO₂ emissions. Combined application of biochar @ 5.0 t ha⁻¹ with vermicompost @ 7.5 t ha⁻¹ resulted in significantly higher growth parameters, yield attributes and grain yield compared to the unamended control, indicating improved crop response under integrated nutrient management. Yield improvement under this treatment can be attributed to enhanced nutrient availability, improved root-zone environment and better soil moisture retention. This treatment also enhanced soil organic carbon, available phosphorus and potassium, cation exchange capacity and soil porosity, while reducing bulk density, reflecting improvement in soil physical and chemical quality. Soil CO₂ emissions declined consistently with increasing biochar application across crop growth stages, suggesting enhanced carbon stabilization, reduced microbial decomposition of native soil organic matter and improved carbon use efficiency. Similar reductions in soil CO₂ emissions following biochar application have been reported earlier (Lehmann et al 2021). In contrast, sole application of organic manures increased CO₂ emissions due to rapid mineralization of labile organic carbon. The study concludes that integration of biochar with organic manures represents an effective climate-smart soil management strategy for enhancing maize productivity, improving soil health, reducing carbon losses and strengthening climate resilience of Himalayan agroecosystems. The combined effects of biochar levels and organic manure treatments on maize productivity, soil properties and soil CO₂ emissions are summarized in Table 1.

Table 1: Effect of biochar and organic manure treatment combinations on maize productivity, soil properties and soil CO₂ emissions under temperate Himalayan conditions

Treatment combinations	Grain yield	Soil organic carbon	Available P & K	Bulk density	Soil CO ₂ emissions
Biochar 0 t ha ⁻¹ + No manure (Control)	Low	Low	Low	High	Moderate
Biochar 0 t ha ⁻¹ + Vermicompost @ 7.5 t ha ⁻¹	Moderate	Moderate	High	Reduced	High
Biochar 0 t ha ⁻¹ + FYM @ 15 t ha ⁻¹	Moderate	Moderate	Moderate	Reduced	High
Biochar @ 2.5 t ha ⁻¹ + No manure	Moderate	Moderate	Moderate	Reduced	Reduced
Biochar @ 2.5 t ha ⁻¹ + Vermicompost @ 7.5 t ha ⁻¹	High	High	High	Lower	Reduced

Biochar @ 2.5 t ha ⁻¹ + FYM @ 15 t ha ⁻¹	Moderate-High	High	Moderate	Lower	Reduced
Biochar 5.0 t ha ⁻¹ + No manure	High	High	High	Lower	Lowest
Biochar @ 5.0 t ha ⁻¹ + Vermicompost @ 7.5 t ha ⁻¹	Highest	Highest	Highest	Lowest	Lowest
Biochar @ 5.0 t ha ⁻¹ + FYM @ 15 t ha ⁻¹	High	High	Moderate-High	Lower	Reduced

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2.3 Root Morphological and Physiological Responses of Soybean to Pusa Hydrogel and Foliar Nutrition under Water-Limited Conditions

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Keywords: Nodule development, Pusa Hydrogel, Relative water content, Root traits, Thiourea, Vermiwash

1. Background

Soybean (*Glycine max* L.) productivity under rainfed conditions is strongly constrained by soil moisture stress, which adversely affects root development, nodulation, plant water status, and ultimately yield and quality. Root traits and nodulation play a pivotal role in water and nutrient uptake, particularly biological nitrogen fixation, which is highly sensitive to drought stress. Relative water content (RWC) is a key physiological indicator of plant hydration and stress tolerance. Agronomic interventions such as superabsorbent polymers (Pusa hydrogel) improve soil moisture retention, while foliar nutrition (vermiwash and thiourea) enhances physiological resilience and metabolic activity under moisture-limited environments. The present study was undertaken to evaluate the combined effects of Pusa hydrogel and foliar nutrient sprays on root traits, nodulation, relative water content, seed quality, and economics of rainfed soybean in the Northwest Himalayan region.

2. Materials and Methods

A field experiment was conducted during Kharif 2022 at the Agronomy Farm, SKUAST-K, Wadura, under rainfed conditions. The soil was silty clay loam with neutral pH and medium fertility status. The experiment was laid out in a factorial randomized block design (RBD) with three replications. Treatments consisted of three levels of Pusa hydrogel (0, 2.5, and 5.0 kg ha⁻¹) and five foliar nutrient sprays: control, water spray, 2% urea, thiourea @ 500 ppm, and vermiwash (1:10 dilution). Pusa hydrogel was incorporated into the soil at sowing, while foliar sprays were applied at the flowering stage. Observations were recorded on root length, root volume, number of rootlets, nodulation traits, relative water content (RWC), oil and protein content, and economics. RWC was estimated using the whole-leaf method, oil content by NIR spectroscopy, and protein content using the Kjeldahl method.

3. Results & Conclusion

Root length was not significantly affected by treatments; however, root volume and number of rootlets increased significantly with higher hydrogel levels, with the maximum values recorded at 5.0 kg ha⁻¹. Among foliar treatments, vermiwash (1:10) produced the highest root volume and rootlet number. Nodulation traits (number of nodules and nodule weight) improved significantly with increasing hydrogel levels and were maximized under vermiwash application. Relative water content (RWC) increased significantly with hydrogel application, with the highest values observed at 5.0 kg ha⁻¹, while foliar application of thiourea and vermiwash resulted in the highest RWC among sprays. Oil content increased significantly with hydrogel and foliar treatments, with the highest oil percentage recorded under thiourea followed by vermiwash, whereas protein content and harvest index were not significantly influenced. Economically, the highest net returns were obtained with 5.0 kg ha⁻¹ hydrogel + vermiwash, while the highest benefit–cost ratio was achieved

with 2.5 kg ha⁻¹ hydrogel + vermiwash.

The study demonstrated that integrating Pusa hydrogel and foliar-applied vermiwash is an effective strategy for improving root architecture, nodulation, plant water status, oil content, and profitability of rainfed soybean in the Northwest Himalayan region. Application of Pusa hydrogel at 5.0 kg ha⁻¹ significantly enhanced root volume, nodulation, relative water content, and oil yield, while vermiwash (1:10) proved superior among foliar sprays. From an economic perspective, 2.5 kg ha⁻¹ hydrogel combined with vermiwash offered the most cost-effective option. Overall, moderate hydrogel application coupled with organic foliar nutrition can sustainably enhance soybean performance under water-limited conditions.

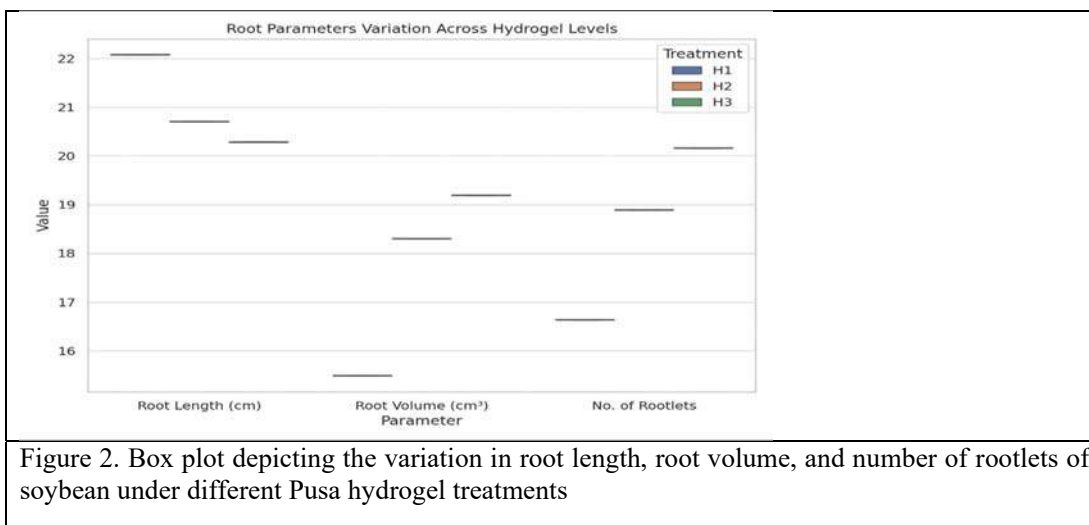


Table 2: Effect of Pusa hydrogel and foliar nutrient spray on root and nodule parameters

Treatment	Root Length (cm)	Root Volume (cm ³)	No. of Rootlets (plant ⁻¹)	No. of Nodules (plant ⁻¹)	Nodule Weight (g plant ⁻¹)
Pusa Hydrogel (kg ha ⁻¹)					
H1: 0	22.07	15.49	16.63	18.68	1.12
H2: 2.5 kg ha ⁻¹	20.70	18.30	18.89	21.10	1.66
H3: 5.0 kg ha ⁻¹	20.28	19.19	20.16	22.12	1.79
SEm±	0.70	0.58	0.58	0.56	0.05
CD (p ≤ 0.05)	NS	1.68	1.67	1.63	0.15
Foliar Nutrient Sprays					
F1: Control	19.63	13.70	15.43	21.61	1.50
F2: Water Spray	20.54	14.82	15.62	22.55	1.54
F3: 2% Urea	21.71	17.60	18.20	18.80	1.31
F4: Thiourea @ 500 ppm	21.95	19.97	20.40	15.46	1.11
F5: Vermiwash (1:10)	21.26	22.23	23.16	24.75	2.14
SEm±	0.90	0.75	0.74	0.73	0.07
CD (p ≤ 0.05)	NS	2.17	2.15	2.10	0.20

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2.4 Socio-Economic Impacts of Declining Traditional Water-Harvesting Structures on Agricultural Livelihoods in the Shivalik Kandi Belt.

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Keywords: Kandi belt, Livelihood security, Rainfed agriculture, Shivalik region, Traditional water harvesting

1. Background

The Shivalik Kandi belt is characterized by a fragile ecosystem where agriculture is predominantly rainfed and highly vulnerable to climatic variability. Traditionally, communities in this region relied on indigenous water-harvesting systems primarily Talabs (ponds), Kuhls (diversion channels), and Bowlies (spring-fed tanks) to manage the seasonal scarcity of water. However, recent decades have seen a significant decline in these structures due to rapid urbanization, neglect, and shifting rainfall patterns. This study investigates how the deterioration of these communal assets has translated into socio-economic distress for smallholder farmers, exacerbating the region's existing fodder and cereal deficits

2. Material and Methods

The research employed a mixed-methods approach across selected districts in the Jammu Shivalik's (Reasi and Samba). Primary data was collected through structured interviews and Focus Group Discussions (FGDs) with 200 farming households. The physical status of 40 traditional Talabs was assessed through field surveys to categorize their functionality (functional, partially silted, or abandoned). Socio-economic impacts were measured using indicators such as changes in cropping intensity, livestock population shifts, and household migration patterns over a ten-year trajectory.

3. Results and Conclusion

Findings reveal that over 65% of traditional ponds in the study area are currently non-functional due to heavy siltation and encroachment. This decline has led to a direct 22% reduction in supplemental irrigation capacity during the Rabi season. Socio-economically, the loss of these structures has forced a shift from water-intensive crops to less profitable hardy varieties, contributing to the regional trend of declining maize and wheat productivity. Furthermore, a strong correlation was found between the drying of Talabs and the reduction in local bovine populations, as water for livestock becomes increasingly scarce.

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2.5 Weed growth and Productivity of direct seeded rice (*Oryza sativa* L.) Under different sowing dates and weed management practices

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Keywords: Rice, Sowing dates, weed management

1. Background

Weeds are most severe and widespread biological constraints to crop production in India and alone cause 33% of losses out of total losses due to pests. Manual weeding is considered to be the best, but it is very much costly. That is the reason why herbicides have been considered to be better alternative to hand weeding in DSR (Singh *et al.*, 2006). Herbicides are being extensively used to control weeds, but single herbicides cannot control all types of weeds in agricultural fields (Sar *et al.*, 2022). Therefore, an integrated weed management strategy is strongly recommended to improve agricultural sustainability. For effective weed management of direct seeded rice, integrated approaches must be considered and optimized. Sowing time is a non-monetary input, but greatly affects the productivity of rice. Several studies have shown that sowing of rice after onset of monsoon gave higher grain yield due to less infestation of weeds.

2. Material and Methods

A field investigation was carried out during *kharif*, 2024 and 2025 at Agriculture research station, Faculty of Agricultural Sciences, SOADU, Bhubaneswar to study the productivity of direct seeded rice under different sowing dates and weed management practice. The soil of the experimental field was sandy loam in texture with acidic in reaction (pH 5.9), low in organic C (0.48%), available N (242.24 kg/ha) and available P₂O₅ (22.20 kg/ha) and medium in available K₂O (156.86 kg/ha). The experiment was laid out in split plot design with three replications. Treatments consisted of three sowing dates (S₁: 10th june; S₂:25th june; S₃:10th july) in main plot and five weed management practices (W₁: Pendimethalin at 1kg/ha at 3 DAS, W₂: Pendimethalin at 1kg/ha *fb* fenoxaprop-p-ethyl + ethoxysulfuron (tank-mix) 90+15 g/ha at 20 DAS, W₃: Pendimethalin at 1 kg/ha followed by 1 HW at 35 DAS, W₄: Hoeing and weeding at 20 and 40 DAS and W₅: Weedy check) in subplot. Both pre-emergence and post-emergence herbicides were sprayed with a 500 L/ha spray volume. Plant protection measures were used as needed, and all other suggested agronomic practices were adhered to. Weed samples were sun-dried and then oven-dried at 70° C until a consistent weight was reached in order to record their biomass. At harvest, mustard yield characteristics and seed yield were noted and statistically examined at the 5% significance level.

3. Results and Conclusion

The predominant weeds in the experimental plots were *Poa annua*, *Digitaria sanguinalis* and *Echinochloa colona* among the grasses; *Cyperus iria* among the sedges, and *Ludwigia parviflora*, *Melochia corchorifolia* and *Alternanthera philoxeroides* among the broadleaved weed. Results revealed that the lowest density and dry weight of all types of weeds and maximum value of growth and yield attributes was recorded under normal sowing dates (25th june) followed by early sowing dates (10th june). Among the weed management practices, hand weeding twice 20 and 40 DAS recorded the lowest density of total weeds and maximum value of yield attributes and yield and it

was at par with pendimethalin at 1kg/ha at 3 DAS followed by 1 HW at 35 DAS. The maximum grain and straw yield was recorded with timely sown (25th june) as compared to early (10th june) and late sown (10th july) rice. Interaction effect found significant and it was indicated that timely sown (25th june) along with hoeing and weeding at 20 and 40 DAS recorded the highest grain (4707 kg/ha) and straw (5603 kg/ha) yields over others and it was at par with timely sown (25th june) along with application of pendimethalin 1 kg/ha followed by 1 HW at 35 DAS. The highest net return and return/rupee invested was associated with timely sown (25th june) along with application of pendimethalin 1 kg/ha followed by 1 HW at 35 DAS. Thus, timely sown (25th june) along with application of pendimethalin at 1 kg/ha followed by 1 HW at 35 DAS appeared to be promising for effective weed management, higher productivity and profitability in direct seeded rice.

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2.6 Bio-formulation of Phosphorus solubilizers: A potential technology for solubilizing Phosphorus in Acid soils

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Keywords: Acid soil; Bio-formulation; Phosphorus solubilizers; Rhizosphere; Solubilizing index

1. Background

Phosphorus (P) makes up around 0.05% (w/w) of soil, however only 0.1% of that amount is accessible to plants due to poor solubility and fixation in all soil types. Phosphorus solubilizing microorganisms (PSMs) through their various mechanisms of solubilization, and mineralization are able to convert the unavailable form into bioavailable form facilitating increased uptake by plant roots. Although, several of these bacterial or fungal strains etc. have been identified as the potential PSM, their performance under different soil conditions is not reliable and therefore, needs the region specific native and compatible strains for increase efficiency.

2. Material and Methods

The present study focuses on isolating native PSM(s) from the rhizospheric zone of different land use systems {viz. *Bambusa vulgaris* (bamboo), *Parkia roxburghii* (tree bean), *Alnus nepalensis* (alder), *Citrus reticulata* (Khasi mandarin), *Oryza sativa* (rice), *Setaria italic* (foxtail millet), *Zea mays* (maize), *Curcuma longa* (turmeric), *Sesamum indicum* (sesame), *Phaseolus vulgaris* (French bean), *Arachis hypogaea* (groundnut), *Vigna radiate* (green gram), *Glycine max* (soybean) and *Lens culinaris* (lentil)} in acidic soils of Northeast, India. Isolation was carried out by serial dilution method and plating in the sterilized Pikovaskaya's (PVK) medium and colonies forming a clear halo zone was selected and pure cultures of such colonies was further processed for identification through morphological and molecular characterization by following the standard procedure.

P solubilizing ability of a particular PSM was assessed in terms of the solubilization index (SI) (Alam *et al.*, 2002) qualitatively and quantitatively using spectrophotometer at 882nm for available phosphorous (P) (Jackson, 1973). Rhizosphere colonizing ability was tested in the sterilised soil in small pots with the host plants grown for 30 days duration with inoculation of isolated efficient PSM strains and without inoculation as check and quantified by serial dilution and plating technique at 10 days interval. 8 types of bio-formulations was prepared, out of which 3 nos. are solid form (powder form) and 5 nos. are in liquid form. In solid form the carrier media used were sterilized vermicompost (VC), FYM and charcoal. Liquid media prepared were BIOF. 1, BIOF.2, BIOF.3, BIOF.4 and BIOF.5 of different composition.

3. Results and Conclusion

The viable population of PSMs in different land use systems ranges from 0 to 8.00×10^6 cfu ml⁻¹ with the highest PSM population in rice (upland and lowland) areas (annual crops) and zero in perennial plantation areas. Altogether, 18 nos. of native phosphorus solubilizing strains viz. PPS-01, PPS-02, PPS-03...and PPS-018 were isolated in the sterilized Pikovaskaya's (PVK) media supplemented with insoluble tri-calcium phosphate (TCP)/hydroxyl apatite as the phosphorus source. These strains were pure cultured and screened in Pikovskaya's media for halo formation and morphologically characterized. Their P solubilizing index (in plate) ranges from 2.295 to 3.20 and solubilization in broth (Av. P) mg/L ranges from 247.1 to 571.8 mg/L. Solubilizing index was

found to be highest in strains isolated from maize and rice land use areas. In sterile soils the colonizing potential and performance was found to be better in strains isolated from rice and maize land use areas. In these 8 types of bio-formulations, 3 nos. of strains (isolates) of already identified and deposited native phosphorus solubilizers with GenBank accession number PQ269770, PQ213357 and PQ212525 were used as the inoculum. After preparation, the shelf life study was carried out for these bio-formulations. Three strains (inoculum) of high solubilizing index were selected for bio-formulation preparation in solid (charcoal base, FYM base and vermi-compost base) and liquid based (BIOF. 1, BIOF. 2, BIOF. 3, BIOF. 4 and BIOF. 5) carrier materials. Solid and liquid base viable population at 6th month ranges from 1.4×10^7 to 2×10^7 cfu ml⁻¹ (Table). The shelf life study found best in vermi-compost base, followed by BIOF. 1 which is in liquid form.

Table: Shelf life study of different types of bio-formulations

Initial	After 6 months: viable population count (cfu ml ⁻¹)							
	VC	FYM	Charcoal	BIOF. 1	BIOF. 2	BIOF. 3	BIOF. 4	BIOF. 5
5.61×10^8	2×10^7	1.4×10^7	0.5×10^7	1.6×10^7	1.1×10^7	1.1×10^7	1.3×10^7	0.4×10^7

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2.7 Bioassay Study for Herbicide Resistance in *Phalaris minor* under Pot Culture Conditions

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Keywords: *Phalaris minor*, herbicide resistance, clodinafop resistance, alternate herbicides, wheat cropping system

1. Background

Little seed canary grass, *Phalaris minor* Retz., is a major grassy weed of wheat in North-Western India and has developed resistance to several post-emergence herbicides due to their continuous and repeated use (Soni et al 2024). Resistance to multiple herbicides is now widespread, and sequential or mixture applications of different mode-of-action herbicides have been evaluated for improved management (Kaur et al 2025). The evolution of herbicide resistant *P. minor* populations and the need to explore novel herbicides and integrated strategies are important for sustainable weed management in wheat systems (Sangam and Walia 2025).

2. Material and Methods

The experiment was conducted during Rabi 2022–23 and 23–24 under pot culture conditions. Seeds of ten *P. minor* biotypes (P1–P10) were collected from farmers' fields of Gadhigarh tehsil of Jammu region (P1–P5) and R.S.Pura, Tehsil of Jammu region (P7–P10) and compared with a known susceptible population. The treatments consisted of clodinafop (30, 60 and 120 g/ha), sulfosulfuron (12.5, 25 and 50 g/ha), pinoxaden (20, 40 and 80 g/ha), mesosulfuron + iodosulfuron (7.2, 14.4 and 28.8 g/ha), fenoxaprop (50, 100 and 200 g/ha) and an untreated check. Herbicides were applied at 30 DAS when plants were at 2–4 leaf stage. The experiment was laid out in a Completely Randomized Design with three replications. Dry biomass (mg/plant) was recorded at 30 days after spray. Data were analyzed using standard analysis of variance technique for CRD.

3. Results and Conclusion

The effect of different herbicides on dry biomass of *Phalaris minor* at 30 days after application was consistent over the two consecutive Rabi seasons (2022–23 and 2023–24).

- **Clodinafop** at 30 g/ha partially reduced biomass, whereas higher doses (60 and 120 g/ha) resulted in complete control in most populations, except population **P7**, which survived with, indicating possible resistance.
- **Sulfosulfuron** at 12.5 g/ha moderately reduced biomass, while doses of 25–50 g/ha caused complete suppression in all populations.
- **Pinoxaden** at 20 g/ha reduced biomass partially, whereas 40–80 g/ha achieved complete control across all populations.
- **Mesosulfuron + Iodosulfuron (RM)** at 7.2 g/ha showed partial suppression, while 14.4–28.8 g/ha completely controlled *P. minor*.
- **Fenoxaprop** at 50 g/ha reduced biomass moderately, whereas 100–200 g/ha resulted in complete mortality.
- The **untreated check** consistently recorded the highest biomass, confirming uncontrolled weed growth.

Hence, across both years, the survival of **population P7 under Clodinafop** indicates a localized resistance issue in the Jammu region. Overall, the trends were consistent across seasons, reflecting the stable herbicide responses of *P. minor* populations in this area..



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2.8 Integrated soil and nutrient management practices for resource-efficient chilli production and sustainable soil health

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Keywords: Climate-resilient agriculture, hill agroecosystems, integrated nutrient management, soil health.

1. Background

Chilli (*Capsicum annuum* L.) is a nutritionally and economically important spice and vegetable crop, contributing to dietary quality and rural livelihoods through its richness in capsaicin, vitamins, antioxidants and essential minerals. Despite India's global leadership in chilli production and trade, productivity remains below potential due to inefficient soil and nutrient management. These limitations are particularly evident in hill agroecosystems such as Himachal Pradesh, where acidic soils, low organic carbon, high nutrient fixation and fragile soil structure constrain crop performance and resource-use efficiency. Such environments are highly sensitive to climatic variability, making sustainable intensification a critical challenge. Within the framework of the Sustainable Development Goals, sustainable chilli production in hill regions aligns with SDG 2 through enhanced productivity, SDG 12 through efficient and responsible input use and SDG 13 by strengthening soil carbon stocks and agroecosystem resilience (Timilsina et al 2025). Soil health is central to this alignment, as it governs nutrient cycling, soil-water relations and biological activity that buffer crops against climate-induced stresses.

Prolonged reliance on imbalanced inorganic fertilization accelerates nutrient mining, degrades soil structure and reduces water-holding capacity, thereby increasing vulnerability to climatic stress, whereas sole dependence on organic inputs often fails to meet crop nutrient demands under intensive production systems. Integrated soil and nutrient management (ISNM), which combines organic manures with inorganic fertilizers, provides a climate-adaptive strategy by improving soil organic carbon, nutrient availability, aggregation and water-use efficiency. Field-level observations from the hill regions of Himachal Pradesh indicate that integrated nutrient management consistently outperforms the sole application of either organic or inorganic nutrient sources in chilli-based cropping systems (Sheetal 2023). Organic inputs enhance soil physical resilience, moisture retention and microbial-mediated nutrient transformations, while inorganic fertilizers ensure timely nutrient supply during critical growth stages, particularly under acidic soil conditions. In the acidic soils of the Dhauladhar hill region of Kangra district, Himachal Pradesh, the adoption of integrated nutrient management is crucial for sustaining chilli productivity and maintaining soil health. Accordingly, the present investigation was undertaken to evaluate integrated nutrient management practices within the framework of climate-resilient hill agroecosystems and sustainable natural resource management.

In the acidic soils of the Dhauladhar hill region of Kangra district, Himachal Pradesh, INM approach is essential for sustaining chilli productivity and soil health. Therefore, the present investigation was undertaken to evaluate integrated nutrient management practices within the context of climate-resilient hill agroecosystems and sustainable natural resource management.

2. Material and Methods

The field experiment was conducted during the kharif season of 2024 at the experimental farm of Krishi Vigyan Kendra, Kangra, under Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India. The study evaluated nine integrated nutrient management

treatments on chilli (*Capsicum annuum* L.) variety 'Him Palam Mirch-1' using a randomized block design (RBD) with three replications. Treatments comprised combinations of inorganic fertilizers, farmyard manure, vermicompost and foliar application of vermiwash. Inorganic fertilizers were applied as per treatment schedules with nitrogen supplied in split doses and full doses of phosphorus and potassium at transplanting. Vermiwash was applied as a 10% foliar spray at 21-day intervals in designated treatments. Composite soil samples (0-15 cm) were collected before transplanting and after harvest, then were analyzed for physical and chemical properties which includes bulk density, particle density, porosity, soil pH, soil organic carbon, soil nitrogen, phosphorus and potassium levels using standard sampling procedures. Crop observations on growth, yield attributes and fruit yield were recorded from ten randomly selected plants per plot and the resultant data was analyzed statistically using analysis of variance appropriate for randomized block design and standard statistical procedures given by Gomez and Gomez.

3. Results and Conclusion

The effect of integrated nutrient management on growth, yield, nutrient uptake and soil health of chilli was evaluated under hill agroecosystem conditions during the kharif season of 2024. Integrated application of organic manures and reduced levels of inorganic fertilizers significantly improved vegetative growth parameters, particularly plant height and branching, while phenological traits such as days to 50 per cent flowering and days to first harvest remained unaffected with increased productivity level. Among the nine treatments evaluated, application of 75 per cent recommended NPK in combination with vermicompost resulted in superior growth and yield attributes, including higher number of fruits per plant, greater fruit length and increased average fruit weight, leading to significantly enhanced green and dry fruit yields, indicating enhanced nutrient-use efficiency through partial substitution of mineral fertilizers. Integrated nutrient management significantly increased nitrogen, phosphorus and potassium concentration and uptake in both stalk and fruit. Post-harvest soil analysis showed significant improvement in available N, P and K while soil pH, organic carbon and physical properties remained stable. Overall, the results demonstrated that integrated nutrient management enhances chilli productivity, maintains soil functional health and provides a resource-efficient and sustainable nutrient management strategy for hill agroecosystems.

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2.9 Knowledge of Farmers About Major Diseases And Management Strategies In Paddy-Wheat Based Cropping System In Sangrur District Of Punjab

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Keywords: Diseases, Knowledge, Management strategies, Paddy, Wheat.

1. Background

Agriculture is a vital sector of India's economy, supporting millions of livelihoods and contributing significantly to global food production. Rice (*Oryza sativa*) and wheat (*Triticum aestivum*) are major staple crops, with India ranking second globally in their production. Punjab, known as the "Granary of India," plays a key role in rice and wheat cultivation, particularly Sangrur district, which has high cropping intensity and productivity. However, excessive use of nitrogen fertilizers has increased the incidence of major diseases such as sheath blight and false smut in paddy, and yellow rust and Karnal bunt in wheat. The recent emergence of dwarfing disease in paddy has further challenged farmers. Limited awareness and over-reliance on chemicals often result in economic losses. Therefore, enhancing farmers' knowledge of disease identification and management is essential for sustainable productivity. The present study assesses farmers' knowledge of paddy and wheat disease management.

2. Material and Methods

The study was conducted in Sangrur district of Punjab. Five blocks were randomly selected, followed by two villages from each block and twenty farmers from each village, forming a total sample of 200 respondents. Data were collected through personal interviews. A structured knowledge test was developed to assess farmers' understanding of disease symptoms, occurrence, and management practices. Initially, 50 items were prepared based on expert consultation and literature review. After item analysis (difficulty index 30–70% and discrimination index 0.3–0.7), 34 items were finalized. The test showed high reliability (0.843) using the split-half method and Spearman-Brown formula. Content validity was ensured through expert evaluation. Knowledge scores were categorized into low, medium, and high levels based on total scores.

3. Results and Conclusion

Most respondents were middle-aged (38–53 years), educated up to senior secondary level, possessed medium landholdings (10–25 acres), and had considerable farming experience. Farmers mainly consulted agricultural universities, KVKs, and cooperative societies for advice. Mass media exposure was generally low, with television being the most commonly used medium.

Regarding disease knowledge, awareness varied across topics. About 67% correctly identified major paddy diseases, while 70% recognized yellow rust symptoms in wheat. Knowledge of specific symptoms and resistant varieties was comparatively lower. Overall knowledge levels showed that: 32% had low knowledge, 57.5% had medium knowledge, 10.5% had high knowledge. The Correlation analysis has revealed that Education ($r=0.2709$) and operational landholding ($r=0.3381$) had positive relationships with knowledge. Age (-0.2006), experience (-0.06359), and family size (-0.08735) showed negative correlations. Extension contact had a positive influence

(0.2155), while mass media exposure showed minimal impact. The majority of farmers possessed a medium level of knowledge regarding paddy and wheat disease management. Education, landholding size, and extension contact positively influenced knowledge levels, while age and experience showed negative associations. The findings highlight the need for targeted educational and extension interventions, particularly for farmers with lower education and smaller landholdings, to improve disease management practices and enhance crop productivity.

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2.10 Agronomic Optimization of Plant Population and Nitrogen Dose for Maximizing Yield and Quality of Fodder Maize

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Keywords: Crude protein, Fodder maize, Nitrogen levels, Planting density, IVDMD, Fibre fractions

1. Background

Fodder scarcity is a major limitation to livestock productivity in temperate Himalayan regions. Fodder maize (*Zea mays* L.) is widely preferred due to its high biomass potential, palatability, and digestibility (Sattar *et al.*, 1994). It contains more non-structural carbohydrates than other cereal forages. Hence, there is no need for external carbohydrate sources like molasses or jaggery while preparing silage since sugars and water-soluble carbs are more crucial for silage preservation (Daiz., 2018). Planting density regulates plant population per unit area, influencing biomass accumulation, while nitrogen fertilization plays a critical role in chlorophyll synthesis, protein formation, and vegetative growth. Optimizing these two factors is essential for improving both quantitative and qualitative attributes of fodder maize.

2. Material and Methods

The experiment was conducted at the Agronomy Research Farm, SKUAST-K, Wadura (34°21'N, 74°23'E; 1590 m amsl). The soil was silty clay loam with neutral pH and medium fertility status. The experiment was laid out in split plot design with three replications. Main plot treatments included three planting densities (30 × 10 cm, 40 × 10 cm and 50 × 10 cm) while sub-plot treatments comprised five nitrogen levels (Control, 75%, 100%, 125% and 150% RDN). The crop was harvested at 75% silking stage.

Yield was recorded as green fodder yield (q ha⁻¹). Crude protein was estimated using the Kjeldahl method. NDF and ADF were determined using Van Soest fibre analysis. IVDMD was estimated by the Tilley and Terry method. Economic analysis included calculation of gross returns, net returns and benefit-cost ratio.

3. Results and Conclusion

The highest plant density (30 cm × 10 cm) produced maximum green fodder yield per hectare due to greater plant population. Yield increased progressively with nitrogen levels, with 150% RDN producing the highest biomass. Crude protein content increased significantly with increasing nitrogen levels, with 150% RDN recording the highest protein percentage. Fibre fractions (NDF and ADF) were comparatively lower under higher nitrogen application, contributing to improved digestibility. IVDMD was significantly higher under 150% RDN, indicating superior forage quality. Planting density had a marginal effect on crude protein and fibre content compared to nitrogen fertilization. Economic evaluation indicated that although 150% RDN recorded maximum yield, 125% RDN produced comparable productivity with improved economic efficiency, suggesting it as an optimal nitrogen dose under temperate valley conditions.

The study demonstrated that optimizing planting density and nitrogen fertilization significantly enhances fodder maize productivity under temperate valley conditions. Closer spacing (30 × 10 cm) combined with higher nitrogen fertilization significantly enhanced biomass yield and forage quality of Shalimar Fodder Maize-1 under temperate valley conditions. While 150% RDN

maximized yield and quality parameters, 125% RDN emerged as a balanced and economically efficient option. Strategic management of plant population and nitrogen dose is crucial for sustainable fodder production in temperate agro-ecosystems.

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2.11 Yield and Growth Assessment of Multicut Oat Genotypes to Unravel Nutritional Variability in Fodder Biomass through Zn Biofortification.

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Keywords: Bio- fortification, multi cut oat, zinc sulphate, fodder productivity and yield attributes.

1. Background

Oat (*Avena sativa* L.) is a crucial winter fodder crop in India that helps overcome livestock feed shortages, but its yield is restricted by nutrient imbalance, particularly zinc (Zn) deficiency. Oats are highly sensitive to Zn, which plays a vital role in energy production, enzyme activity, protein synthesis, and photosynthesis, thereby enhancing shoot growth and leaf area. Applying Zn fertilisers significantly improves agronomic traits and fodder yield, while biofortification strategies are emerging as effective solutions to address micronutrient deficiencies and boost multicut oat production.

2. Material and Method

The experimental consisted of eight treatments viz., Trt.1: recommended dose of fertilizers*(recommended dose of fertilizers, 80: 40: 20 kg/ha) (No Zinc), Trt.2: recommended dose of fertilizers + soil application of Zinc Sulphate @ 25 kg/ha, Trt.3: recommended dose of fertilizers + foliar spray of Zinc Sulphate @ 0.5 % at 45 days after sowing, Trt.4: recommended dose of fertilizers + foliar spray of Zinc Sulphate @ 0.5 % at 90 days after sowing, Trt.5: recommended dose of fertilizers + foliar spray Zinc Sulphate @ 0.5% at 45 days after sowing and 90 days after sowing, Trt.6: recommended dose of fertilizers + soil application of Zinc Sulphate @ 25 kg/ha + Foliar spray of ZincSulphate @ 0.5 % at 45 days after sowing, Trt.7: recommended dose of fertilizers + soil application of Zinc Sulphate @ 25 kg/ha + Foliar spray of ZincSulphate @ 0.5 % at 90 days after sowing, Trt.8: recommended dose of fertilizers + soil application of zinc sulphate @ 25 kg/ha + Foliar spray of ZincSulphate @ 0.5% at 45 days after sowing & 90 days after sowing and two Oat varieties viz., JHO-851 and OL-10. Two types of oats (JHO-851 and OL-10) were used in the main plots of the split plot design, while varied administrations of zinc sulphate were set up in the subplots. There were eight treatments altogether, with a total of sixteen treatment combinations, and each treatment was reproduced three times. Zinc sulphate heptahydrate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) @ of 25 kg/ha was used to supply zinc. There were 48 plots in all. Each plot measured 12 m² in gross area and 6.4 m² in net area. With the help of a liner weighing 100 kg /ha, the seeds were planted using the Kera method in the furrows that had been manually opened at a 20-cm interval between rows. The rows were then sealed with a light planker.

3. Result and Conclusion

In addition to evaluating the impact of zinc (Zn) treatments on the growth, productivity, and yield of oat cultivars under investigation, the study also aimed to biofortify oat forage with zinc. Among the cultivars, JHO-851 consistently outperformed OL-10 in terms of growth attributes, yield components, and forage productivity. At both harvest stages (60 and 105 days after sowing), all zinc application treatments significantly improved growth parameters, yield attributes, and forage yield compared to the control (Trt.1: recommended dose of fertilizers without zinc). Among the different zinc application methods, soil application combined with foliar spraying at 45 and 90

days after sowing resulted in the greatest improvement in crop growth and forage production. Treatment 6 recorded superior performance at 60 days after sowing, while Trt.8 was found to be the most effective at the final harvest stage. In conclusion, the present investigation demonstrates that agronomic biofortification of oats with zinc is an effective strategy, as it enhances zinc enrichment in forage while simultaneously improving crop growth, yield, and overall productivity.

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2.12 Effect of nitrogen management on protein of sweet corn under organic farming

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Keywords: Nitrogen management, sweet corn, organic farming, protein content

1. Background

Sweet corn is one type of specialty maize which is grown for fresh green cobs for human consumption and also used as raw and processed material for the food industry throughout the world. Its taste and nutritional value have made it a valued crop in all countries and the scope of sweet corn production is constantly increasing (Olabode and Sangodele, 2015) [2]. Due to its very sweet taste and tenderness, cultivation of sweet corn is the first choice of farmers nowadays. The ill-effects of chemicals used in agriculture have changed the mindset of some consumers of different countries who are now buying organic products with high premium for health. A large number of studies have investigated consumer behavior towards organic food purchases. The broad factors behind consumer purchases of organic foods are health, environment and food safety & quality. The systematic work on productivity and economics of different maize based organic cropping systems have been done in India & Rajasthan which is providing technical knowledge to farmers and help them in adoption of organic production of crops.

2. Material and Methods

The experiment was conducted at the Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur which is situated in South- Eastern part of Rajasthan at an altitude of 582.17 metre above mean sea level with 24°35 N latitude and 74°42 E longitude and this area falls under agro-climatic zone IV a (Sub-humid Southern Plains and Aravalli Hills) of Rajasthan during *kharif* 2022. This climate of place is subtropical characterized by mild winters and moderate summer associated with high relative humidity during the months of July to October and soil of experimental site was clay loam in texture having 252.8, 25.82 and 305.8 kg ha⁻¹ available nitrogen, phosphorus and potassium respectively in 0-30 cm soil depth with 7.9 and 0.67% organic carbon. The experiment was laid out in Randomized Block Design with three replications.

3. Results and Conclusion

It can be inferred from the data presented in Table 1 reveal that protein content of sweet corn was significantly influenced by the nitrogen management under organic farming. Data reveals that the significantly maximum protein content (10.56%) was recorded under treatment T₆ (50% RDN through FYM + 25% RDN through vermicompost at 30 DAS + 25% RDN through vermicompost at 45 DAS), which was significantly higher by 12.40 per cent over control. The increase in protein content in grain under the influence of vermicompost may be attributed to increase in N content in grain, which as a significant role in synthesis of protein in grain. Khan *et al.* (2017) [1]

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2.13 Optimizing Land Configuration and Weed Management Practices for Enhanced Productivity of Field Pea under Temperate Conditions of NWH

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Keywords: Broad bed and furrow, Field pea, Integrated weed management, imazethapyr Pendimethalin, Ridge and furrow, Seed yield.

1. Background

Field pea crop productivity under temperate Agro-climatic conditions gets reduced primarily by way of unfavourable land preparation and excessive crop weed competition during the critical stages of the crop growth. The crop has been grown under diverse agro-ecologies of Kashmir valley with invariable low production and productivity. The productivity of this crop can be increased by way of agronomic manipulations best suited to the crop for resource conservation and applying different weed management practices.

2. Materials and Methods

An experiment entitled “Optimizing Land Configuration and Weed Management Practices for Enhanced Productivity of Field Pea under Temperate Conditions of north west Himalayas was undertaken during rabi seasons 2023-2024 at Dryland Agriculture Research Station, Rangreth, SKUAST-Kashmir. The experiment consisted of fifteen treatments viz; Land configuration comprised of (i) flat bed planting (ii) ridge and furrow planting, and (iii) broad bed and furrow planting - laid out in main plot while the five weed management practices adopted were (i) pendimethalin 1.0 kg ai ha⁻¹ as a pre-emergence herbicide (ii) imazethapyr 10% SL @ 55g ha⁻¹ by application at 15-20 days after sowing (iii) pendimethalin 30 EC as a pre-emergence herbicide followed by application of imazethapyr 10% SL @ 55g ha⁻¹ @ 15-20 days after sowing (iv) weedy check treatment and (v) weed-free treatments. The experiment was laid out in split plot design (SPD) and replicated thrice. The soil of the experimental field was silty clay in texture, low in organic carbon and medium in nitrogen, phosphorus and potassium. Fertilizer NPK @ 30-60-30 kg/ha was applied as a common dose to all the treatments.

3. Results and Conclusion

The experimental results revealed that broad bed and furrow planting significantly improved yield-attributing parameters such as number of pods per plant(13.52), seeds per pod, and test weight(18.23 g), resulting in higher yield (1349 kg ha⁻¹) compared to flat-bed planting, though it was statistically at par with ridge and furrow planting. This can be attributed to improved soil physical environment and better root zone aeration under raised bed systems which inturn enhances better drainage, moisture distribution, and nutrient availability that leads to promote better crop establishment and reproductive growth. The major weeds associated with the crop were *Cirsium* spp., wild tulip, *Cyperus* spp., and *Bromus* spp. Among weed management practices, the weed-free treatment recorded the highest values of yield attributes and seed yield. However, integrated herbicide application of pendimethalin 30 EC as pre-emergence followed by imazethapyr 10% SL at 15–20 DAS produced significantly higher pods per plant (13.13), test weight (18.43 g), and seed yield (1387 kg ha⁻¹) than individual herbicide treatments. This can be attributed to the effective control of early and late emerging weeds by the two herbicides in

sequence. The weedy check resulted in the lowest values of all yield parameters and caused approximately 20% reduction in seed yield compared to the weed-free treatment.

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2.14 Optimizing Rice Productivity through Crop Establishment Methods and Enhanced Efficiency Nitrogenous Fertilizer under Temperate Ecosystem.

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Keywords: EENF, Establishment Methods, Grain, LAI, Rice, SRI, Yield

1. Background

Rice productivity under temperate conditions is strongly influenced by establishment method and nitrogen management. Crop establishment techniques regulate root growth, tillering, canopy development and nutrient uptake while nitrogen fertilization determines vegetative vigor and biomass accumulation. The System of Rice Intensification (SRI) is known to improve plant growth through better root aeration and spacing. Enhanced Efficiency Nitrogen Fertilizers (EENFs) reduce nitrogen losses and improve nutrient availability, thereby increasing crop performance. EENFs can significantly mitigate greenhouse gas emissions and improve overall nitrogen fertilizer performance (Ming *et al.*, 2024). In addition, controlled-release and enhanced-efficiency fertilizers have been highlighted as effective strategies for improving nitrogen use efficiency by minimizing losses such as volatilization and leaching (Sharma *et al.*, 2025). The present study was undertaken to evaluate the combined influence of establishment methods and EENF on growth and yield parameters of rice.

A field experiment was conducted to evaluate the effect of crop establishment methods and enhanced efficiency nitrogenous fertilizers (EENF) on growth and yield of rice under temperate conditions. The experiment was laid out in a split-plot design with three establishment methods viz., Transplanted Rice (TPR), Direct Seeded Rice (DSR) and System of Rice Intensification (SRI) in main plots and five nitrogen treatments viz., Control, 100% RDF (urea), 50% EENF, 75% EENF, and 100% EENF in sub-plots. Among establishment methods, SRI recorded significantly higher grain yield (7.98 t ha⁻¹), plant height (128.1 cm) and leaf area index (3.58) compared to TPR (7.15 t ha⁻¹, 121.9 cm, 3.24) and DSR (6.07 t ha⁻¹, 120.3 cm, 2.89). Grain yield under SRI was 31.47% higher than DSR. Nitrogen treatments significantly influenced growth and productivity. Application of 100% EENF recorded the highest grain yield (9.52 t ha⁻¹), plant height (126.05 cm), and LAI (3.67), followed by 75% EENF (8.65 t ha⁻¹; 120.01 cm; 3.26). The control recorded the lowest grain yield (6.09 t ha⁻¹). Notably, 75% EENF produced 7.19% higher yield than 100% RDF (8.07 t ha⁻¹), indicating improved nitrogen use efficiency. The results demonstrate that integration of SRI with enhanced efficiency nitrogen fertilizer significantly improves growth and grain yield of rice under temperate valley conditions.

2. Material and Methods

The experiment was conducted under temperate valley conditions in a split-plot design with three replications. Crop establishment methods viz., Transplanted Rice (TPR), Direct Seeded Rice (DSR) and System of Rice Intensification (SRI) were assigned to main plots, while nitrogen treatments comprising Control, 100% RDF (urea), 50% EENF, 75% EENF, and 100% EENF were allotted to sub-plots. Observations on plant height, leaf area index (LAI), and grain yield were recorded and analysed statistically at 5% level of significance.

3. Results and Conclusion

Establishment methods significantly influenced growth and yield. SRI recorded the highest

plant height (128.1 cm) and LAI (3.58), outperforming TPR (121.9 cm; 3.24) and DSR (120.3 cm; 2.89). Grain yield was also maximum under SRI (7.98 t ha⁻¹), which was 11.60% and 31.47% higher than TPR and DSR, respectively.

Nitrogen application significantly enhanced growth and productivity. Plant height increased from 107.98 cm in control to 126.05 cm under 100% EENF, while LAI improved from 2.76 to 3.67. Grain yield increased progressively with EENF levels with 100% EENF recording the highest yield (9.52 t ha⁻¹), 56.32% higher than control and 17.97% higher than 100% RDF. Notably, 75% EENF (8.65 t ha⁻¹) also surpassed conventional urea (8.07 t ha⁻¹) indicating improved nitrogen efficiency.

SRI significantly improved growth and yield of rice compared to TPR and DSR. Enhanced efficiency nitrogen fertilizer further boosted productivity with 100% EENF recording the highest performance. Importantly, 75% EENF produced higher yield than conventional RDF, suggesting scope for reducing nitrogen input without compromising yield. Integration of SRI with EENF offers a sustainable strategy for temperate rice production.

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2.15 Influence of Zinc Fortification on Yield and Yield Components of Maize (*Zea mays* L.) under Rainfed Conditions

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Keywords: Maize, Yield, Zinc

1. Background

Zinc is very important micronutrient for human health as it acts like an anti-depressant to overcome the depression Maqbool and Beshir. 2018. Moreover, it plays a vital role in the regulation of arterial blood pressure, functioning of the endocrine system and also reduces respiratory tract infection such as COVID-19, thus served as ‘metal of life’ in humans (Nakanishi *et al* 2022). Hence, considering the importance of zinc and maize crop in the entire food chain zinc fortification seems to be promising approach to reduce zinc malnutrition as well as to surmount zinc deficiency in soil, plants and animals. Since, the techniques used for zinc fertilisations determine the effectiveness of zinc use efficiency therefore, appropriate method of zinc fertilization should be adopted (Kumar *et al* 2025).

2. Material and Methods

A field experiment was conducted during *Kharif* 2022 at the research farm of Advanced centre for Rained Agriculture (ACRA) at Dhiansar under SKUAST-Jammu geographically located at 32° 39' north and longitude 74° 53' east at an altitude of 332 meters above mean sea level. The soil of the experimental field was sandy loam in texture with sand (65.53 %), silt (18.23 %) and clay (16.24 %), neutral in reaction with pH 6.64, low in organic carbon (2.6 g/kg) and available nitrogen (174.04 kg/ha) but medium in available phosphorus (14.17 kg/ha) and available potassium (116.11 kg/ha). The experiment was conducted in randomized block design (RBD) with three replications. The experiment consists of twelve treatments of zinc fortification *viz.* Control-T₁, recommended ZnSO₄ @10 kg/ha-T₂, seed priming with water-T₃, seed priming with 1% ZnSO₄ -T₄, seed priming with 2% ZnSO₄-T₅, seed treatment with ZnSO₄ @ 2g/kgseed -T₆, seed treatment with ZnSO₄ @ 4g/kg seed-T₇, seed priming with water + foliar application of 0.5% ZnSO₄ at tasselling and silking stage -T₈, seed priming with 1% ZnSO₄ + foliar application of 0.5% ZnSO₄ at tasselling and silking stage-T₉, seed priming with 2% ZnSO₄ + foliar application of 0.5% ZnSO₄ at tasselling and silking stage-T₁₀, seed treatment with ZnSO₄ @ 2g/kgseed+foliar application of 0.5% ZnSO₄ at tasselling and silking stage-T₁₁ and seed treatment with ZnSO₄ @ 4g/kgseed +foliar application of 0.5% ZnSO₄ at tasselling and silking stage-T₁₂.

3. Results and Conclusion

Yield and yield attributes of maize were significantly influenced by Zinc fortification in Maize crop. Amongst the different fortification treatments, significantly highest length of cob (20.2 cm), cob weight (107.9 g), number of grains/cob(355.8), grain yield (47.7 q/ha) and stover yield (80.8q/ha) was recorded with treatment seed treatment with ZnSO₄ @ 4g/kg seed + foliar application of 0.5% ZnSO₄ at tasselling and silking stage where as significantly lowest value of cob length(15.0 cm), cob weight (80.8 g), number of grains/cob (235.2), grain yield (36.6 q/ha) and stover yield (62.2 q/ha) were recorded with treatment Control. Significantly highest yield and yield attributes in treatment T₁₂ was might be due to the application of zinc, which enhance fertilization and seed set. Moreover, improved carbohydrate metabolism due to efficient activity of starch synthase enzyme was responsible for increased seed weight, yield per plant and eventually resulted

in higher yield attributes and yield. The results are in close conformism with the findings of Kandali *et al* 2021.

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2.16 Effect of Graded Phosphorus and Citric Acid Levels on Productivity and Quality of Soybean in an Alfisol

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Keywords: Phosphorus, citric acid, P content and Soybean

1. Background

Soybean is widely regarded as a “miracle crop” due to its exceptionally high protein content (40–42%) and oil content (18–20%), making it a strategic crop for addressing global food and nutritional security. Among essential nutrients, phosphorus (P) plays a pivotal role in soybean growth and productivity. Adequate phosphorus supply promotes vigorous root and shoots development, enhances symbiotic nitrogen fixation, improves nutrient and water use efficiency, stimulates pod formation, and minimizes the occurrence of unfilled pods collectively contributing to higher yield potential. Despite its importance, phosphorus availability in soils is often limited. A substantial proportion of soil P exists in forms bound to mineral constituents or organic matter, rendering it poorly available for plant uptake and thereby constraining crop productivity.

To cope with phosphorus deficiency, plants have evolved several adaptive mechanisms. These include the establishment of mycorrhizal associations, development of longer root hairs and cluster roots, secretion of phosphatase enzymes, and rhizosphere acidification through the release of low-molecular-weight organic acids (LMWOAs) (Marschner and Romheld, 1994). Root exudates such as amino acids, sugars, phenolic compounds, and other metabolites play a crucial role in this process. They compete for adsorption sites, lower rhizosphere pH, and form soluble complexes with metal cations, thereby mobilizing fixed phosphorus and enhancing its availability and uptake by plants (Wang *et al.*, 2016).

2. Materials and Methods

A pot experiment with sixteen treatment combinations and three replications was conducted during the Kharif season at the College of Agriculture, KSNUAHS, Navile, Shivamogga, to evaluate the effect of graded phosphorus and citric acid levels on soybean growth, yield attributes and nutrient uptake in an Alfisol. The treatments consisted of four levels of phosphorus (0, 40, 60, and 80 kg ha⁻¹) and four levels of citric acid (0, 2.5, 5.0, and 7.5 kg ha⁻¹), arranged in a factorial combination (T₁–T₁₆). Each pot contained 12 kg of soil. Recommended quantities of FYM, Rhizobium, and PSB were applied seven days before sowing. Soybean variety JS-335 was used. Fertilizers supplying 30 kg N, 80 kg P₂O₅, and 37.5 kg K₂O ha⁻¹ were applied as a basal dose through urea, DAP, and MOP, respectively. Two seeds were sown per pot at a depth of 3–5 cm. The experimental soil was slightly acidic (pH 5.9) with low EC (0.013 dS m⁻¹), organic carbon of 5.8 g kg⁻¹, low available N, high available P, and medium available K. The soil also contained high DTPA-extractable Fe and low exchangeable Al.

3. Results and Conclusion

Yield attributes of soybean were positively impacted by graded levels of P and CA. The number of seeds pod⁻¹ increased significantly with increasing dose of P and CA, showing maximum value (3.07) under treatment with 80 kg P ha⁻¹ + 7.5 kg CA ha⁻¹, compared to the control (1.53). Test weight also improved significantly, with the highest value (12.31 g) under T₁₆. Pod weight plant⁻¹ increased significantly with higher P levels (0.30 g plant⁻¹ at 80 kg P ha⁻¹), whereas CA

alone showed no significant effect. Similarly, the highest seed yield ($2118.76 \text{ kg ha}^{-1}$) and plant yield ($2507.72 \text{ kg ha}^{-1}$) were recorded under T_{16} (Fig. 1), which were significantly superior to control (6.38 and 10.07 g pot^{-1} , respectively). Nutrient concentration in seed and plant improved progressively with increasing P application and further enhancement was observed with CA. The highest seed N (5.22%), P (0.69%), K (1.86%), Ca (0.72%), Mg (0.56%) and S (0.44%) contents were recorded at 80 kg P ha^{-1} . Application of $7.5 \text{ kg CA ha}^{-1}$ further improved N and P content, likely through enhanced P solubilization and reduced fixation. The combined application, particularly T_{16} , resulted in superior nutrient accumulation due to improved P availability, enhanced root proliferation, better nodulation and increased NUE, ultimately translating into higher productivity and better seed quality.

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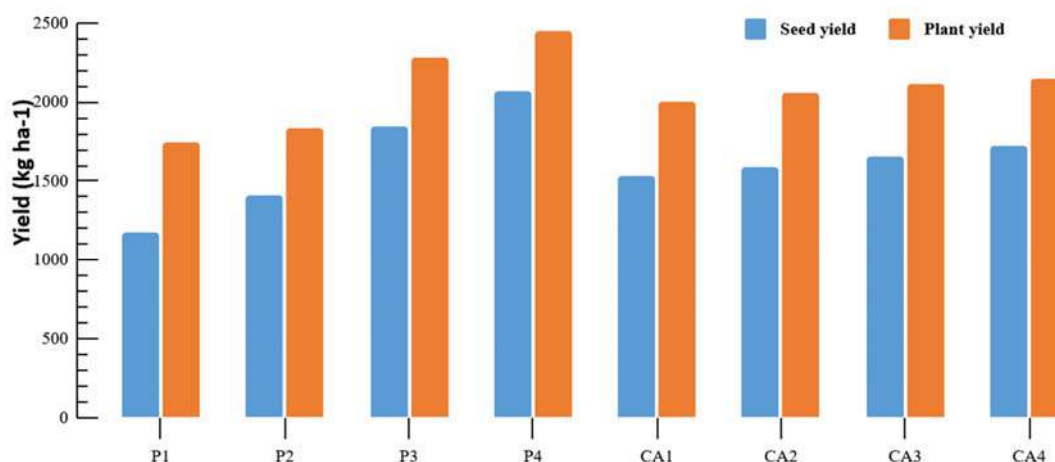


Fig. 1 Seed and plant yield as influenced by phosphorus (P) and citric acid (CA) application

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2.17 Evaluation of biointensive pest management practices against insect pests in bitter gourd (*Momordica charantia* L.)

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Keywords: Bittergourd, fruit fly, biological control, climate smart agriculture

1. Background

Developing climate-smart production systems requires integration of resilient crop varieties, eco-friendly pest management strategies, and reduced chemical dependency to sustain productivity under changing climatic conditions. The present study evaluated biointensive pest management (BIPM) practices in bitter gourd (*Momordica charantia* L.) as a model for climate-resilient vegetable production.

2. Materials and Methods

Field experiments were conducted during 2023–24 and 2024–25 at the Regional Agricultural Research Station, Kumarakom, Kerala India using the variety, Priya. The experiment comprised three treatments with seven replications in a randomized block design (plot size: 40 m²). The treatments included: (T1) Biointensive pest management (BIPM) practices; (T2) Package of Practices (POP) recommendation involving chemical control; and (T3) untreated control. The BIPM module (T1) consisted of installation of cue lure traps (15/ha) for monitoring and management of fruit flies, application of *Lecanicillium lecanii* (NBAIR VI8) @ 5 g/L combined with neem oil (2.5 ml/L) for sucking pests, and *Bacillus thuringiensis* (NBAIR Bt G4) @ 10 ml/L for management of leaf webber (*Diaphania indica*). The chemical POP treatment (T2) included jaggery 1% + malathion 50 EC @ 2 ml/L. Observations were recorded on percentage fruit damage, incidence of lepidopteran larvae, aphids, epilachna beetle, and yield parameters.

3. Results and Conclusion

The results demonstrated significant differences among treatments. The mean percent of damaged fruits caused by fruit fly *Zeugodacus cucurbitae* in bittergourd was lowest (29.33%) in plots treated with Jaggery 1% + Malathion 50 EC @ 2ml/L, followed by plots with BIPM practices (32.44%), both being significantly different from each other. The untreated control recorded the highest fruit damage (58.14%), severe aphid infestation, and maximum epilachna beetle incidence. Both the chemical treated plot and BIPM plots recorded more than forty per cent reduction in damage over control plots. The BIPM treatment reduced fruit damage substantially compared to control and maintained lower pest populations, particularly aphids (0.66 post-treatment) and epilachna beetles (0.60 post-treatment). Although the chemical POP treatment recorded slightly higher immediate yield (4.62 t/ha) compared to BIPM (3.40 t/ha), BIPM achieved a 30.26% yield increase over control with significantly reduced pest pressure and lower ecological risk.

The findings highlight that climate-smart vegetable production is not solely dependent on breeding for tolerance but must integrate biointensive pest management within the production system. In conclusion, the integration of improved varieties with biointensive pest management practices provides a viable pathway toward climate-smart production systems that ensure productivity, environmental sustainability, and long-term resilience in vegetable agroecosystems.

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2.18 Optimizing leaf litter recycling in agroforestry systems for resilient farming

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Keywords: Biowaste, nutrient, Coconut litter, Composting

1. Background

Multipurpose trees in an agroforestry system contribute significantly to the diverse functions and ecosystem services provided by the system and are regarded “integral” components. The litter that remains as a biowaste in the tree bases undergoes *in situ* decay and adds to the soil fertility, but, this takes a considerably long period (Bisht *et al.*, 2014) Hastening the process with decomposers offers scope for faster mineralisation and nutrient release enhancing its potential as nutrient source in crop production. In the homestead agroforestry practice prevalent in Kerala, the litter are burnt for ash production as a result of which the nutrients present in them go waste. With the increasing need to conserve natural resources and energy, recycling of the tree litter assumes major significance.

2. Materials and Methods

The experiment exploring the possibility of optimizing the decomposition process in jack and coconut litter, was conducted at College of Agriculture Vellayan, Kerala Agricultural University adopting different methods C₁: Composting inoculum powder formulation @ 20g kg⁻¹, C₂: Composting inoculum of *Bacillus subtilis* liquid formulation @ 1000 ml m⁻³, C₃: Earthworms (*Eudrillus eugineae*) @ 50nos.m⁻³, C₄: Co composting with poultry manure @ 10% w/w, C₅: C₄+ C₃, C₆: C₂+ C₃ and C₇: Natural decomposition in factorial CRD in three replications. Weighed quantities of the litter in each species were soaked overnight, drained and filled in cement pots (50 cm height and 25 cm diameter at the top) @ 200 g pot⁻¹. The moistened litter was mixed with fresh cowdung (4:1 by weight) in all treatments except C₄, C₇ and C₈. The litter in C₄ was mixed with poultry manure @ 10% w/w and that in C₇ and C₈ were kept as such for natural decomposition on a thin layer of soil and without soil, respectively. Inoculum were applied in layers and later were mixed with the turnings done during composting. Water was sprinkled at regular intervals to avoid drying of the material. The compost production was considered as complete when the litter was converted to a fine powdery mass and C: N ratio was lowered to less than 25: 1. The time taken for 95 % weight loss was recorded and quality parameters ascertained. The data were subjected to statistical analysis adopting ANOVA technique and critical differences were computed to assess significant effects.

3. Results and Conclusion

Perusal of the data analysed revealed that composting of leaf litter with different organisms and co-composting could significantly reduce the time taken for complete decomposition in both litter species. Co- composting was found to be the best method for hastening the decomposition. Decomposition was completed in 105 days in jack and 121 days in coconut litter, compared to the 206 and 238 days taken for natural decomposition in jack and coconut, respectively. The final composts of both litter had significantly higher amounts of nutrients and lower C: N ratio compared to the initial litter. Nutrient contents of the co composted jack litter (N -1.87%, P- 0.73%, K- 0.16%) and coconut litter (N- 2.48%, P- 0.44%, K- 0.20 %) were comparatively higher indicating the suitability of this method in accelerating the decay and use as a composting technology for the

selected tree species leaf litter.

Table 1. Comparative evaluation of jack leaf litter compost prepared by the different composting methods

Treatments	N (%)	P (%)	K (%)	C: N Ratio	Time decomposition for (days)
C ₁	1.07	0.59	0.17	21.40	180
C ₂	1.30	0.64	0.20	27.89	165
C ₃	1.54	0.54	0.10	26.00	196
C ₄	1.87	0.73	0.16	16.63	105
C ₅	1.35	0.80	0.25	21.60	138
C ₆	1.21	0.68	0.19	18.79	172
C ₇	1.12	0.52	0.10	32.53	206
C ₈	1.26	0.54	0.12	33.83	216

C₁ – CI (powder)

C₂ – CI (liquid)

C₃ – Earthworms C₄ – Co-composting

C₅ – C₁ + C₃

C₆ – C₂ + C₃

C₇ – Natural decomposition with soil C₈ – Natural decomposition without soil

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2.19 Improving Productivity and Profitability of Fine Rice Through Nano DAP Fertilization

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Keywords: Seedling dipping, Foliar application, Yield

1. Background

Co-friendly fertilizer Nano Di-ammonium phosphate in liquid formulations are manufactured by Nano Biotechnology Research Center in association with Indian Farmers Fertilizers Cooperative Limited to avoid the imbalanced and excessive use of Di-ammonium phosphate. Nano Di-ammonium phosphate contains 8 per cent nitrogen and 16 per cent phosphorus by weight in its nano form. Seedling dipping with nano DAP enhances seedling vigor, promotes root growth which leads to higher biomass production. (Swetha *et al.* 2017). However, foliar application of nano Diammonium phosphate enters the leaf through stomatal and cuticular pores which increase in phosphorus concentration not only in shoots but also in roots, which ultimately increases the rapid uptake of phosphorus by rice crop (Talboys *et al.* 2020). The present study was carried out to evaluate effect of nano DAP on yield and economics of fine rice.

2. Material and methods

A field experiment was conducted during summer season of 2023 and 2024 at research farm of Division of Agronomy, SKUAST-Jammu. The experiment was conducted in randomized block design with three replications. The experiment comprised of ten treatments viz Recommended potassium, 100% recommended NPK, 75% recommended N,P, 100% recommended K, 50% recommended N, P, 100% recommended K, 75% recommended N,P, 100% recommended K + seedling dipping with nano DAP @ 5 ml/litre + foliar spray with nano DAP @ 2 ml/l, 75% recommended N,P, 100% recommended K + seedling dipping with nano DAP @ 5ml/litre + foliar spray with nano DAP @ 4 ml/litre, 50% recommended N,P and 100% K + seedling dipping with nano DAP @ 5 ml/l + foliar spray with nano DAP @ 2 ml/l, 50% recommended N,P and 100% recommended K + seedling dipping with nano DAP @ 5 ml/l + foliar spray with nano DAP @ 4 ml/l, 50% recommended N,P and 100% recommended K + seedling dipping with nano DAP @ 5 ml/l + 2 foliar spray with nano DAP each @ 2 ml/l, 50% recommended N,P, 100% recommended K + seedling dipping with nano DAP @ 5 ml/l + 2 foliar spray with nano DAP each @ 4 ml/l. The observations recorded during the course of investigation were tabulated and subjected to analysis of variance techniques as described by Gomez and Gomez (1984)

3. Results and Conclusion

Experimental results revealed that Seedling dipping and foliar application of nano DAP recorded significantly higher yield attributes, grain yield and straw yield with 75% recommended N,P, 100% recommended K + seedling dipping with nano DAP @ 5 ml/litre + foliar spray with nano DAP @ 4 ml/l. Maximum net returns and benefit cost ratio was recorded with 75% recommended N,P, 100% recommended K + seedling treatment with nano DAP @ 5 ml/l + foliar spray with nano DAP @ 4 ml/l which was closely followed by 75% recommended N,P, 100% recommended K + seedling dipping with nano DAP @ 5 ml/l + foliar spray with nano DAP @ 2 ml/l. Hence, on the basis of 2 year it was concluded that 75% recommended N,P, 100% recommended K + seedling dipping with nano DAP @ 5 ml/litre + foliar spray with nano DAP @ 4 ml/l. was found to be the economical viable option for achieving higher productivity and profitability for the rice growers.

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2.20 Mulching Mediated Weed Suppression in Rainfed Nectarine Orchards of the Mid-Hill Himalayas

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Keywords: Mulching, Nectarine, Rainfed cultivation, Hydrothermal regimes, Himachal Pradesh, Weed infestation

1. Background

Nectarine (*Prunus persica* L. Batsch var. *nucipersica*), a natural mutant of peach belonging to the family Rosaceae, has gained considerable popularity due to its smooth, fuzz-less skin, attractive appearance, and superior eating quality. The cultivar ‘Snow Queen’ is an early-maturing variety producing small to medium-sized fruits with bright deep-red skin and creamy-white, juicy flesh, and is well adapted to mid-hill conditions up to 6000 m above mean sea level. Despite its high market demand and nutritional richness in vitamins A and C and antioxidants, nectarine productivity in the mid-hills of Himachal Pradesh remains below its potential, largely due to rainfed cultivation, erratic rainfall distribution, and soil moisture stress. Under such conditions, in-situ soil moisture conservation and efficient weed management are critical for sustaining orchard productivity. Mulching, defined as the non-chemical practice of covering the soil surface with organic or synthetic materials, creates favorable soil conditions by conserving moisture, moderating soil temperature, and suppressing weed growth, thereby enhancing crop growth, yield, and quality (Kader *et al.*, 2017). Weed infestation is a major constraint in fruit orchards, as weeds compete with trees for water, nutrients, and light, and serve as hosts for pests and diseases. Both organic and inorganic mulches act as physical barriers that effectively restrict weed emergence while improving soil hydrothermal regimes (Sharma and Sharma, 2017). Although the beneficial effects of mulching have been well documented in several stone fruits, systematic studies on nectarine remain limited. Therefore, the present investigation was undertaken to evaluate the effect of mulching on weed dynamics of nectarine cv. Snow Queen under rainfed mid hills of Himachal Pradesh.

2. Material and Methods

The field experiment was conducted during a single cropping season (2021) in a 10-year-old rainfed nectarine orchard at the Model Farm, Directorate of Research, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.), located in the mid-hill sub-temperate zone of Himachal Pradesh (1155 m amsl). The experiment was laid out in a Randomized Block Design (RBD) with seven treatments and four replications, comprising unmulched control (UM), grass mulch (GM, 10 t ha⁻¹), pine needle mulch (PM, 10 t ha⁻¹), black plastic mulch (BP, 100 μ), transparent plastic mulch (TP, 100 μ), nylon mulch mat (MM, 90 GSM), and recommended practice (RP).

Organic mulches were applied uniformly (8–10 cm thick), while synthetic mulches were laid over the tree basin with provision for rainwater infiltration and maintained until fruit harvest. Weed biomass was recorded using a 0.25 m² quadrat at 60, 90, 120, 150, and 180 days after mulch application, oven-dried at 65 °C, and expressed as g m⁻². Data were subjected to one-way analysis of variance (ANOVA) under RBD to evaluate treatment effects using SPSS statistical software, and significance was tested at the 5% level.

3. Results and Conclusion

Mulching treatments significantly influenced weed biomass at all observation stages in the nectarine orchard under mid-hill Himalayan conditions. Weed biomass increased markedly in the unmulched control (UM) from 41.7 g m⁻² at 60 days to 120.8 g m⁻² at 120 days, while similar trends were observed under recommended practice (RP) (39.2–107.1 g m⁻²) and transparent polythene mulch (TP), which recorded the highest weed biomass (62.7–148.6 g m⁻²). In contrast, substantial weed suppression was achieved with mulching. Nylon mulch mat (MM) and black plastic mulch (BP) resulted in near-complete to complete weed control, with weed biomass ranging from 0.0 to 3.2 g m⁻² across all stages.

Among native organic mulches, pine needle mulch (PM) and grass mulch (GM) consistently and significantly reduced weed biomass compared to UM and RP. Pine needle mulch recorded lower weed biomass (11.3–21.2 g m⁻²) than grass mulch (13.5–25.8 g m⁻²), particularly at later stages, indicating superior and prolonged weed suppression. Overall, weed suppression followed the order MM > BP > PM > GM > RP > UM > TP. Although synthetic mulches provided maximum weed control, native organic mulches offered an effective and ecologically sustainable alternative by reducing weed pressure while improving soil cover and organic matter status, making them well-suited for rainfed nectarine orchards in the mid-hill Himalayan region.

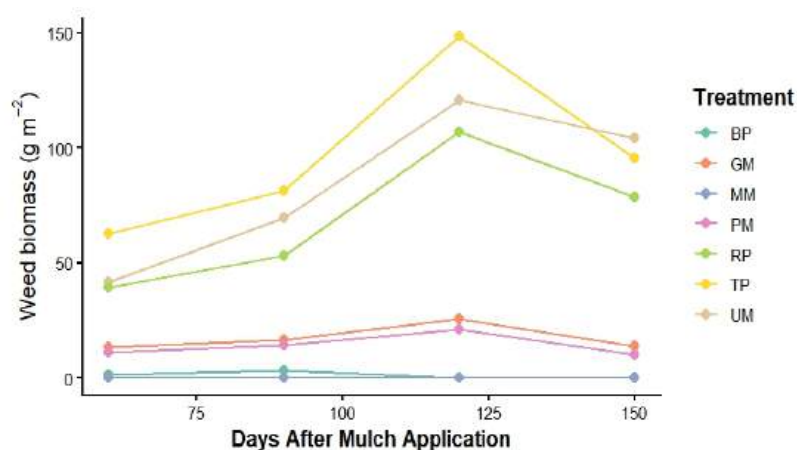


Figure 1. Effect of different mulches on weed biomass at 60, 90, 120 and 150 days after mulch application in nectarine orchard

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2.21 Spatial Variability of Soil Carbon and Nitrogen Pools across Contrasting Land-Use Systems

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Keywords: Land-use systems, Soil fertility, Soil organic carbon, Total nitrogen, Himalayan Pir Panjal region

1. Background

Soil carbon (C) and nitrogen (N) are fundamental to soil fertility, ecosystem productivity, and climate change mitigation, as they influence nutrient cycling, microbial activity, and organic matter storage in terrestrial ecosystems (Lal *et al.*, 2018). Land-use systems strongly affect these soil pools by altering the amount of organic inputs, intensity of soil disturbance, and pathways of nutrient transformation. Research has consistently shown that land-use type is a key determinant of soil organic carbon and total nitrogen stocks, with natural vegetation systems typically exhibiting higher C and N levels compared to cultivated lands due to greater biomass inputs and reduced disturbance (Paltineanu *et al.*, 2024). Recent large-scale analyses further indicate that variability in soil carbon and nitrogen stocks is influenced not only by land use but also by soil properties such as texture, pH, and topographic factors, highlighting the interconnected nature of environmental controls on soil nutrient pools. Understanding how these critical soil components respond across contrasting land-use systems is therefore essential for developing sustainable land management strategies that maintain soil fertility and enhance carbon sequestration in sensitive mountainous Himalayan Pir Panjal region landscapes.

2. Material and Methods

The study was carried out between 2022 and 2024 in the Pir Panjal Himalayan region of Jammu and Kashmir. Four representative land-use systems *viz.* rice-wheat, maize-wheat, uncultivated fallow, and forest were selected from seven locations covering diverse physiographic conditions. Soil samples were collected using a stratified random sampling technique at depths of 0-15, 15-30, and 30-60 cm. After air drying and sieving, samples were analyzed using standard analytical procedures. Soil reaction and electrical conductivity were determined to characterize chemical properties, while texture was assessed by the hydrometer method. Soil organic carbon was estimated through wet oxidation, and total nitrogen was measured using the Kjeldahl digestion method. Statistical analysis was performed using a two-way ANOVA under a randomized block design (RBD) to evaluate the effects of soil depth and land-use system, using the R statistical software. and correlation analysis was used to examine relationships between soil carbon and nitrogen pools.

3. Results and Conclusion

Across all sites, soils were slightly acidic to neutral in reaction, exhibited low electrical conductivity, and were mainly coarse loamy in texture. Significant differences in soil carbon and nitrogen contents were observed among land-use systems. Forest soils consistently exhibited the highest concentration of soil organic carbon (2.8-3.5%) and total nitrogen (0.28-0.35%), reflecting continuous organic residue inputs and minimal anthropogenic disturbance. In contrast, cultivated systems such as rice-wheat and maize-wheat showed comparatively lower carbon and nitrogen concentrations (SOC: 1.2-2.1%; TN: 0.15-0.25%), likely due to repeated tillage, crop removal, and enhanced mineralization. A significant and consistent decrease in both carbon and nitrogen

contents with increasing soil depth was evident under all land-use systems. Statistical analysis revealed a significant positive relationship ($p < 0.05$) between soil organic carbon and total nitrogen, indicating their coupled behavior and shared stabilization mechanisms in soil. The findings demonstrate that land-use management strongly governs soil carbon and nitrogen dynamics in the Pir Panjal Himalayas. Preservation of forest cover and adoption of sustainable management practices in cultivated lands are essential for improving soil fertility, enhancing carbon sequestration, and ensuring long-term sustainability of Himalayan agro-ecosystems.

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2.22 Productivity of pearl millet (*Pennisetum glaucum* L.) cultivars as influenced by zinc and iron application under rainfed agro-ecosystem

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Keywords: Pearl millet, iron, zinc productivity and rainfed agro-ecosystem

1. Back ground

Traditional pearl millet cultivars generally exhibited reduced productivity because of inherent genetic constraints, a limitation further intensified by their cultivation in nutrient-deficient soils. Advances in breeding have led to the development of both conventional and biofortified varieties with enhanced micronutrient density, thereby strengthening food and nutritional security in dryland farming systems. So balanced fertilization improves physiological performance and biomass accumulation compared to the application of single or limited nutrient combinations, particularly with respect to micronutrient supply. Among these elements, zinc and iron are especially crucial due to their involvement in key enzymatic and physiological processes. Therefore, the present study carried out to evaluate the suitable variety and optimizing zinc and iron application with respect to its affect on the growth, yield and nutrient uptake in different pearl millet cultivars while also assessing the relative economics of the various treatment combinations.

2. Material & Methods

A field experiment was conducted during the *kharif* 2024 at the Research Farm of Advanced Centre for Rainfed Agriculture (ACRA), RakhDhiansar of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu to study the influence of zinc and iron application on productivity of pearl millet (*Pennisetum glaucum* L.) cultivars under rainfed agro-ecosystem. The site lies in the subtropical Shiwalik foothills of Jammu and Kashmir at 332 m above mean sea level, positioned at 32°39' N latitude and 74°53' E longitude. The soil of experimental field was sandy loam in texture, slightly acidic in reaction, low in organic carbon, available nitrogen, potassium and zinc) while medium in available phosphorus and iron). The experiment was laid out in a Factorial Randomized Block Design and replicated thrice, comprising 14 treatment combinations having two pearl millet varieties *viz.*, HHB 299 and Pusa 1201 along with seven nutrient doses *viz.*, T₁: Control, T₂: Soil application of 25 kg ha⁻¹ ZnSO₄, T₃: Soil application of 20 kg ha⁻¹ FeSO₄, T₄: Soil application of 25 kg ha⁻¹ ZnSO₄ + Foliar application of 0.5% FeSO₄ (25 and 45 DAS), T₅: Soil application of 20 kg ha⁻¹ FeSO₄ + Foliar application of 0.5% ZnSO₄ (25 and 45 DAS), T₆: Soil application of 25 kg ha⁻¹ ZnSO₄ + Soil application of 20 kg ha⁻¹ FeSO₄ and T₇: T₆ + Foliar application of 0.5% ZnSO₄ + Foliar application of 0.5% FeSO₄ (45 DAS), all supplemented with a uniform application of recommended dose of fertilizers of 100:60:25 kg ha⁻¹ of N, P₂O₅, and K₂O, respectively.

3. Results and Conclusion

Among both the varieties of pearl millet, significantly highest plant height (198.13 cm) was recorded in Pusa 1201 as compared to HHB 299 variety of pearl millet. Plant height variations in varieties could result from variations in internodal length and genetic characteristics of Pusa 1201 for taller growth habit resulting in more vigorous shoot development. Amongst the nutrient doses,

treatment T₇ reported highest plant height (218.05 cm) where soil application of 25 kg ha⁻¹ ZnSO₄ and 20 kg ha⁻¹ FeSO₄ followed by foliar application of 0.5% ZnSO₄ and 0.5% FeSO₄ at 45 DAS was applied. However, highest no. of tillers and dry matter accumulation was observed in variety HHB 299 compared to Pusa 1201. Likewise, among the nutrient doses, highest no. of tillers and dry matter accumulation was observed in treatment T₇ where soil application of 25 kg ha⁻¹ ZnSO₄ and 20 kg ha⁻¹ FeSO₄ followed by foliar application of 0.5% ZnSO₄ and 0.5% FeSO₄ at 45 DAS was applied. Among the varieties, HHB 299 recorded significantly highest number of ear head m⁻² (21.22), girth of ear head (9.63 cm), weight of grains ear head⁻¹ (40.71 g) and 1000-grain weight (11.26 g) alongwith highest values of grain and stover yield. However, Pusa 1201 recorded significantly highest length of ear head (25.15 cm) as compared to HHB 299 variety of pearl millet. Among the different nutrient doses treatment T₇ recorded significantly highest number of ear head m⁻² (24.08), length of ear head (28.10 cm), girth of ear head (10.76 cm), weight of grains ear head⁻¹ (46.79 g) and 1000-grain weight (12.92 g) in pearl millet. With respect to nutrient uptake, HHB 299 showed highest total uptake of nitrogen, phosphorus, potassium, zinc and iron as compared to Pusa 1201. Moreover, treatment T₇ recorded significantly highest total nitrogen, phosphorus, potassium, zinc and iron uptake of pearl millet while treatment T₁ (control) recorded the lowest nutrient uptake.

Based on the observed results, it can be concluded that higher growth and yield in pearl millet can be achieved with soil application of 25 kg ha⁻¹ ZnSO₄ and 20 kg ha⁻¹ FeSO₄ followed by foliar application of 0.5% ZnSO₄ and 0.5% FeSO₄ at 45 DAS in HHB 299 variety. Besides, It also ensured better nutrient uptake through improved nutrient availability and higher absorption by the crop. Hence, this nutrient management practice proved agronomically superior by significantly enhancing crop growth, yield performance and nutrient uptake.

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2.23 Effect of organic and inorganic nutrient applications on yield and economics of maize under rainfed conditions

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Keywords: Organic, Inorganic, FYM, Maize, Yield

1. Background

Globally maize is grown on an area of about 197.19 million hectares with production of 1125.03 million tones and the average productivity is 5.71 t ha⁻¹. In India, it is cultivated on an area of 9.21 million hectare with production of 25.13 million tones and productivity of 2.63 t ha⁻¹. In J&K Union Territory, maize is grown on an area of about 262.35 thousand hectares with a production of 5744 thousand tones and productivity of 2.12 t ha⁻¹ (Anonymous, 2019). Application of organic sources of nutrients not only supply N, P and K but also make unavailable sources of elemental nitrogen, bound phosphates, micronutrients, and decomposed plant residues into an available form to facilitate to plant to absorb the nutrients. The use of inorganic fertilizer has not been helpful because it is associated with soil acidity, nutrient imbalance and reduction in crop yield (Abrol et, al. 2007 and Singh *et.al* 2023). The application of organic manure to meet the nutrient requirement of crop would be an inevitable practice since organic manures generally improve the soil physical, chemical and biological properties along with conserving capacity of the moisture holding capacity of soil and this, resulting in enhanced crop productivity along with maintain the quality of crop produce. Although organic manures contain plant nutrients in small qualities compared to inorganic fertilizers, the presence of growth promoting principle like enzymes and hormones, besides plant nutrient make them essential for improvement of soil fertility and productivity.

2. Material and methods

A field experiment was conducted under rainfed condition during *kharif* season of 2024 at Research farm of Advanced Centre for Rainfed Agriculture Rakh-Dhiansar of SKUAST-Jammu (32° 39' N 74° 53' E 332 m amsl), under rainfed condition. The soil of experimental site was sandy loam in texture, with a pH 6.5, low in organic carbon (0.18 %), and available nitrogen (178 kg/ha), and medium available phosphorus (18 kg/ha) and potassium (108 kg/ha). The experiment consisted of ten treatments of inorganic and organic combinations of nutrient sources, viz T₁: Control; T₂: 100 % recommended fertilizer dose-RFD (60:40:20 NPK kg/ha); T₃: 50 % RFD NPK; T₄: 50 % N (crop residue); T₅: 50 % N (FYM); T₆: 50 % RFD + 50 % N (crop residues); T₇: 50 % RFD + 50 % N (FYM); T₈: FYM 10 t/ha; T₉: 100 % RFD + ZnSO₄ 20 kg/ha and T₁₀: Farmers practice (FYM 4 t/ha + urea 40 kg/ha). Maize (var *Mansar*) was shown in the month of June- July and harvested in September-October during *kharif* seasons 2024, respectively. The crops were sown in lines with a spacing of 60 cm x 20 cm, respectively.

3. Result and Conclusion

The results revealed that the maximum grain yield of maize (28.17 q/ha) and stover yield 52.25q/ha was obtained with the application of 50 % recommended NPK + 50% N FYM (T₇) which was statistically at par with FYM @ 10 t/ha (T₈) and 50 % recommended NPK + 50% N Crop Residue (T₆) with grain yield of 27.83 and stover yield 54.90, grain yield 26.03 and stover yield 51.23 q/ha. over rest of the combinations of organic and inorganic. The minimum grain yield of 12.92 q/ha and stover yield 26.40 q/ha was obtained in the control (unfertilized plot). Similarly highest net returns

to the tune of Rs 51068/ ha were realized with the application of application of 50 % recommended NPK + 50% N FYM (T₇) with corresponding benefit:cost ratio of 3.01. The application of 50 % recommended NPK + 50% N FYM (T₇) also recorded maximum RWUE of 4.80 while control evinced the minimum RWUE of 2.20.

It can be safely concluded that with the application of 50 % recommended NPK through inorganic fertiliser in combination with application of 50% N through FYM was found to be best in terms yield, economics and RWUE of maize under subtropical conditions of Jammu.

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2.24 Zinc oxide-green nanoparticles: A strategy to mitigate adverse effects of moisture stress in wheat (*T. aestivum* L.)

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Keywords: Nanoparticles, wheat, root morphology, moisture stress, micronutrients.

1. Background

Wheat (*Triticum aestivum* L.) is an essential crop and source of nutrition for more than half of the global population and is cultivated primarily in Asian countries (Sharma *et al.* 2022). Moisture stress disrupts the soil plant-atmosphere continuum, adversely affecting wheat productivity and plant growth. Zinc oxide nanoparticles (ZnO-NPs) have gathered interest for their potential to alleviate the negative effects of moisture stress on wheat.

When subjected to moisture stress, plants experience growth reduction, leading to decreased yield and quality. ZnO-NPs, recognized for their unique properties, can enhance plant resilience by improving physiological and biochemical traits under moisture stress (Hassan *et al.*, 2018; Asadzade *et al.*, 2015). Previous research works have indicated that applying ZnO-NPs can enhance root development and promote soil water retention, helping wheat plants access moisture more effectively. Furthermore, these nanoparticles can stimulate the production of stress-related hormones, thereby bolstering the plant's adaptive mechanisms. Thus, the utilization of ZnO-NPs not only improves growth and yield but also enhances overall plant health in moisture stress conditions, making it a promising approach for sustainable wheat cultivation in water-scarce regions.

2. Material and Methods

In the present study, two sizes of zinc oxide-nanoparticles (ZnO-NPs) viz., 20 and 30 nm were used as foliar application on HD 3226 and HD 3298 wheat cultivars during the *rabi* season of 2023-2024. The solution of ZnO-NPs (40 mg kg⁻¹ and 60 mg kg⁻¹) and ZnSO₄ (equal amount of Zn in) foliar application was given.

The plant growth attributes such as plant height, photosynthetic rate, chlorophyll content, relative water content, relative growth rate, net assimilation rate, root morphology was determined. The biochemical parameters of leaves such as protein, proline, catalase (CAT), superoxide dismutase (SOD) were estimated. Among the yield attributes, panicle length, grain weight (panicle⁻¹), number of grains (panicle⁻¹), number of tillers and grain yield (plant⁻¹) were determined. The zinc (Zn) content in grains was also determined. The study investigated the effects of 20 and 30 nm sizes of ZnO-NPs on the physiological, biochemical, yield attributes, and quality parameters of wheat crop of varieties HD 3226 and HD 3298.

3. Results and Conclusion

High-resolution Transmission Electron Microscopy (TEM) confirmed that the green synthesized ZnO nanoparticles had average sizes of 20 and 30 nm. Application of ZnO nanoparticles significantly improved physiological, biochemical, and yield attributes of wheat under moisture stress. Growth parameters such as absolute and relative growth rate and net assimilation rate increased, along with photosynthetic rate, stomatal conductance, transpiration rate, and chlorophyll content, indicating improved photosynthetic efficiency and stress tolerance. Root traits including length, surface area, and volume also increased, suggesting enhanced water and nutrient uptake. Biochemical responses showed higher protein and proline content along with

increased antioxidant enzyme activities (SOD and CAT), indicating better metabolic activity and protection against oxidative stress. Yield attributes such as plant height, productive tillers, spikelet number, filled grains, grain weight, and biomass improved significantly. Additionally, zinc concentration in grains increased, demonstrating improved micronutrient accumulation and enhanced nutritional quality of wheat.

In conclusion, the use of zinc oxide green nanoparticles has proven to be highly beneficial in enhancing the physiological and biochemical attributes of wheat varieties HD 3226 and HD 3298 under moisture stress conditions, particularly the 20 nm size compared to the 30 nm size. The study provides strong statistical evidence of the positive effects of ZnO nanoparticles on plant growth, yield, and quality attributes, establishing them as potential tools for improving crop resilience and nutritional zinc quality in the condition of moisture stress.

Therefore, integrating ZnO nanoparticles into agricultural practices may promote improved food security and contribute to sustainable agricultural systems under moisture stress conditions. However, studies in the future ahead are encouraged to explore the mechanisms behind nanoparticle interactions in plant systems and their long-term impacts on soil health and plant performance.

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2.25 Optimizing Water and Nutrients for Late-Sown Wheat under Semi-Arid Bundelkhand

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Keywords: Late sown wheat, NUE, Semi-arid Bundelkhand, WUE.

1. Background

The Bundelkhand region of Uttar Pradesh, India covers an area of 2.94 M ha, receives an average annual rainfall of approximately 1,000 mm. But the region has suffered from over drainage and soil erosion for years because of high slopes, low vegetative cover, and less underground depth for groundwater storage (Prakash *et al.*). In such water-scarce environments, deficit irrigation strategies targeting critical stages have been shown to enhance water productivity while maintaining acceptable yields (Ali *et al.* 2007). Thus, optimization of irrigation scheduling and nutrient management becomes a critical strategy to sustain productivity in semi-arid regions. That is why, a two-year field study was conducted to evaluate the effects of five irrigation schedules and three fertilizer levels on growth, yield, and water use efficiency (WUE) of late-sown wheat.

2. Material and Methods

The two year field study on late sown wheat was conducted at Agriculture Research Farm, Banda University of Agriculture & Technology, Banda (Uttar Pradesh) during winter season of 2023-24 and 2024-25. A split-plot design was employed that replicated three times with irrigation frequency as the main-plot factor and fertility levels as the sub-plot factor. In the main plot, five irrigation schedules (No irrigation, one irrigation, two irrigations, three irrigations & four irrigations) were tested that cover a wide range of moisture ecology from severe water stress (rainfed) to well-watered conditions, ensuring that the most critical growth stages receive water as frequency increases. Alongside, three levels of fertilizers (75% recommended NPK, 100% recommended NPK & 125% recommended NPK) were also examined to optimizing nutrient doses with irrigation availability. Total 15 treatments of irrigation and fertilizer were laid out to find the interactive effect of moisture and nutrient to culminate the impact of heat stress during reproductive stages in late sown wheat. A high yielding popular wheat variety 'DBW 187 (Karan Vandana)' was chosen for late sown conditions. Notably, it exhibited lower yield reduction under late-sown conditions compared to the leading check variety. To assess the performance, observations regarding growth attributes, yield attributes and water use efficiency were taken randomly from representative plants from all 45 plots. Statistical analysis was done with the help of window-based SPSS (Statistical Product and Service Solutions) Version 10.0, SPSS, Chicago, IL.

3. Results and Conclusion

The interactive effect of irrigation scheduling and nutrient doses was evaluated in terms of growth, yield and water use efficiency of late sown wheat. The results revealed that four irrigation frequencies (I_4) and 125% recommended NPK (N_3) were outperformed regarding growth and yield of wheat whereas water use efficiency was higher in the no irrigation (I_0) treatment. Among the treatments, I_4 exhibited the highest dry matter accumulation of 825.7 gm^{-2} and 769.1 gm^{-2} during 2023-24 and 2024-25, respectively. The higher mean grain yield of 38.69 q ha^{-1} and 35.8 q ha^{-1} were also recorded under I_4 during the corresponding years. This highlights the importance of timely and extended irrigation during critical growth stages in overcoming the constraints of late sowing. Among the fertility levels, N_3 recorded significantly higher growth attributes, resulting in

greater dry matter accumulation of 758.5 g m^{-2} and 711.4 g m^{-2} during 2023–24 and 2024–25, respectively. Similarly, N_3 surpassed in yield attributing characters leading to significantly higher grain yield of 32.33 q ha^{-1} and 29.7 q ha^{-1} during the corresponding years. The interaction effects further underscore the need for harmonized water and nutrient supply to boost yield and input efficiency. In late-sown wheat, where the growing period is shortened and temperatures are higher, excessive irrigation may not proportionally enhance yield and instead result in inefficient water use. Strategic irrigation during critical growth stages, such as CRI and flowering, can help maintain higher WUE in water-prone areas like Bundelkhand.

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2.26 Energy Evaluation and Economic Analysis of Lettuce (*Lactuca sativa* L.) var. *LS-2* as Influenced by Different Organic Manures and Planting Densities under Temperate Conditions

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Keywords: Economic analysis, Energy use efficiency, Lettuce, Organic manure, Planting density

1. Background

Lettuce (*Lactuca sativa* L.) is an important leafy vegetable widely cultivated for its high nutritional value and economic importance. The demand for fresh leafy vegetables is increasing rapidly due to growing awareness regarding healthy diets and balanced nutrition. Sustainable agricultural practices are necessary to maintain soil fertility, enhance productivity and ensure economic profitability of vegetable crops. Organic manures such as farmyard manure (FYM), vermicompost, poultry manure and sheep manure play an important role in improving soil structure, microbial activity and nutrient availability. Planting density is another critical agronomic factor affecting growth, yield and efficient utilization of available resources. Optimum spacing ensures better light interception, nutrient uptake and reduces competition among plants. Yield may be increased for any crop upto 25% by using optimum spacing in leafy vegetable (Bansal *et al.*, 1995). In addition to yield, evaluation of agricultural practices based on energy use efficiency and economic returns is essential for sustainable crop production systems. Energy analysis provides a comprehensive assessment of energy inputs and outputs involved in crop cultivation and helps determine the sustainability of agricultural practices (Mohammadi and Omid, 2010). Therefore, the present investigation was conducted to evaluate the effect of different organic manures and planting densities on energy use efficiency and economic profitability of lettuce production under temperate conditions of Kashmir.

2. Materials and Methods

The experiment was conducted during *Rabi* 2023 at the Vegetable Experimental Farm of Krishi Vigyan Kendra (KVK), Budgam, Kashmir under temperate climatic conditions. The soil of the experimental site was clay loam in texture with slightly alkaline pH, high organic carbon and medium levels of available nitrogen, phosphorus and potassium. The experiment was laid out in a factorial Randomized Complete Block Design (RCBD) with two factors: organic manures and planting densities. Manures were applied at five levels: M₀ (no manure), M₁ (FYM @ 20t/ha), M₂ (Vermicompost @ 5t/ha), M₃ (Poultry manure @ 5t/a) and M₄ (Sheep manure @ 3.25t/ha) while planting densities was studied at three levels: S₁ (25×35cm) S₂ (35×35cm) and S₃ (45×35cm). This resulted in a total of 15 treatment combinations, which were replicated three times, making total 45 plots of 2×2.4 m² plot size. After harvesting, yield from each plot was recorded and converted to kg/ ha. Energy input and output were calculated using standard energy equivalents. Energy parameters such as energy ratio, energy productivity, specific energy and net energy were computed using standard formulas. Economic analysis included cost of cultivation, gross returns, net returns and benefit-cost ratio.

3. Results and Conclusion

The results revealed significant variation in both energy parameters and economic returns

among different treatment combinations. Among all treatments, T₁₀ (poultry manure @ 5 t/ ha with 25 × 35 cm spacing) recorded the highest net returns (Rs. 738,400 per hectare) with a benefit-cost ratio of 3.98, indicating the highest economic profitability. In contrast, the lowest net returns (Rs. 163,120 per hectare) and benefit-cost ratio (1.09) were observed in T₃ (control with 45 × 35 cm spacing). Energy analysis showed that the maximum energy input (34,244 MJ) was recorded in T₁₃ (sheep manure @ 3.25 t/ ha with 25 × 35 cm spacing), while the minimum energy input (1,594 MJ) was observed in T₃ (control with 45 × 35 cm spacing). The highest energy output (18,455.2 MJ) was obtained in T₁₀ (poultry manure @ 5 t/ ha with 25 × 35 cm spacing), which may be attributed to higher yield under this treatment combination. The maximum energy ratio (3.91) and energy productivity (4.89) were recorded in T₃ (control with 45 × 35 cm spacing), whereas the minimum energy ratio (0.30) and energy productivity (0.38) were observed in T₁₅ (sheep manure @ 3.25 t/ha 45×35cm spacing). The highest net energy (11,757.2 MJ) was recorded in T₇ (vermicompost @ 5 t ha⁻¹ with 25 × 35 cm spacing). Based on the results, it can be concluded that application of poultry manure @ 5 t/ ha combined with 25 × 35 cm planting density is the most economically viable and productive practice for lettuce cultivation under temperate conditions. This combination produced the highest yield, energy output and economic returns, making it a suitable recommendation for commercial lettuce production

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2.27 Bioefficacy of Different Herbicides Against *Cyperus* spp. in Direct-Seeded Rice and Their Effect on Rice Growth Parameters

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Keywords: Direct-seeded rice, *Cyperus* spp., crop growth, herbicide efficacy, sedge control

1. Background

Direct-seeded rice (DSR) is increasingly adopted as an alternative to transplanted rice because it reduces labour requirement, water consumption, and production costs. However, severe weed infestation remains one of the major constraints in DSR, particularly during early crop establishment when weeds compete aggressively for nutrients, moisture, light, and space. Among weed flora, sedges such as *Cyperus* spp. are especially problematic because of their rapid growth, high reproductive capacity, and adaptability under moist soil conditions, often resulting in significant yield losses. Effective herbicidal management is therefore essential to suppress *Cyperus* weeds and maintain crop vigour. Recent findings showed that sequential herbicide application involving pre-emergence and post-emergence treatments significantly reduced *Cyperus iria* population and improved rice growth parameters such as plant height, leaf area, and grain yield in direct-seeded rice systems (Verma *et al.*, 2025). Similarly, post-emergence application of bentazone at suitable doses effectively controlled sedges and enhanced tiller production, dry matter accumulation, and overall crop performance in DSR (Tirkey *et al.*, 2024). Therefore, evaluation of different herbicides against *Cyperus* spp. is important for identifying efficient weed control strategies that improve rice growth and productivity under direct-seeded conditions. The present study carried out to study the Bioefficacy of Different Herbicides Against *Cyperus* spp. in Direct-Seeded Rice and Their Effect on Rice Growth Parameters.

2. Material and Methods

A field experiment was conducted at Faculty of Agriculture, SKUAST Kashmir, Wadura during Kharif 2019. The soil of the experimental field was slightly acidic in reaction pH (5.9), medium in available Nitrogen (327 kg ha⁻¹), Phosphorus (17.3 kg ha⁻¹) and Potassium (248 kg ha⁻¹) with high organic carbon content (0.98%). The experiment was laid out in Randomized block design (RBD) comprised of nine treatments including seven herbicidal treatments viz, Halosulfuron (75 WG) @ 35 g ha⁻¹, Bensulfuronmethyl (60 DF), @ 60 g ha⁻¹, Cyhalofopbutyl (10 EC) @ 100 g ha⁻¹, Bispyribacsodium (10 SC) @ 30 g ha⁻¹, Ethoxysulfuron (15 WDG) @ 45 g ha⁻¹, Pretilachlor @ 700 g ha⁻¹ Pendimethalin (30 EC) fb 2,4-D (58 SL) (0.75 kg ha⁻¹ + 1.0 kg ha⁻¹), along with Weedy check and Weed free within three replications. Weed control in the experimental field was done as per the treatments including weedy check and weed free. The herbicide pendimethalin fb 2,4-D (0.75 kg ha⁻¹ + 1.0 kg ha⁻¹) were applied as pre-emergent at 3 DAS, while as cyhalofopbutyl (100 g a.i ha⁻¹) bispyribacsodium (30 g a.i ha⁻¹) ethoxysulfuron (45 g a.i ha⁻¹) and halosulfuron (35 g a.i ha⁻¹) as post emergent were applied at 25 DAS. The herbicides were sprayed on moist soil on the plots with a knapsack sprayer equipped with a flat fan nozzle using 500 liters of water per hectare. The observation were recorded at 20 days intervals. The data obtained in respect of various observations were statistically analyzed by method described by Cochran and Cox (1963). The significance of 'F' and 't' was tested at 5 percent level of significance. The critical difference value was determined when 'F' test was significant. Analysis of the data was done by using OP Stat software programme.

3. Results and Conclusion

The data pertaining to plant height, Leaf area index and dry matter accumulation under different treatments recorded at different growth intervals. The results indicated that different weed control treatments had significant effect on the plant height, leaf area index and dry matter accumulations at different growth intervals of the crop. Among the herbicides used, application of Bispyribacsodium @ 30 g a.i. ha⁻¹ recorded significantly height plant height (118.66cm) at maturity, leaf area index (5.22) at 80 DAS and dry matter accumulation (147.03 q ha⁻¹) at maturity as compared to rest of the weed control treatments and control (weedy check). The highest benefit: cost ratio of 1.49 was recorded with the application of bispyribacsodium @ 30 g ha⁻¹. Therefore, from the present study it can be concluded that application of bispyribacsodium @ 30 g ha⁻¹ is promising for improving rice growth parameters by controlling weeds especially cyperus weed spp. in direct seeded rice.

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2.28 A Novel Colony for Wild Ground Nesting bees of family Halictidae genus Lasioglossum

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Keywords: Nesting bees, colony, soil

1. Background

The rearing and habituation of genus *Lasioglossum* is a challenge for ecologists (Richards, 2020). Unlike managed honey bees, the majorities of *Lasioglossum* bee species are solitary and do not form large colonies. A significant proportion of these wild bees are ground-nesting species that construct tunnels and brood chambers in soil. These nests require specific environmental conditions, including suitable soil texture, proper drainage, adequate moisture, and access to nearby floral resources (Nelson *et al.* 2022). Therefore, present invention relates to the development of an artificial colony design intended for habituation and rearing of *Lasioglossum* bees, which are an ecologically significant group of pollinators responsible for the fertilization of a wide range of agricultural crops and wild plant species.

2. Material and Methods

Multiple sites were selected for colony installation aimed for restoration of bees under natural conditions. A novel colony design for genus *Lasioglossum* bees in the form of a rectangular wooden box partially filled with selected well drained loose clay to loam soil type. The wooden box is constructed with specific dimensions to provide stability, portability, and sufficient nesting space. A defined depth of soil is filled inside the box and maintained at a gentle slope (5-7), which plays a critical role in facilitating drainage and preventing water accumulation. The colony is placed in open environments near flowering plants to ensure easy access to floral resources, and mustard plants are grown in the surrounding area to provide a continuous and abundant supply of nectar and pollen. This integrated design creates a favorable microhabitat that encourages wild bees to establish nests, thereby enhancing bee restoration, recovery, pollination efficiency and ecological resilience.

3. Results and Conclusion

The colony design proposed consists of a wooden box made from durable and environmentally friendly wood, selected as the primary construction material due to its natural insulating properties, which help maintain stable internal temperatures and protect developing bee larvae from extreme environmental fluctuations. The dimensions of the box are carefully chosen, with a length ranging from 60 to 65 centimeters, a width of 30 to 32 centimeters, and a depth of 15 to 17 centimeters. These dimensions ensure that the colony provides adequate surface area for multiple nesting sites while remaining manageable and easy to install in different field conditions. The wooden structure allowed for easy fabrication using locally available materials, making the design accessible to farmers, researchers, and conservation practitioners.

The soil is filled up to a depth of approximately 11.5 to 12 cm, sufficient enough to allow bees to excavate tunnels and brood chambers while also maintaining structural integrity. The soil is lightly compacted to resemble natural ground conditions, ensuring that it is neither too loose, which could lead to tunnel collapse, nor too compact, which would hinder excavation. This balance is essential for successful nest establishment and brood development. A distinguishing feature of the

invention is the maintenance of a gentle soil slope ranging between 5 and 7 degrees. This sloping design is inspired by natural nesting preferences of many *Lasioglossum* bees, which often select slightly inclined surfaces such as embankments or raised ground. The slope facilitates effective drainage of excess water during rainfall or irrigation, thereby preventing water stagnation and nest flooding. By reducing moisture accumulation, the slope significantly lowers the risk of fungal growth, larval mortality, and nest abandonment, which are common challenges in artificial nesting environments.

The soil used in the colony is selected from loam to clay types, as these soils provide the ideal combination of particle sizes required for stable tunnel construction. Loamy soils offer good aeration and drainage, while clay components contribute to tunnel strength and durability. The soil must be free from excessive organic debris, stones, or contaminants that could obstruct tunnel excavation. Importantly, soils prone to waterlogging or extreme dryness are avoided, as they negatively affect bee nesting success. The careful selection and preparation of soil are critical components of the invention, as they directly influence nest stability and brood survival.

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2.29 Management of various diseases in groundnut (*Arachis hypogaea* L.) varieties under rainfed conditions.

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Keywords: *Arachis hypogaea*, *Cercospora leaf spot* *Cercospora arachidicola*

1. Background

Groundnut (*Arachis hypogaea* L.) also known as peanut, is an important oilseed leguminous under rainfed conditions. Now a day the groundnut crop is totally being extinct in the rainfed as well as in the irrigated areas of Jammu region. The current investigation will reframe the possibilities of groundnut cultivation in rainfed areas of Jammu region along with the study of most prevalent diseases. Rainfed groundnut cultivation coupled with attack by a variety of diseases which lower the production of groundnut. These diseases causes about 32 to 68% yield losses and the damages include defoliation, reduction in number of pods, and low seed quality. Considering harmful impact of fungicides on environment and human health, uses of alternative methods are necessary. Now a day, control of plant disease by biological means has attained special attention all over the world. Keeping in view the significance of these diseases the groundnut material will be screened under

2. Material and Methods

The study was carried out thrice in research field at ACRA-Dhiansar SKUAST-Jammu during 2022, 2023 and 2024 to observe the incidence of different diseases in groundnut varieties under rainfed conditions and management of observed diseases through seed treatment and soil application with biocontrol agents and spray with botanicals. Biocontrol agents and botanicals were evaluated through spray, seed treatment and soil application under open field condition at research field of ACRA-Dhiansar. During the first year the ground varieties: RG559-3, RG578, RG 510 and three local varieties from Samba district (total six varieties) were evaluated in the research trial during the year Kharif 2022. Six varieties: three varieties from Rajasthan Agricultural Research Institute, Durgapur (Jaipur) and three local varieties was taken to observe the disease incidence. Among all the six varieties three local varieties of groundnut was affected with 40 percent *Cercospora* leaf spot fungal disease caused by *Cercospora arachidicola* early leaf spot disease. During the second and third year the experiment was laid out in the research field. Only one one local variety was taken for further work with following treatments: Seed treatment with *Trichoderma viride* @10g/kg of seed followed by soil application of *Trichoderma viride* @10kg/ha multiplied in 250kg FYM applied at the time of sowing, Seed treatment with *Trichoderma harzianum* @10g/kg seed followed by soil application of *Trichoderma viride* @10kg/ha multiplied in 250kg FYM applied at the time of sowing, Spray of neem based formulation @ 2% T4: Spray with leaf extract of *Calotropis procera* @5% as compared with Control

3. Results and Conclusion

The experimental trial on local varieties was laid out at ACRA Dhiansar, during the year. Seed treatment with *Trichoderma viride* @10g/kg of seed followed by soil application of *T viride* @10kg/ha multiplied in 250kg FYM applied at the time of sowing showed minimum disease incidence as compared with control. Result showed promising increasing plant height, branching and pod yield significantly. The research work showed to identify the strategies of managing

diseases in groundnut. The present study confirmed the effectiveness of the bioagents and plant extracts against diseases of groundnut, which can be used as an alternative of fungicide and reduced the probability of pathogen resistance.

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2.30 Biological control of Guava cottony cushion scale, *Icerya purchasi* using entomopathogens

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Keywords: Guava cottony cushion scale, *Icerya purchasi*, *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium lecanii*

1. Background

Icerya purchasi, commonly known as cottony cushion scale is an economically important pest of Guava, especially in India and other tropical region of the world. Both nymphs and adults of the pest suck plant sap, causing yellowing of leaves, premature defoliation, dieback of twigs and thus causing economic loss as well. Most of the orchardists resort to chemical management of the pest. Experiments were therefore conducted to assess the efficacy of botanical; Azadirachtin and entomopathogens against this pest.

2. Material and Methods

Experiments were conducted for three consecutive years (2019 – 2020, 2020 – 2021 and 2021 -2022) at the Research Farm of Advanced Centre for Rainfed Agriculture (ACRA), Dhiansar, SKUAST-Jammu, to assess the efficacy of various entomopathogens against Guava cottony cushion scale, *Icerya purchasi*. Entomopathogenic fungi *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium lecanii* talc formulations @ 5g /L of water, along with Azadirachtin 10000 ppm @ 1 ml/L of water were sprayed. Pre Spray Count and Post Spray Count (Number per leaf) were recorded. Per cent reduction in mealy bug nymphs and adults population was then calculated. Data was analyzed using Statistical Software OPSTAT.

3. Results and Conclusion

Significantly highest percent reduction in mealy bug population was recorded in Azadirachtin spray (50.77% reduction) followed by *B. bassiana* spray (49.68% reduction) at 7 DAS. Fruit yield was however significantly highest in Azadirachtin and *L. lecanii*. Application of Azadirachtin 10000 ppm @ 1 ml/L or entomopathogen *Beauveria bassiana* or *Metarhizium anisopliae* or *Lecanicillium lecanii*, @ 5g/L can also provide 45 – 50% reduction in the mealy bugs population, hence may be combined with other management techniques.

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2.31 Optimizing Fertility Levels and Varietal Selection for Enhanced Productivity, Oil Yield, and Profitability of Summer Sesame (*Sesamum indicum* L.)

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Keywords: Antioxidant, Top dressed, Pronounced, Nutrient management

1. Background

Sesame (*Sesamum indicum* L.) is one of the most ancient and nutritionally important oilseed crops, valued for its high-quality edible oil, rich antioxidant content, and adaptability to diverse agro-climatic conditions. Despite its significance, sesame productivity in India remains relatively low, particularly during the summer season, due to imbalanced nutrient management and poor varietal selection (FAO, 2022). In semi-arid regions, these constraints become more pronounced due to limited soil fertility and environmental stress. Therefore, optimizing fertilizer levels along with the identification of suitable high-yielding varieties is essential for enhancing productivity, oil yield, and economic returns (Meena *et al.*, 2017). The present study was undertaken to evaluate the combined effect of fertility levels and varietal performance on summer sesame.

2. Materials and Methods

The experiment was conducted during the summer season of 2023–24 at the Research Farm, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh). The soil of the experimental field was sandy loam in texture, low in available nitrogen and medium in phosphorus and potassium, with nearly neutral pH. The study was laid out in a split-plot design with three replications. The main plot treatments consisted of three fertility levels: F1 (75% RDF), F2 (100% RDF), and F3 (125% RDF: 60:40:20 kg N:P₂O₅: K₂O ha⁻¹). The subplot treatments included five sesame varieties: TKG-308, JTS-8, TKG-22, GT-10, and GT-11.

The crop was sown at recommended spacing (30 cm × 10 cm). Fertilizers were applied as per treatment, with full phosphorus and potassium and half nitrogen applied as basal, and the remaining nitrogen top-dressed later. Standard agronomic practices were followed uniformly. Observations on growth parameters, yield attributes, seed yield, oil content, and oil yield were recorded. Data were analyzed using ANOVA, and significance was tested at 5% level ($p \leq 0.05$) as described by Gomez and Gomez (1984).

3. Results and Conclusion

The results revealed that fertility levels significantly influenced growth and yield of sesame. Application of 125% RDF (F3) recorded the highest seed yield (5.20 q ha⁻¹), oil content (36.65%), and oil yield (1.91 q ha⁻¹), compared to 75% RDF (4.59 q ha⁻¹). Yield attributes such as capsules per plant (75.00), seeds per capsule (42.66), and test weight (3.38 g) were also maximized under higher fertility levels, indicating improved nutrient availability and better source–sink relationship. Among the varieties, TKG-308 produced the highest seed yield (5.41 q ha⁻¹), followed by GT-10 (5.24 q ha⁻¹) and JTS-8 (5.21 q ha⁻¹), while GT-11 recorded the lowest yield (3.83 q ha⁻¹). The interaction effect indicated that TKG-308 under 125% RDF was the most productive combination. Economic returns were also higher under increased fertility levels, highlighting the importance of balanced nutrient management and varietal selection. The study demonstrates that application of 125% RDF significantly enhances growth, yield attributes, seed yield, and oil yield of summer sesame. Among the tested varieties, TKG-308 proved to be the most productive and economically

viable. Therefore, the combination of 125% RDF and TKG-308 is recommended for maximizing productivity and profitability under semi-arid conditions.

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2.32 Effect establishment and crop intensified practices on productivity and profitability of mustard

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Keywords: Mustard, tillage, intercropping, Planting densities

1. Background

Mustard, an important oilseed crop across the globe, provides nutritional security and livelihood support to millions. In India, it occupies about 6.18 million hectares, with production and productivity reaching 10.99 million tonnes and 1.78 t ha⁻¹, respectively (MoA, GoI, 2024). Tillage, a fundamental agro-technical operation, manipulates soil to enhance crop yields and plant growth by improving soil properties while minimizing degradation, erosion and greenhouse gas emissions through conservation tillage practices. Mid-hill agroecosystems in Jammu & Kashmir face constraints like rainfed conditions, soil erosion, nutrient depletion, and low yields. This research evaluates precision establishment techniques (raised beds, conservation tillage, optimal planting densities) and intensified sequences (mustard + field pea, mustard + wheat or mustard + garlic intercropping) to achieve 25–30% yield gains, improve resource use efficiency (N, water, land), and boost economic returns (Faroda *et al.* 2007).

2. Materials and Methods

The experiment was carried during winter (*rabi*) season of 2024-25 at the Research Farm of RARS, Rajouri, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. It consisted of twelve treatment combination with three tillage practices (T₁: conventional tillage, T₂: minimum tillage, T₃: raised bed) as main plot and maize based intercropping (C₁: Mustard, C₂: Mustard + Field Pea, C₃: Mustard + Wheat, C₄: Mustard + Garlic) as sub plot, arranged in split plot design replicated thrice. The soil of experimental field was silty clay in texture, pH (6.8) in reaction, organic carbon (6.30) available nitrogen (247.6), but medium in available phosphorous (14.6) and potassium (163.9).

3. Results and Conclusion

Results revealed that significantly higher growth parameters, yield attributes, grain & stover yield, NPK uptake, and B: C ratio were noticed under raised bed method which was comparable with conventional method. Among mustard based intercropping, significantly higher growth parameters, yield attributes, yield, and NPK uptake were observed in C₁: Mustard which was at par with C₂: Mustard + Field Pea, and C₄: Mustard + Garlic. However, highest B: C ration was found under C₄: Mustard + Garlic intercropping system.

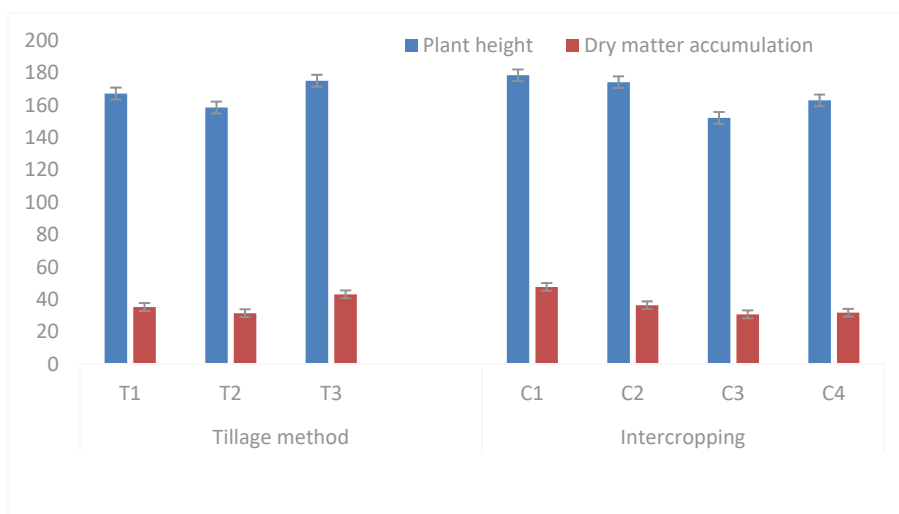


Fig 1 Effect of tillage methods and intercropping on Plant height and dry matter accumulation of mustard.

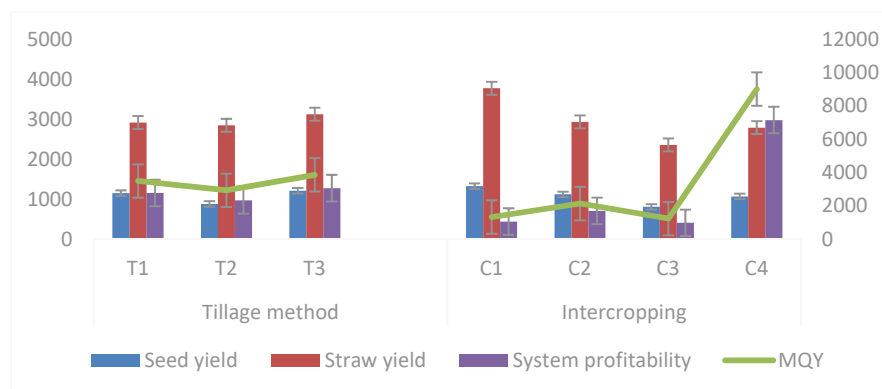


Fig 2 Effect of tillage methods and intercropping on yield and system study of mustard

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2.33 Improvement in Salt Leaching in Simulated Sodic Soil Columns using consortia of Halophilic and halotolerant bacteria

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Keywords: Sodic soil, chemical amendment, Halophilic & Halotolerant bacteria, Microbial consortium, Soil reclamation, Column study

1. Background

Salt-affected soils are a major constraint for the sustainable agriculture due to excessive accumulation of soluble salts and exchangeable sodium, which deteriorate soil structure, reduce permeability, and limits crop productivity. While traditional reclamation methods like chemical amendments (e.g., gypsum or sulphur) and leaching are widely used, they often demand large amounts of water and extended treatment times. Recently, biological methods employing salt-tolerant microorganisms have emerged as eco-friendly alternatives for soil remediation. Halophilic and halotolerant bacteria can thrive in high-salinity environments and improve soil physicochemical properties through processes such as ion exchange, organic acid production, and enhanced soil aggregation. These microbial activities may facilitate salt removal via leaching, offering a promising approach to reclaim salt-affected soils. Therefore, the present study aimed to evaluate the effects of a consortium of halophilic and halotolerant bacteria, in conjunction with chemical amendments, on salt removal from sodic soils.

2. Materials and Methods

Sodic soil samples were collected from the Vasantdada R&D Farm, Vasantdada Sugar Institute, Manjari, Pune. A soil column experiment was conducted using soil, collected from 0–3 ft depth from sugarcane field, to which a halophilic and halotolerant bacterial consortium (20 L ha⁻¹), gypsum (12 t ha⁻¹), and sulphur (3 t ha⁻¹) were applied. Following treatment, the columns were leached with deionized water, and the effluent was collected periodically for analysis of pH, electrical conductivity (EC), and cations (Na⁺, Mg²⁺, and K⁺). After incubation, from 6th day leachate started to leaching which was analyzed for major ionic composition.

3. Results and Conclusion

The results indicated that columns treated with the bacterial consortium in combination with gypsum and sulphur initiated effluent discharge 15 days earlier than the untreated control. Application of the bacterial consortium significantly accelerated salt leaching, reducing the time required for effluent EC to reach 8.95–11.73 μS by approximately 25–28 days compared to the control. Among the chemical amendments, gypsum application resulted in the highest leaching of cations, with Na⁺ (196.75 meq L⁻¹), K⁺ (0.625 meq L⁻¹), and Ca²⁺ + Mg²⁺ (84.2 meq L⁻¹), followed by the bacterial consortium treatment, which recorded Na⁺ (178.92 meq L⁻¹), K⁺ (0.491 meq L⁻¹), and Ca²⁺ + Mg²⁺ (82.8 meq L⁻¹) in the leachate. These findings suggest that the bacterial consortium alone has considerable potential as an amendment for the reclamation of sodic soils in the sodic soil regions of Maharashtra, India. This may be alternative to chemical amendments which are often constrained by high dose, limited availability, and potential secondary environmental impacts, including nutrient imbalance and soil degradation with prolonged use. In addition, chemical amendments do not actively contribute to long-term soil biological health. Further investigations are required to validate these findings across diverse saline and sodic soils varying in salinity, and alkalinity under both controlled laboratory and field conditions. Moreover, comprehensive studies incorporating local irrigation water quality, along with assessments of

water-use efficiency and crop productivity, are necessary to establish the practical feasibility and agronomic effectiveness of these amendments in agricultural systems.

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2.34 Managing Healthy Soils for Enhanced Pulse Productivity and Sustainability

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Keywords: Pulses, Soil health, Nutrient management, Tillage

1. Background

Soil health is the cornerstone of sustainable agriculture, particularly for pulse crops, which are inherently sensitive to physical, chemical, and biological soil properties. Pulses, including beans, chickpeas, lentils, and peas, are crucial components of global food systems, valued for their high protein content and their unique ability to fix atmospheric nitrogen through symbiotic relationships with rhizobia bacteria. This biological nitrogen fixation not only reduces the need for synthetic nitrogen fertilizers but also enriches soil fertility for subsequent crops. However, despite their agronomic significance, pulse productivity often remains suboptimal, particularly in resource-limited agro-ecological regions. The primary constraints to pulse production are multifaceted and deeply rooted in soil health degradation. These include declining soil organic matter, which impairs water retention and nutrient availability; widespread deficiencies in key micronutrients such as zinc and boron; the prevalence of soil-borne diseases that affect root health and nodulation; and poor soil physical conditions like compaction and structural decline (Kumar *et al.*, 2019; Meena *et al.*, 2020). Conventional agricultural practices, often focused on high-input, monoculture systems, have exacerbated these issues. The central premise is that an ecologically grounded, integrated approach to soil management is essential to unlock the full productive potential of pulses and build resilient farming systems (Lal, 2015). This study evaluates critical soil-health factors and management techniques that impact pulse production in various agro-ecological regions. As leguminous crops, pulses enhance soil fertility through biological nitrogen fixation, but their yield is frequently restricted by inadequate soil organic matter, deficiencies in micronutrients, the presence of soil-borne diseases, and less than optimal physical conditions. We examined integrated soil management practices-including appropriate nutrient application, utilization of biofertilizers (such as *Rhizobium* and PSB), addition of organic matter, retention of crop residues, and implementation of conservation tillage-for their effectiveness in enhancing soil structure, microbial biomass, and nutrient cycling. The role of cover cropping, crop rotations, and liming in correcting soil acidity and enhancing nutrient availability was also evaluated. Evidence indicates that combining organic and inorganic nutrient sources significantly boosts nodulation, nitrogen fixation, and grain yield. Furthermore, site-specific soil testing and micronutrient supplementation (Zinc, Boron, etc) emerged as critical interventions for bridging yield gaps. Overall, the findings emphasize that managing soil health through integrated, ecologically grounded approaches enhances pulse productivity while improving long-term soil resilience, carbon sequestration, and sustainability. Strengthening farmer capacity in soil testing, precision nutrient management, and conservation practices is essential for optimizing pulse-based production systems.

2. Materials and Methods

This study is a comprehensive review and synthesis of existing research on soil health management in pulse-based cropping systems. The methodology involved evaluating a wide array of peer-reviewed studies, field experiments, and on-farm trials conducted across diverse agro-ecological zones. The authors systematically examined integrated soil management practices,

focusing on their effects on key soil health indicators and pulse crop performance.

The evaluated interventions were categorized into several core areas. First, **nutrient management strategies** were assessed, including the application of synthetic fertilizers, the use of organic amendments (such as farmyard manure and compost), and the combined or integrated use of both. Second, the review analyzed **conservation agriculture practices**, such as minimal tillage and crop residue retention, for their impact on soil structure, moisture conservation, and organic matter buildup (Jat *et al.*, 2014). The effectiveness of these interventions was measured against parameters such as soil organic matter content, soil microbial biomass, nutrient cycling efficiency, nodulation success rates, nitrogen fixation levels, and ultimately, pulse grain yield.

Results and Conclusions

The synthesis of evidence from multiple studies yielded several key findings with significant implications for pulse production. A primary result was the consistent superiority of **integrated nutrient management** over either sole organic or sole inorganic applications. Combining organic sources (like crop residues or farmyard manure) with inorganic fertilizers and biofertilizers led to a synergistic effect. This integrated approach not only supplied balanced nutrition but also significantly improved soil physical properties (structure and water-holding capacity) and biological activity (microbial biomass and earthworm populations). The result was a marked increase in root nodulation and the efficiency of biological nitrogen fixation, directly translating to higher grain yields (Sharma *et al.*, 2016; Ganeshamurthy *et al.*, 2019).

Biofertilizers, particularly *Rhizobium* and PSB, emerged as a cost-effective and environmentally sound intervention. Their application consistently enhanced nutrient availability, especially nitrogen and phosphorus, which are critical for pulse growth. The use of these bio-inoculants was shown to reduce dependence on chemical fertilizers, thereby lowering production costs and mitigating the environmental pollution associated with fertilizer runoff and greenhouse gas emissions (Yadav *et al.*, 2017; Thilagarathna *et al.*, 2020).

In conclusion, the evidence overwhelmingly supports a paradigm shift from managing soils for pulses through a narrow, input-centric lens to a holistic, integrated approach. Managing soil health through ecologically grounded practices—including integrated nutrient management, biofertilizer use, conservation tillage, residue retention, and strategic liming with micronutrient supplementation - can simultaneously enhance pulse productivity and improve long-term soil resilience. This integrated strategy not only addresses immediate yield constraints but also builds soil carbon, reduces the carbon footprint of agriculture, and ensures the sustainability of pulse-based production systems (Kopittke *et al.*, 2019; FAO, 2021).

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2.35 Response of Nano Formulation of Nitrogen and Phosphorus in Finger Millet Production under Rainfed Temperate Condition

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Keywords: Finger Millets, Foliar Spray, Nano urea, Nano DAP, Temperate Condition

1. Background

A field investigation was carried out during *Kharif* season of 2023 and 2024 at Agronomy Research Farm, Division of Agronomy, Faculty of Agriculture SKUAST-K to find out the response of Nano formulations of nitrogen and phosphorus in Finger Millet (*Eleusine coracana* L.) under temperate condition. The soil of experimental field was silty clay loam with neutral pH and high organic carbon. The study comprised ten treatments, out of which application of two sprays of Nano Urea and Nano DAP with basal dose of NPK @ (40:20:20 kg ha⁻¹) (T₉) increased grain yield by 47.15% in 2023 and 51.04% in 2024 compared to the absolute control (T₁₀), highlighting the superior efficiency of nano-formulated fertilizer in improving finger millet productivity under temperate conditions.

Finger millet (*Eleusine coracana* L.) a climate resilient, nutrient rich and drought tolerant crops, plays a vital role in food security across rainfed regions. In addition to its adaptability, finger millet is valued for its high calcium and dietary fiber content, making it a key component in food and nutritional security. However, its productivity in temperate regions remains sub-optimal due to nutrient deficiencies and poor fertilizer use efficiency. Conventional fertilizers often face challenges like leaching, volatilization, and low nutrient recovery, especially under rainfed and resource-constrained conditions. Efficient nutrient management, especially through innovative approaches like nano fertilizers, is essential to enhance its productivity, which boosts efficient nutrient uptake by efficient absorption and utilization. Recent advancements in nanotechnology offer promising alternatives to conventional fertilizers, with nano-formulations like Nano Urea and Nano DAP providing targeted and efficient nutrient delivery.

2. Materials and Methods

The field experiment was conducted in two consecutive *Kharif* seasons of 2023 and 2024 at the Agronomy Research Farm, Faculty of Agriculture, SKUAST-K, Wadura. The experiment was laid out in Randomized Complete Block Design (RCBD) with ten treatments and three replications. The variety used was VL-Mandua 352, released by ICAR-VPKAS, suitable for temperate climates, with a crop duration of 100-120 days. The sowing was done on 20th May in *Kharif* 2023 and 18th May in *Kharif* 2024. The treatments included different combinations of conventional NPK (40:20:10, 60:30:15, 80:40:20 kg/ha) and reduced NPK doses (20:10:10, 30:15:15, 40:20:20 kg/ha as basal) supplemented with 1 or 2 foliar sprays of Nano Urea and Nano DAP @ 4 ml litre⁻¹. An absolute control (no fertilizer application) was also maintained. Standard agronomic practices were followed throughout the crop period.

3. Results and Conclusion

Treatment T₉: NPK @ 40:20:20 kg ha⁻¹ as basal + 2 spray of Nano Urea and Nano DAP each @ 4 ml/litre water was recorded maximum length of fingers, Number of effective shoots, average weight of fingers, Number of fingers per earhead, Number of grains per earhead and test weight than-T₃: NPK @ 80:40:20 kg ha⁻¹ (50% N as basal and 50% as top dressing), T₂: NPK @ 60:30:15

kg ha⁻¹ (50% N as basal and 50% as top dressing), T₁: NPK @ 40:20:10 kg ha⁻¹ (50% N as basal and 50% as top dressing) and T₁₀: Absolute Control during both the years, whereas T₁₀: Absolute Control was recorded significantly lower length of fingers, Number of effective shoots, average weight of fingers, Number of fingers per earhead, Number of grains per earhead and test weight than all other treatments except T₁: NPK @ 40:20:10 kg ha⁻¹ (50% N as basal and 50% as top dressing), T₂: NPK @ 60:30:15 kg ha⁻¹ (50% N as basal and 50% as top dressing) and T₃: NPK @ 80:40:20 kg ha⁻¹ (50% N as basal and 50% as top dressing) during both the years.

Grain yield was found significantly higher in T₉: NPK @ 40:20:20 kg ha⁻¹ as basal + 2 spray of Nano Urea and Nano DAP each @ 4 ml/litre water than rest of the treatments except T₈: NPK @ 40:20:20 kg ha⁻¹ as basal + 1 spray of Nano Urea and Nano DAP each @ 4 ml/litre water and T₇: NPK @ 30:15:15 kg ha⁻¹ as basal + 2 spray of Nano Urea and Nano DAP each @ 4 ml/litre water and T₆: NPK @ 30:15:15 kg ha⁻¹ as basal + 1 spray of Nano Urea and Nano DAP each @ 4 ml/litre water during both the years, while T₁₀: Absolute control was produced significantly lower grain yield than all other treatment during both the years. All the treatments where nutrients was applied were recorded statistically similar straw yield and biological yield but they were significantly higher than T₁₀: Absolute Control which was produced significantly lower straw yield and biological yield than all other treatments during both the years. All the parameters of yield attributes and yield was recorded higher with the application of fertilizer doses accompanied with nano urea and nano DAP foliar application might be due to nano scale particles having high mobility and surface area responsible for enhancing the efficient absorption and utilization of nutrients by the crop lead to increasing the productivity of finger millet. In other hand application of fertilizer in soil alone under rainfed condition due to moisture scarcity crop unable to absorb efficiently than foliar application of nano particles. The results were also confirmed by (Chandan 2023) and Khati (2023).

On the basis of above findings application of nano urea with nano DAP either 1 or 2 spray with reduced dose of fertilizer applied as basal either 40:20:20 or 30:15:15 kg ha⁻¹ NPK as basal dose can be recommended for efficient nutrient management and higher finger millet production.

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2.36 Integrated Biochar and Organic Amendments for Sustainable Vegetable Production and Climate Resilience

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Keywords: Biochar; climate resilience; organic amendments; soil health; vegetable production

1. Background

Vegetable crops are vital for nutritional security, dietary diversity, and rural livelihoods worldwide. Rich in vitamins, minerals, and antioxidants, they play a key role in combating malnutrition. However, intensive cultivation practices, including excessive use of chemical fertilizers, pesticides, and continuous cropping, have caused serious soil degradation. This includes loss of soil organic matter, nutrient imbalance, reduced microbial activity, and poor soil structure, ultimately affecting productivity and crop quality. These issues are further aggravated by climate change, which increases drought, heat stress, and erratic rainfall. Such variability disrupts soil processes, reducing nutrient availability and water-use efficiency. Therefore, sustainable and climate-resilient agricultural practices are urgently needed.

Biochar and organic amendments have gained attention as effective soil management strategies. Biochar, a carbon-rich material produced through biomass pyrolysis, has high stability, porosity, and cation exchange capacity, improving soil properties and aiding carbon sequestration. Organic amendments such as farmyard manure, compost, vermicompost, and crop residues enhance soil fertility by supplying nutrients and stimulating microbial activity. Their combined use offers synergistic benefits. Biochar improves nutrient retention and provides microbial habitat, while organic amendments supply nutrients and enhance biological activity. This integration improves soil health, nutrient-use efficiency, and crop productivity. This study synthesizes existing knowledge on the combined effects of biochar and organic amendments on soil properties, vegetable yield, and environmental sustainability, with emphasis on climate resilience.

2. Material and Methods

This study is based on a review and synthesis of scientific literature on biochar and organic amendments in vegetable systems. Data were collected from peer-reviewed journals, books, conference proceedings, and research reports. Major vegetable crops such as tomato, cabbage, spinach, brinjal, and okra were included to represent diverse systems. Both field and controlled studies were considered. Soil physical properties (bulk density, porosity, water-holding capacity), chemical properties (soil organic carbon, pH, N, P, K), and biological parameters (microbial biomass, enzyme activity, soil respiration) were analyzed. Crop productivity indicators such as yield, biomass, and quality traits were also evaluated. The effects of biochar (5–20 t ha⁻¹) and organic amendments were assessed individually and in combination. Comparative analysis focused on synergistic effects, nutrient-use efficiency, and climate resilience indicators such as carbon sequestration, improved water-use efficiency, and reduced greenhouse gas emissions.

3. Results and Conclusion

Biochar significantly improves soil physical properties such as porosity and water-holding

capacity, enhancing moisture retention and reducing crop water stress. Its porous structure promotes aeration and root growth, supporting plant performance under drought conditions. Chemically, biochar increases cation exchange capacity, improving retention of essential nutrients (N, P, K) and reducing leaching losses. Organic amendments (compost, farmyard manure, vermicompost) enhance soil fertility by supplying nutrients, increasing organic matter, and stimulating microbial activity. This boosts nutrient mineralization, decomposition, and overall soil biological functioning, leading to improved nutrient cycling and soil health.

The combined application of biochar and organic amendments produces strong synergistic effects. Biochar provides a stable microbial habitat, while organic inputs supply nutrients and labile carbon, increasing microbial biomass and enzyme activity. This enhances nutrient-use efficiency, soil aggregation, water infiltration, and retention. Consequently, vegetable crops show improved root growth, higher yields (25–40%), and better quality attributes. From a climate perspective, biochar contributes to carbon sequestration and reduces greenhouse gas emissions (N_2O , CH_4). Organic amendments complement these effects by improving soil structure and resilience to climatic stresses. Additionally, integrated use reduces reliance on synthetic fertilizers, lowering costs and environmental impact. However, biochar performance depends on feedstock, pyrolysis conditions, soil type, and application rate. Excessive use may cause nutrient imbalance or increased alkalinity; therefore, site-specific management is essential. In conclusion, integrating biochar with organic amendments is a sustainable and climate-smart strategy that enhances soil health, improves crop productivity and quality, and supports long-term agricultural resilience.

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2.37 Linking Rice Residue Management and Nitrogen Scheduling to Microbial Nitrogen Cycling and Crop Productivity

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Keywords: Rice-wheat system, Residue management, Nitrogen scheduling, Soil nitrogen transformation, Microbial activity

1. Background

The rice–wheat system (RWS) of the Indo-Gangetic Plains is crucial for food security but is increasingly constrained by soil degradation, inefficient nitrogen (N) use, and improper residue management practices such as burning. These practices adversely affect soil microbial processes governing nitrogen transformations and ultimately crop productivity. Integrating residue management with optimized N scheduling is hypothesized to enhance soil biological functioning, improve nitrogen cycling and sustain wheat productivity.

2. Material and Methods

A two-year field experiment (2020-2022) was conducted on a sandy loam soil at Punjab Agricultural University, Ludhiana, using a split-plot design with three replications. The main plot treatments included three residue management practices: conventional tillage with residue incorporation (CT+R₁₀₀), zero tillage with full residue retention (NT+R₁₀₀), and partial residue retention using *Smart Seeder* (SS+R₁₀₀). Sub-plot treatments comprised four nitrogen scheduling strategies: N_{24:48:48} (recommended split; 24, 48, 48 kg N ha⁻¹ at sowing, 21 and 55 days after sowing (DAS), respectively), N_{48:72} (48 and 72 kg N ha⁻¹ at sowing and 55 DAS), N_{60:60} (60 and 60 kg N ha⁻¹ at sowing and 55 DAS), and N_{80:40} (80 and 40 kg N ha⁻¹ at sowing and 55 DAS). Soil samples (0–15 cm) were analyzed for enzymatic activities (urease, protease, L-asparaginase), nitrification processes, microbial populations and mineral nitrogen fractions using standard colorimetric protocols. Wheat yield and nutrient uptake were also recorded at crop maturity. Statistical analysis was performed using analysis of variance (ANOVA) and multivariate techniques.

3. Results and Conclusion

Residue management and nitrogen scheduling influenced soil biological properties and nitrogen transformation processes, although there was no significant interaction among themselves. NT+R₁₀₀ significantly enhanced nitrogen cycling enzymes *viz.* protease and L-asparaginase but had no significant effect on urease activity when compared with CT+R₁₀₀. Total nitrification enzyme activity including heterotrophic nitrification was significantly increased under no and partial tillage practices over conventional tillage with residue incorporation. However, autotrophic nitrification remained unaffected by residue management practices. Nitrogen cycling microbes *viz.* N-fixers were significantly affected by zero till with residue retention, on the other hand ammonia oxidizers and nitrate reducers remained at par among residue management practices. Furthermore, soil ammoniacal and nitrate N contents were also higher by ~7.4% and ~6.9%, under NT+R₁₀₀ over CT+R₁₀₀, respectively. Among nitrogen schedules, N_{48:72} consistently improved microbial activity, heterotrophic nitrification, and microbial biomass nitrogen over N_{80:40}. Wheat grain yield was significantly higher under NT+R₁₀₀ (~6.6%) and N_{48:72} (~10.9%) compared to conventional tillage and nitrogen management practices. Multivariate analysis revealed strong positive associations among microbial biomass, enzymatic activity, and mineral nitrogen, with residue management exerting a stronger influence than nitrogen scheduling. In conclusion, the combination of zero tillage with full residue retention (NT+R₁₀₀) and balanced split nitrogen application (N_{48:72})

enhanced soil nitrogen cycling, microbial functioning, nutrient availability, and wheat productivity. This integrated approach offers a sustainable strategy for improving nitrogen use efficiency, maintaining soil health and serve as practical alternative to rice residue burning in intensive rice-wheat systems.

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2.38 Evaluation of various biorationals against banded leaf and sheath blight disease of maize under rainfed conditions

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Keyword: Zea mays, Banded Leaf and Sheath Blight (BLSB), *Rhizoctonia solani* f.sp. *sasakii* Exner

1. Background

Maize (*Zea mays* L.) is an important food, feed and fodder crop of India which is grown in the plains under irrigated and rainfed conditions and also on the hills or mountains. The major growing area of maize in our country is J&K, HP, Rajasthan, Punjab, Haryana and MP. About 70-80% of its production in the country is consumed in the form of chapatti, pop corn, and rest is used as animal feed especially in poultry. Jammu division of J&K state occupies highest area under cultivation of maize. It is major kharif season crop of this region. Maize has potential and so extreme yields can be achieved through cultivation of hybrid and composite variety with better crop management, especially diseases and pest. Diseases are major limiting factor for successful production of maize. The crop is attracted by the various diseases but the important disease is banded leaf and sheath blight (BLSB) disease caused by *Rhizoctonia solani* f.sp. *sasakii* Exner. It is very destructive disease of maize and considered to be a major constraint for limited production. This disease causes losses in grain yield to the extent of over 90%. The disease incidence recorded in India ranges from 10-42% (Kumar *et al.* 2000). Farmers rely solely on chemical fungicides for its management. Managing this disease through biorationals is therefore, of paramount importance.

2. Materials and Methods

An experiment was conducted to access the efficacy of different treatments i.e. fungicides and biorationals agents, against the banded leaf and sheath blight (BLSB) disease caused by *Rhizoctonia solani* f.sp. *sasakii* Exner. at ACRA farm Dhiansar during the kharif season 2021, 2022 & 2023. One chemical and eight bio-rational agents alone and in possible combinations were evaluated under in vivo conditions. Ten treatments including check were evaluated under field conditions in three replications in design RBD. The popular variety mansar of maize in that area was used for experimentation. Banded leaf and sheath blight disease severity was recorded on 1-5 disease ratings scale (Ahuja and Payak, 1983). Further PDI (Percent Disease Index) was calculated by using the formula given by Wheeler, 1969.

3. Results and Conclusion

Seed treatment with *Trichoderma viridae* @ 0.4% and two foliar sprays at 40 and 55 days after sowing with Propiconazole @ 0.1% was most effective in which reducing the intensity of banded leaf and sheath blight disease in maize 22.99% and found to manage the disease banded leaf and sheath blight 68.71% over the check, thereby resulting in 48.05% increase in yield as compared to check. The application of bio-rational Neem oil was found second effective against the banded leaf and sheath blight disease of maize over the check. The research work showed to identify the strategies of managing diseases in maize. The present study confirmed the effectiveness of the combination of fungicides & bioagents against diseases of maize, which can be used as reduced the probability of pathogen resistance.

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2.39 Dry matter partitioning in cotton under varying irrigation and fertigation regimes in semi-arid Punjab

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Keywords: Irrigation, Fertigation, Crop growth, Cotton Background

1. Background

Cotton, an important commercial fibre and cash crop in the world which plays a significant role in agriculture, industries and contribute to the national income. India ranks first in terms of area and production of cotton and contribute 20% of the total global cotton production. During 2024-25, India holds largest area under cotton with 113.60 lakh hectares which is about 36% of the world area (Anonymous, 2024). Cotton simultaneously produces vegetation and reproductive branches throughout its growing season and has extensive tap root system due to which it accesses the nutrients and water from deeper layers of soil (Kaur et al 2022). Yield of cotton is directly related to the sink structures (seed count, abscised bolls, final seed cotton yield and its fibre partitioning) which is largely affected by physio-chemical properties of soil, environmental conditions and agronomic management practices (Dusserre et al 2022). Both the soil nutrients and water play a vital role in overall growth, development and yield. Keeping all these in view, the following study is conducted to analyze the above ground biomass and its partitioning into stem, leaves and fruiting bodies of cotton under various irrigation and fertigation regimes.

2. Material and Methods

A field experiment was carried out at Punjab Agricultural University, Regional Research Station, Faridkot to evaluate the effect of different irrigation methods on the growth dynamics of cotton. The experiment comprised of three different irrigation methods *viz.*, surface flood (Control 1: C₁), surface drip (Control 2: C₂) and sub surface drip. Under sub-surface drip three irrigation levels (I₁: 60% Etc, I₂: 80% Etc and 100% Etc) and two fertilizer levels [(F₁: 75% RDN (112.5kg/ha); F₂: (84.3 kg/ha)] were fixed. Irrigation and fertilizer under surface flood and surface drip was provided as per the recommendations of Punjab Agricultural University. All the treatments were assigned in Randomized complete block design (RCBD).

3. Results and Conclusion

The results indicated that irrigation methods pose significant effects on the growth dynamics of cotton especially from 90 days after sowing. Among irrigation methods, drip irrigation systems outperformed surface flood irrigation in enhancing biomass production and growth rates. Under sub-surface drip irrigation, increasing water and nitrogen levels improved total dry matter accumulation, its distribution to different plant components and highest crop and relative growth rates. Overall, the sub surface drip fertigation method saves water and provide more favorable soil-plant environment, thereby maximizing growth potential and biomass productivity of cotton.

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2.40 Adoption of Natural Farming Practices in Mandi District of Himachal Pradesh.

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Keywords: Indigenous practices, Fertilizers, Concoctions, Chemicals

1. Background

Natural Farming is a traditional method of chemical-free farming that relies on livestock and locally available resources while disregarding the use of artificial pesticides or fertilizers. It is primarily focused on on-farm biomass recycling, with a particular emphasis on biomass mulching and the use of on-farm livestock dung-urine formulations (concoctions), occasionally working for soil moisture, and avoiding the use of any synthetic chemical inputs, either directly or indirectly. Its goal is to promote traditional indigenous practices that provide farmers with freedom from externally purchased inputs (seeds to some extent, fertilizers, herbicides, insecticides, fungicides, etc.). Natural farming is a self-developing, self-nourishing and self-sufficient farming. So, in this system, there is not any human made exploitation. It is a pain free, care free and loan free farming (Palekar, 2010). Himachal Pradesh practices Natural Farming under Prakritik Kheti Khushhal Kissan Yojana (PK3Y). The scheme seeks to enhance farmer's income while reducing cost of cultivation. The scheme was launched by the honorable Chief Minister of Himachal Pradesh in the financial year of 2018-19. The scheme went beyond its initial goal of covering 500 farmers, instead covered 2,669 in 2018-19. By 2019-20, 54,914 farmers were engaged in Natural Farming on 2,451 hectares of land. The scheme has now targeted to include more farmers under its stretch and cover an area of 20,000 hectares (NITI Aayog, 2021).

2. Materials and Methods

A descriptive research design was used for fact finding with adequate interpretation. Out of each of eight selected gram panchayats, further, fifteen farmers were selected using a random number generator from the list obtained from various Block Development Offices. The equal numbers of farmers were taken from each gram panchayat to ensure uniformity in the sampling procedure. Thus, total sample size for the present study was 120.

3. Results and Conclusion

Among Transitioning to Natural Farming practices maximum adoption was shown by rain water conservation (82.50%), use of indigenous cow (80.00%) and vermicomposting (51.67%). Among Cropping Systems and Nutrient Management practices, predominance of leguminous crops (80.00%) was observed, followed by application of jivamrit (63.33%), intercropping (55.83%), mixed cropping (51.67%) and application of bijamrit (46.67%). For the overall adoption of Natural Farming practices, the study concluded that most farmers (66.67%) fell in the medium adoption category demonstrating smaller percentages in the high (17.50%) and low (15.83%) adoption category (Table-1)

Table-1

S.no	Practices	Full adoption		Partial adoption		No adoption	
		f	%	f	%	f	%
Transitioning to Natural Farming							
1.	Construction of nalas	45	37.50	22	18.33	53	44.17
2.	Rain water conservation	99	82.50	15	12.50	6	5.00
3.	Using local seeds	36	30.00	68	56.67	16	13.33
4.	Practicing crop tree association	58	48.33	46	38.33	16	13.33
5.	Using indigenous cow	96	80.00	10	8.33	14	11.67
6.	Formation of compost pits	46	38.33	15	12.50	59	49.17
7.	Vermicomposting	62	51.67	27	22.50	31	25.83
Cropping Systems and Nutrient Management							
8.	Use of FYM	39	32.50	30	25.00	51	42.50
9.	Use of leaf litter, crop by products and wood ash	33	27.50	46	38.33	41	34.17
10.	Minimum tillage practices	47	39.17	65	54.17	8	6.67
11.	Mulching	55	45.83	53	44.16	12	10.00
12.	Green manuring	49	40.83	56	46.67	15	12.50
13.	Application of jivamrit	76	63.33	27	22.50	17	14.17
14.	Application of bijamrit	56	46.67	33	27.50	31	25.83
15.	Application of ghanjivamrit	45	37.50	18	15.00	57	47.5
16.	Application of panchvagya	19	15.83	8	6.67	93	77.5
17.	Intercropping	67	55.83	35	29.17	18	15
18.	Using contour bunds across the slope	29	24.17	22	18.33	69	57.5
19.	Planting of leguminous crops	96	80.00	19	15.83	5	4.17
20.	Mixed cropping	62	51.67	50	41.67	8	6.67
21.	Use of erosion preventing crops in alternate rows	47	39.17	34	28.33	39	32.50
22.	Use of thrimurthy tonic	0	0.00	0	0.00	120	100.00

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2.41 Assessment of Long-Term Trends in Minimum Temperature and Its Impact on Vegetation Dynamics Using GDD NDVI Relationship

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Keywords: *Temperature Trends, Growing Degree Days (GDD), Normalized Difference Vegetation Index (NDVI), Vegetation Dynamics*

1. Background

Rising temperatures, particularly minimum temperature, are significantly influencing vegetation dynamics and crop phenology under changing climate conditions (Chen *et al.*, 2024). Growing Degree Days (GDD) provide a reliable measure of thermal accumulation controlling plant growth, while the Normalized Difference Vegetation Index (NDVI) is widely used to monitor vegetation health and productivity. Recent studies show that NDVI responds strongly to variations in temperature and accumulated heat units such as GDD, although the relationships vary across regions and cropping systems (Burke *et al.*, 2024). Integrating GDD–NDVI relationships with long-term minimum temperature trends enhances understanding of vegetation responses and supports climate-resilient agricultural planning.

2. Material and Methods

The study was conducted in Bathinda district, located in the south-western part of Punjab (30.58°N, 74.18°E; 211 m above mean sea level). The region lies away from the Shivalik hills and is characterized by a semi-arid climate with pronounced seasonal variability. The average annual rainfall is about 450 mm, of which nearly 80% is received during the southwest monsoon (July to mid-September), while the remaining occurs in winter. Summers are extremely hot, with temperatures often exceeding 47°C, accompanied by dust storms, whereas winters can be very cold, with minimum temperatures approaching 0°C. Daily weather data, including minimum temperature (Tmin), maximum temperature (Tmax), rainfall, and solar radiation, were collected from the Agrometeorological Observatory at the Punjab Agricultural University (PAU) Regional Research Station, Bathinda, for the period 1982–2023. Climatic variability and trends were analyzed using the Mann–Kendall (MK τ , MK_S) test and Sen's slope estimator. Geospatial analysis was performed using GIS tools, including the Raster Calculator, to derive the Normalized Difference Vegetation Index (NDVI) from MODIS satellite imagery. NDVI data corresponding to wheat and cotton growing seasons were extracted to assess crop responses under climatic extremes. Finally, relationships between climatic parameters and NDVI were established for both crops during their respective growing periods.

3. Results and Conclusion

A pronounced concentration of significant trends during Julian days 250–310 aligns with crucial cotton growth stages, indicating heightened sensitivity to climatic variability. Minimum temperature trends (MK_S) revealed marked temporal fluctuations, with warming phases during days 1–100 and 250–320, cooling between days 120–200, and relatively stable conditions around days 180–240; Sen's slope analysis corroborated these patterns, showing positive trends (up to +0.10 °C year⁻¹) and negative trends (down to –0.08 °C year⁻¹). For maximum temperature (Tmax), an initial cooling trend (days 1–60) was followed by a warming phase (days 61–140), after which a persistent cooling trend dominated from days 200–310, intensifying toward the end of the year.

These findings underscore key seasonal windows that are critical for crop response and adaptation planning. The relationship between CGDD and NDVI shows a strong positive association ($R^2=0.76$), explaining about 76% of NDVI variability. NDVI increases with heat accumulation up to ~ 2800 °C days, reflecting active vegetative and reproductive growth, but declines thereafter due to crop maturity, senescence, or heat stress. In contrast, the relationship between NDVI and rainfall is weaker ($R^2=0.25$), indicating that rainfall explains only 25% of NDVI variation. Although NDVI generally increases with rainfall—especially at lower levels (0.1–6 mm/day) due to improved moisture and photosynthesis—other factors such as temperature and radiation play a more dominant role. Overall, cotton growth is strongly influenced by seasonal temperature changes, especially during critical growth stages. Temperature plays a dominant role in crop development, while rainfall has a lesser impact, highlighting the need for climate-adaptive management.

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2.42 Sulphur and Zinc Fortification as a Climate-Smart Strategy for Improving Productivity of Groundnut.

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Keywords: Groundnut, Biofortification, Sulphur, Zinc, Yield

1. Background

Groundnut (*Arachis hypogea* L.) is a major oilseed crop contributing significantly to edible oil production, nutritional security and livelihood sustainability in semi-arid regions of India. India ranks second in terms of production with production of 7.56 million tonnes from an area of 4.15 million ha. The crop also plays an important role in improving soil fertility through biological nitrogen fixation and is highly valued in agrarian economies, especially in semi-arid agro-ecologies of South and Southeast Asia. Despite its economic importance, productivity of upland groundnut remains sub-optimal primarily due to imbalanced fertilization and widespread deficiencies of secondary and micronutrients, particularly sulphur and zinc. Sulphur is critically involved in protein synthesis, oil formation and enzymatic regulation, whereas zinc plays a vital role in auxin metabolism, photosynthetic activity and reproductive development. Continuous nutrient mining under intensive cultivation has further aggravated the deficiencies of these nutrients, leading to yield stagnation and deterioration in seed quality. Agronomic biofortification through sulphur and zinc fertilization has emerged as a promising strategy to enhance crop productivity, improve oil quality and sustain soil health. Therefore, the present study was undertaken to evaluate the effect of sulphur and zinc biofortification on growth, yield, quality and economics of upland groundnut.

2. Material and Methods

A field experiment was conducted during the *kharif* season of 2022 at the experimental farm of Lovely Professional University, Punjab. The experiment was laid out in factorial randomized block design comprising nine treatment combinations with three replications. Treatments consisted of three levels of sulphur viz., 20 kg ha⁻¹ basal application, 40 kg ha⁻¹ basal application and 40 kg ha⁻¹ split application, and three levels of zinc viz., 3, 5 and 6 kg ha⁻¹ soil application. Standard agronomic practices were followed for crop management. Observations on growth attributes, yield components were recorded and statistically analysed.

3. Results and Conclusion

Plant height

Application of sulphur and zinc significantly influenced growth, yield and parameters of upland groundnut. Split application of sulphur at 40 kg ha⁻¹ resulted in significantly higher plant height (38.71 cm), enhanced vegetative growth and improved dry matter accumulation, indicating better nutrient assimilation and metabolic activity. Zinc application at 6 kg ha⁻¹ further augmented growth performance through improved physiological efficiency and reproductive development. The favourable effects of sulphur on N-metabolism and, as a result, on the vegetative development of the groundnut plant, may be the cause of the rise in plant height as reported in the experiment. (Akhter *et al.* 2013).

Kernel yield

For the Sulphur treatments, the highest kernel yield was observed in S₃ (40 kg ha⁻¹split) treatment with a yield of 3091.07 kg ha⁻¹. It was followed by S₂ (40 kg ha⁻¹) treatment with a yield

of 2818.48 kg ha⁻¹. The lowest kernel yield was observed in S₁ (20 kg ha⁻¹) treatment with a yield of 2450.43 kg ha⁻¹. It has been discussed that sulphur plays vital role in improving vegetative structure for nutrient absorption and photosynthesis, strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink. These findings are in confirmation to the earlier report of (Nawange *et al.* 2011).

The study clearly demonstrates that the balanced application of sulphur and zinc resulted in a significantly higher kernel yield of groundnut with the split application of sulphur at 40 kg ha⁻¹ followed by basal application of sulphur at 40 kg ha⁻¹ and basal application of sulphur at 20 kg ha⁻¹ in that order each treatment varying significantly from each other and proved to be an efficient nutrient management strategy for enhancing crop performance and ensuring sustainable production under semi-arid agro-ecosystems. Adoption of such biofortification practices can play a crucial role in improving oilseed productivity, nutrient use efficiency and farmer income under resource-constrained conditions.

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2.43 Redesigning rice-based systems: Integrating crop establishment and diversification for resilient productivity and soil regeneration

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Keywords: Climate variability, productivity, Rice-based system, resource-efficient, soil degradation and sustainability.

1. Background

Rice–wheat systems in South Asia are facing challenges such as declining productivity and soil degradation (Batt et al 2021; Upadhaya *et al.*, 2022). This study investigates crop establishment methods and cropping systems, including summer legumes, to enhance productivity and sustainability. The aim is to identify resilient strategies for long-term agricultural intensification, with an emphasis on improving resource use efficiency and soil health.

2. Material and Methods

In 2023–2025, a split-plot design with three replications was used in a field experiment at ICAR–IARI, Regional Station, Pusa, Bihar. Four crop establishment and residue management techniques made up the major plot treatments: Throughout the kharif, rabi, and summer seasons, M1 (ZTDSR–ZT–ZT), M2 (ZTDSR–ZT with standing rice residue retention at 4 t ha⁻¹–ZT), M3 (PTR–CT–CT), and M4 (PTR–CT with rice residue incorporation at 4 t ha⁻¹–CT). Six cropping systems were included in the sub-plot treatments: rice-chickpea-moongbean, rice-lentil-moongbean, rice-mustard-moongbean, rice-linseed-moongbean, rice-wheat-moongbean, and rice-maize-moongbean. Following advised agronomic procedures, crops were cultivated one after the other. Each crop's grain yield was measured and examined using an analysis of variance (ANOVA) suitable for the split-plot design.

3. Results and conclusion

Across seasons, there were notable differences in grain output between crop setting techniques. The maximum yield during kharif was obtained by CESc4 (4.48 t ha⁻¹), which was substantially better than CESc1 (4.12 t ha⁻¹) but statistically comparable to CESc2 (4.39 t ha⁻¹) and CESc3 (4.37 t ha⁻¹). CESc2 yielded the most rabi (3.38 t ha⁻¹), followed by CESc1 (2.99 t ha⁻¹) and CESc3 (2.74 t ha⁻¹). In the summer, CESc3 reported the lowest figure (0.765 t ha⁻¹), whereas CESc2 again produced a noticeably higher yield (1.056 t ha⁻¹). During kharif, cropping system options revealed non-significant variance in grain yield. On the other hand, CSSc6 reported the highest yield (6.93 t ha⁻¹) during rabi, which was noticeably better than all other systems, followed by CSSc5 (4.75 t ha⁻¹). CSSc4 had the lowest rabi yield (1.49 t ha⁻¹). In summer, CSSc2 (1.108 t ha⁻¹) and CSSc3 (1.088 t ha⁻¹) produced significantly higher yields and remained at par with CSSc1 (1.012 t ha⁻¹), while CSSc6 recorded no yield. Increased resource efficiency and resilience in sustainability and soil health are demonstrated by stable yields from treatments such as CESc2 and varied cropping systems (CSSc2/CSSc3). Additionally, summer crops, particularly legumes, enhance soil fertility through residue contribution and biological nitrogen fixation. Systems with yield gaps, such as CSSc6 in summer, can reduce soil cover and organic matter, negatively affecting

soil health over time. In contrast, CESS2 and diverse cropping systems (CESS2/CESS3) showed enhanced productivity, stability, and resource use efficiency. These systems improved sustainability by promoting soil health through continuous cropping and better dynamics of organic matter and nutrients.

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2.44 Performance of soybean [*Glycine max* (L.) Merrill] varieties under different phosphorus levels along with inoculation of PSB

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Keywords: Soybean, Phosphorus, PSB, Varieties, Yield, Nutrient management

1. Background

Soybean (*Glycine max* L. Merrill) is an important legume crop valued for its high protein (40–41%) and oil (20–21%) content, contributing significantly to food, feed and industrial sectors. In India, it also plays a key role in improving soil fertility through biological nitrogen fixation. Varietal selection is a critical factor influencing soybean productivity, as genotypes differ in growth characteristics, nutrient use efficiency and yield potential. These variations affect parameters such as plant growth, nodulation, biomass accumulation and seed yield, and determine their response to nutrient management practices. Phosphorus is an essential macronutrient involved in energy transfer, root development and nodulation; however, its availability in soils is often limited due to fixation. Although phosphorus fertilization improves soybean growth and yield, excessive use may lead to environmental and economic concerns. Phosphate-solubilizing bacteria (PSB) enhance phosphorus availability by converting insoluble forms into plant-available forms, thereby improving nutrient uptake, nodulation and yield. Their integration with phosphorus fertilization offers a sustainable approach to nutrient management. The present study evaluates the interaction of soybean varieties, phosphorus levels and PSB inoculation to identify efficient and sustainable strategies for improving productivity and nutrient use efficiency.

2. Materials and Methods

The field experiment was conducted during the summer season of 2024 at Dusty Acre Farm, College of Agriculture, JNKVV, Jabalpur (M.P.). The experiment was laid out in a **Factorial Randomized Block Design (FRBD)** with four replications. It comprised three soybean varieties:

V1: JS 20-34

V2: JS 20-98

V3: JS 20-116

Six phosphorus management treatments:

P1: 100% recommended dose of nitrogen (control)

P2: 100% N & K + 75% P

P3: P2 + seed treatment with PSB @ 10 g kg⁻¹ seed

P4: P3 + soil application of PSB @ 5 kg ha⁻¹

P5: 100% NPK + PSB seed treatment

P6: 100% NPK + PSB seed treatment + soil application

Observations were recorded on growth parameters (plant height, branches, LAI, nodulation), yield attributes (pods plant⁻¹, seeds pod⁻¹, seed index), and yield (seed and stover yield). Statistical analysis was carried out using analysis of variance (ANOVA).

3. Results and Conclusion

The results revealed that among varieties, JS 20-116 (V3) consistently performed superior in terms of growth parameters. Phosphorus levels combined with PSB significantly influenced plant growth. Treatment P6 (100% RDF of NPK + PSB seed + soil application) produced the highest values for plant height, branching, LAI, and nodulation, indicating enhanced nutrient availability and improved root activity due to microbial inoculation. Yield attributes were also significantly affected. Variety JS 20-116 recorded the highest number of pods per plant (62.14), seeds per pod (2.93) and seed index (12.86 g). Among phosphorus treatments, P6 resulted in maximum pods per plant (54.83) and seeds per pod (2.83). The highest seed yield was recorded with variety JS 20-116 (1354 kg ha⁻¹), followed by JS 20-98 (1024 kg ha⁻¹) and JS 20-34 (727 kg ha⁻¹). Among phosphorus treatments, P6 produced the maximum seed yield (1212 kg ha⁻¹), followed by P5 (1147 kg ha⁻¹). The interaction effect between varieties and phosphorus levels was highly significant. The combination V3 × P6 recorded the highest seed yield (1649 kg ha⁻¹) and stover yield (2446 kg ha⁻¹), indicating that high-yielding varieties respond more efficiently to integrated phosphorus and PSB application. The results clearly demonstrate that PSB inoculation enhances phosphorus availability, improves root nodulation, and increases nutrient uptake, thereby boosting growth and yield. The synergistic effect of phosphorus fertilization and PSB inoculation confirms their importance in sustainable soybean production. The study concluded that integrated phosphorus fertilization and PSB inoculation significantly enhanced soybean growth, nodulation and yield. Variety JS 20-116 performed superiorly, while treatment P6 maximized productivity. Significant variety × phosphorus interaction indicated improved nutrient use efficiency and synergistic effects.

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2.45 Varietal Response of Bio-inoculants on Horticultural Traits in Pumpkin (*Cucurbita moschata* Duch. ex Poir.)

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Keywords: Bio-inoculants, Pumpkin, Quality and Yield

1. Background

Pumpkin (*Cucurbita moschata* Duch. ex Poir.) is an important cucurbitaceous vegetable crop grown widely for its high yield potential and nutritional value. The productivity and quality of pumpkin are greatly influenced by varietal characteristics and nutrient management practices. Continuous use of chemical fertilizers has resulted in declining soil fertility and increased susceptibility of crops to insect pests and diseases. In recent years, bio-inoculants have gained importance as a sustainable approach to improve crop growth, yield and quality through enhanced nutrient availability, production of growth-promoting substances and induction of plant resistance mechanisms. Several studies have reported significant improvement in growth, yield and quality parameters of vegetable crops due to the application of bio-inoculants (Yadav *et al.* 2020). However, the response of bio-inoculants largely depends on crop variety. Therefore, the present investigation was undertaken to study the differential response of pumpkin varieties and bio-inoculants on growth, yield, quality and pest disease incidence.

2. Materials and Methods

The present investigation was carried out during the kharif season at the Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), Chatha, under subtropical agro-climatic conditions of the Jammu region. The experiment comprised three pumpkin varieties (V_1 , V_2 and V_3) and six bio-inoculant treatments (B_1 to B_6 , including control). The treatments were laid out in a Randomized Block Design (RBD) with three replications. Recommended agronomic practices were followed uniformly for all the treatments throughout the entire crop growth period. Observations were recorded on vine length (cm), days to first male and female flower appearance, fruit length (cm), fruit diameter (cm), average fruit weight (kg), fruit yield ($q\ ha^{-1}$), total soluble solids ($^{\circ}Brix$), chlorophyll content ($mg\ g^{-1}$) and incidence of fruit borer (%) and virus (%). The collected data were subjected to statistical analysis and treatment means were compared at the 5 per cent level of significance.

3. Results and Conclusion

Significant differences were observed among bio-inoculant treatments and pumpkin varieties for all the parameters studied. Among the bio-inoculants, B_5 recorded the maximum vine length (379.72 cm), while the minimum vine length (365.42 cm) was observed in the control (B_6). Earliness in flowering was also influenced by bio-inoculant application, with minimum days to first female flower appearance (73.58 days) recorded under B_5 , whereas the control required the maximum number of days (81.78 days). Improved vegetative growth and early flowering under bio-inoculant application may be attributed to enhanced nutrient uptake and better physiological activity (Kumar *et al.* 2019). Fruit characters showed significant improvement due to bio-inoculant application. Maximum fruit length (25.19 cm), fruit diameter (3.12 cm) and average fruit weight (7.35 kg) were recorded under B_5 , which resulted in the highest fruit yield ($255.88\ q\ ha^{-1}$). In contrast, the control treatment recorded the lowest yield ($219.75\ q\ ha^{-1}$). Increased yield under bio-inoculant treatments may be due to improved translocation of photosynthates and better root

development, as reported by Yadav *et al.* (2020). Quality parameters such as total soluble solids and chlorophyll content were significantly influenced by the treatments. Maximum TSS (7.19 °Brix) and chlorophyll content (11.70 mg g⁻¹) were observed under B_s, indicating improved photosynthetic efficiency and fruit quality. With respect to plant protection parameters, minimum fruit borer infestation (25.15%) and virus incidence (21.55%) were recorded under B_s, while the control treatment showed the highest infestation and disease incidence. Reduced pest and disease incidence under bio-inoculant treatments may be attributed to increased plant vigour and induced systemic resistance, which was in agreement with the findings of Meena *et al.* (2022). Among the varieties, V₃ recorded maximum vine length (389.75 cm), fruit length (25.54 cm) and fruit yield (242.10 q ha⁻¹), indicating its superior genetic potential. The observed varietal differences may be attributed to inherent genetic variability and differential response to bio-inoculant application.

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2.46 Influence of planting methods and Fertigation levels on Growth and Yield of Red gram

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Keywords: Redgram, Fertigation, Spacing, Transplanting, Yield

1. Background

Food legumes are important source of protein in the diets of a large section of vegetarian population in the developing countries. Even though India has the largest area under pulses in the world, the average productivity is relatively low and the production is not adequate to meet the demand. The average consumption of pulses is about 31g/CU/day, which is lower than the recommended level of 40g (NNMB, 2012). Pigeon pea has good yield potential but production and productivity is very low because it is cultivated as rainfed crop in marginal lands of semi-arid tropics. Drip irrigation has significant impact on resource saving, crop yield and profitability of farm compared to other means of irrigation methods. Drip fertigation is a highly input efficient method to minimize the irrigation losses, better fertilizer application and adverse environmental impact on crop production. Both water and nutrient uptake enhanced by the plants and realized maximum dry matter production and yield through drip fertigation. The production still falls short of the domestic requirement which is increasing consistently with growing population, rising income, value addition and market opportunities. Globally, redgram is grown in an area of 63.57 lakh hectares with a production of 54.75 lakh tonnes and productivity of 861.25 kg/ha (FAO STAT, 2021).

2. Material and Methods

The field experiments were carried out under drip irrigated conditions at AICRP on Irrigation water management research block, Department of Agronomy, Agricultural College and Research Institute, Madurai, during *Kharif* season of 2014 to study the influence of plant geometry and nutrient levels on transplanted redgram under drip fertigation system. The experiment was laid out in Split Plot Design with three replications. The main plot treatments consisted of three planting geometry viz., G1-75 x 30 cm, G2-75 x 45 cm and G3-75 x 60 cm. The sub plot treatments consisted of fertigation levels; F1- fertigation of 100% RDF (25:50:25 kg NPK/ha), F2-fertigation of 75% RDF, F3- fertigation of 100% RDF + Humic acid @ 1.5 litre ha⁻¹ and F4- fertigation of 75% RDF + Humic acid @ 1.5 litre ha⁻¹ with pigeon pea variety Co (Rg) 7. The seedlings were transplanted at 25 days after sowing from the portrays. The growth and yield observations were recorded in five plants randomly selected in each treatment.

3. Results and Conclusion

Planting of redgram seedlings at 75 x 30 cm spacing (G₁) registered the maximum plant height at 30, 60, and 90 days after planting of the study. Drip fertigation of 100% RDF (25:50:25 kg NPK ha⁻¹) and humic acid @ 1.5 litre ha⁻¹ to transplanted redgram (F₃) resulted in the higher plant height. With regard to interaction, drip fertigation of 100% RDF + 1.5 litre humic acid ha⁻¹ to 75 x 30 cm spaced redgram produced comparatively taller plants at 30, 60 and 90 DAP *Viz.*, (60.5, 100.4 and 133.1 cm) This may be because of optimum moisture and nutrient availability synchronizing with supply and demand of nutrients (Sunilkumar *et al.*, 2024). Transplanting at closer spacing (75 x 30

cm) (G_1) registered the higher grain yield (1202 kg ha^{-1}). Drip fertigation of 100% RDF along with humic acid @ $1.5 \text{ litre ha}^{-1}$ recorded higher grain yield (1361 kg ha^{-1}). It was also found to be higher than the surface irrigation and soil application of RDF. On the basis of study It can be concluded that drip fertigation of 100% RDF ($25: 50: 25 \text{ kg NPK ha}^{-1}$) + Humic acid @ $1.5 \text{ litre ha}^{-1}$ and adopting a spacing of $75 \times 30 \text{ cm}$ is optimum for getting higher yields and economic returns in redgram Co (Rg-7).

Table 1. Effect of spacings, fertilizer levels and humic acid on grain and stalk yield (kg ha^{-1}) of redgram

Main Sub	Grain yield (kg ha ⁻¹)				Stalk yield (kg ha ⁻¹)			
	G ₁	G ₂	G ₃	Mean	G ₁	G ₂	G ₃	Mean
F ₁	1316	1198	1147	1220	3365	3063	2933	3120
F ₂	962	904	900	922	2161	2030	2021	2071
F ₃	1487	1364	1231	1361	3869	3549	3203	3540
F ₄	1041	1034	983	1019	2682	2664	2532	2626
Mean	1202	1125	1065	1130	3019	2827	2672	
	SEd		CD(0.05)		SEd		CD(0.05)	
G	22.9		62.20		25.57		141.95	
F	25.7		56.55		59.69		127.75	
G x F	23.6		52.02		68.40		152.55	
F x G	21.5		45.24		54.07		113.56	
Control	925				2193			

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2.47 Comparative Evaluation of Paddy (*Oryza sativa* L.) varieties under Integrated Nutrient Management, Organic and Natural Farming system

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Keywords: Inorganic fertilizers, Natural farming, Organic farming, Varieties

1. Background

Rice (*Oryza sativa* L.) is one of the most important cereal crop of the world. At global level, it is the staple food for more than half of the world's population. It plays a vital role in ensuring food security and supporting rural livelihoods, especially in developing countries. However, the continuous use of chemical fertilizers leads to a decline in essential nutrient of soil, decreased crop productivity and life span of human beings. The long term use of inorganic inputs can show adverse effect on soil physical properties, microbial population and overall ecosystem of the earth. To address these challenges, the several alternative management approaches were started gaining importance such as Integrated nutrient management (INM), Organic farming and Natural farming etc (Chaudhary *et al.* 2018). The integrated nutrient management consists of the balanced use of inorganic fertilizers, organic manures and biofertilizers to improve the soil health and crop production.

2. Material and methods

This study was conducted in Crop cafeteria, KVK- Jammu during 2019-20 to 2021-22 under factorial randomized block design with three replications comprises eighteen treatments. The first factor consists of six paddy varieties (SJBR-118, SJBR-123, SJBR-129, Basmati-370, Basmati-564 and Pusa Basmati-1121) and second factor consist of Integrated nutrient management, organic farming and natural farming. The plot size is 5x10 m. The observations recorded were effective tillers, yield sustainability index, production efficiency, grain yield, straw yield and harvest index etc. The statistical data was recorded for three consecutive years which was pooled for testing the homogeneity of error variance. This was performed using analysis of variance (ANOVA) for factorial randomized block design to evaluate the main effects of varieties, spacing and their interactions. The significance of difference between the treatment means were tested at 5% level of probability and critical difference for mean values were compared (Gomez and Gomez 1984).

3. Results and Conclusion

The results revealed that the yield attributes and yield were significantly influenced by varieties and nutrient management, while their interaction remain non-significant. Among the varieties, the higher number of tillers (358.71/m²), grain yield (3975 kg/ha), straw yield (6380 kg/ha), yield sustainability index (0.95) and production efficiency (27.74 kg/ha/day) was recorded in Pusa Basmati 1121. With respect to nutrient management, the integrated nutrient management had recorded the higher number of tillers (310.34/m²), grain yield (3992 kg/ha), straw yield (5989 kg/ha), yield sustainability index (0.92) and production efficiency (26.88 kg/ha/day). The superior result of Pusa Basmati 1121 due to increased tiller density, longer panicles and more grains per panicle enhance sink capacity and efficient assimilate translocation which results in better grain

filling and higher yield. However, the yield attributes and yield of crop was higher in INM due to better supply of nutrients from both organic and inorganic source whereas it was reduced under organic and natural farming due to slower release of nutrients and limited nutrient availability.

Treatments	Effective tillers/m ²	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (%)	Yield sustainability index	Production Efficiency (kg/ha/day)
SJBR-118	308.10	3698	6208	37.33	0.88	25.29
SJBR-123	291.57	3183	6158	34.08	0.79	23.68
SJBR-129	310.79	3408	6211	35.43	0.81	23.67
Basmati-370	281.15	2880	5480	34.45	0.69	18.78
Basmati-564	314.94	3350	5260	38.91	0.76	22.67
Pusa Basmati-1121	358.71	3975	6380	38.39	0.95	27.74
SEm (±)	3.57	82.76	102.25	0.51	-	-
CD (5%)	10.72	248.29	306.75	NS	-	-
INM	310.34	3992	5989	40.00	0.92	26.88
Organic farming	283.22	3147	5113	38.10	0.88	23.76
Natural farming	256.47	2756	4451	38.24	0.77	21.77
SEm (±)	3.76	98.22	127.73	0.48	-	-
CD (5%)	11.28	294.66	381.97	NS	-	-
Interaction (V x T)	NS	NS	NS	NS	-	-

INM- Integrated Nutrient management

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2.48 Smart Irrigation Scheduling for Sustainable Late-Sown Wheat Production

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Keywords: Water deficit, irrigation level, evapotranspiration

1. Background

Wheat (*Triticum aestivum* L.) plays a vital role in ensuring food security at both national and global levels. However, its productivity in fragile hill agro-ecosystems remains a major concern. In Himachal Pradesh, wheat is the principal rabi crop, but its performance is often limited by delayed sowing, uncertain winter rainfall, scarce irrigation facilities, and rising terminal heat stress. These constraints are largely linked with the rice–wheat cropping system, where the late harvest of long-duration rice varieties pushes wheat sowing beyond the optimum window, ultimately reducing crop growth duration and yield potential. In such water-limited environments, efficient management of available moisture becomes essential for sustaining wheat productivity. Evapotranspiration-based irrigation scheduling offers a practical and scientific means of improving water use by synchronizing irrigation with the crop's actual water demand at critical growth stages. Similarly, deficit irrigation, which involves applying controlled moisture stress during less sensitive phases, has emerged as a promising approach to enhance water productivity without major yield losses. At the same time, varietal differences in growth and physiological traits influence how wheat responds to delayed sowing and moisture stress. Therefore, this study was undertaken to identify suitable irrigation strategies and wheat cultivars for improving productivity and water use efficiency under hill conditions.

2. Material & Methods

A field experiment was conducted in rabi season of 2021-22 at the Irrigation and Water Management Research Farm, Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, to evaluate the effect of different irrigation regimes on crop and water productivity of late-sown wheat cultivars. The experiment was laid out in a split-plot design with three irrigation levels (100%, 80%, and 60% crop evapotranspiration, ET_C) in main plots and four wheat varieties (HPW 481, HPW 373, HS 490, and VL 892) in subplots, replicated thrice. Cropwat was used for calculation of ET based irrigation scheduling. Standard agronomic practices were followed, and observations on growth attributes, yield components, and productivity were recorded and statistically analysed.

3. Results & Conclusion

Plant height

Results showed that significantly, taller plants at 90 DAS onward were recorded with full irrigation level of 100% ET_C followed by 80% ET_C irrigation level. Plants with significantly lower height were recorded with deficit irrigation of 60% ET_C . The data on periodical plant height indicated that the irrigation regimes have less influence on plant height up to 60 days of crop growth due to receipt of sufficient rainfall coinciding CRI and tillering stage. Among varieties significantly taller plants were recorded for variety 'HS 490' followed by variety 'HPW 481' and 'HPW 373'. Significantly shorter plants were recorded in variety 'VL 892'.

Number of effective tillers and seed yield

Number of effective tillers m^{-2} were significantly influenced by the irrigation regimes results

showed that number of effective tillers m^{-2} increased significantly with an increase in the level of irrigation and significantly higher number of effective tillers m^{-2} at 120 DAS were observed with irrigation of 100% ET_C though it was at par with 80% ET_C . Significantly lower number of tillers m^{-2} were recorded when crop was irrigated with 60% of ET_C . similar results were reported by Jiang *et al.* (2020). Among varieties 'HS 490' recorded the highest number of tillers.

Seed yield

Results showed that significant decrease in seed yield was observed with decrease in irrigation level from 100 % of ET_C to 60 % of ET_C . The increase in yield with irrigation application of 100 % of ET_C over 80 % ET_C and 60% of ET_C level was 5.9% and 15.3%, respectively. Further the increase in yield with irrigation level application of 80 % ET_C over 60 % of ET_C was 8.1 per cent. Similar results were observed by Mishra and Kushwaha (2016) on yield and on yield attributes of wheat. Among varieties significantly higher grain yield was obtained from variety 'HS 490' followed by yield from variety 'HPW 481' and lowest was recorded in 'VL 892'.

The study highlights that evapotranspiration-based irrigation scheduling significantly influences growth and productivity of late-sown wheat under hill conditions. Irrigation at 100% ET_C ensured maximum yield; however, 80% ET_C irrigation maintained comparable productivity with improved water use efficiency, indicating its potential as a sustainable irrigation strategy under water-limited environments. Among the evaluated cultivars, HS 490 demonstrated superior adaptability under delayed sowing and deficit irrigation conditions. Therefore, integration of suitable wheat varieties with optimized evapotranspiration-based irrigation scheduling can enhance water productivity and sustain wheat production in fragile hill agro-ecosystems.

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2.49 Impact of zinc and iron on Yield, Soil Nutrient Dynamics and Plant Uptake in Mungbean [*Vigna radiata* (L.) Wilczek] through Agronomic Bio-fortification

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Key words-Mungbean, Variety, Zinc solubilizing bacteria

1. Background

The culinary value of mungbean (*Vigna radiata* L.) makes it one of the most valuable pulses. Globally, this contributes over 22 Mt of fixed nitrogen annually to agricultural systems via pulse and oilseed legumes (Herridge *et al.*, 2022). The enhanced and inorganic farming method of India has been able to attract special attention from scientists and growers. The crucial aspect in pulse productivity is the use of the proper micronutrients in the appropriate proportions. It performs optimally under humid-moist climatic conditions, it can be successfully established in regions with limited moisture availability due to its moderate drought tolerance and low water requirement (Malik *et al.*, 2021). Deficiencies of essential vitamins, iron (Fe), and zinc (Zn) affect over one-half of the world's population. A significant progress has been made to control micronutrient deficiencies through supplementation, but new approaches are needed, especially to reach the rural poor. Agronomic fortification of pulses with Zn and iron offers a pragmatic solution to combat hidden hunger instead of food fortification and supplementation. Moreover, it also has positive effects on crop production as well.

2. Materials and methods

A two year of experiment was carried out at Instructional Farm, College of Agriculture, Jodhpur (Rajasthan) in the *Kharif* season 2022 and 2023. The field experiment was laid out in Split-Split Plot Design (SSPD) with twenty-four treatment combinations to explore the interaction between iron and zinc and replicated thrice. The main plot treatments consisted of a combination of two factors *viz*, two varieties namely GM 7 and GM 4 and three levels of iron fortification levels namely control (Fe₀), soil application of 20 kg FeSO₄ + 0.5% Fe foliar spray at flower initiation and pod formation stages (Fe₁) and soil application of 25 kg FeSO₄ + 0.5% Fe at flower initiation and pod formation stages (Fe₂) in subplots. In sub-sub plots, seed inoculation with zinc solubilizing bacteria (ZSB) was combined with different doses of zinc sulphate with 0.5 % Zn foliar spray at flower initiation and pod formation stages and there were four treatments *viz*, control (Zn₀), ZSB (SI) + 15 kg ZnSO₄/ha + 0.5 % Zn foliar spray at flower initiation and pod formation stages (Zn₁), ZSB (SI) + 15 kg ZnSO₄/ha + 0.5 % Zn foliar spray at flower initiation and pod formation stages (Zn₂), ZSB (SI) + 25 kg ZnSO₄/ha + 0.5 % Zn foliar spray at flower initiation and pod formation stages (Zn₃) cropping have plot size 5x3m. Soil samples were randomly collected from each plot using a soil auger from 4 to 5 locations at the crop harvest stage, following a uniform sampling protocol. For microbial estimation, Thornton's agar medium was employed to determine bacterial populations. The Colony Forming Unit (CFU) counts were quantified using the serial dilution technique (Salle, 1973), with all analyses performed in triplicate. In ground seed and straw samples, nitrogen (N) was estimated via the micro-Kjeldahl method (Piper, 1966).

3. Results and conclusion

Across varieties and micronutrient treatments, the results indicated that the mungbean variety GM 4 significantly outperformed GM 7 with respect to mean nutrient content, uptake, and total uptake of nitrogen, phosphorus, potassium, zinc, and iron in both stover and seed. The findings further demonstrated that agronomic biofortification through the soil application of iron sulphate (along with 0.5% foliar spray) and inoculation of seed with ZSB and 20 kg $\text{ZnSO}_4 \text{ ha}^{-1}$ along with 0.5% foliar sprays at the FI and PF stages substantially enhanced nutrient acquisition in mungbean. Such integrated zinc and iron management practices also improved grain zinc concentration, indicating considerable potential for addressing zinc malnutrition and mitigating hidden hunger among the rapidly growing population. Finally concluded that, the application of 20 kg $\text{ZnSO}_4 \text{ ha}^{-1}$ along with seed inoculation and foliar sprays of ZnSO_4 (0.5%) at flower initiation and pod formation stages proved most effective in enhancing nutrient content and accumulation of photosynthates.

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2.50 Enhancing apparent recovery of Zn through moderating the zinc application mode under Arjun (*Terminalia arjuna* L.) - mung bean intercropping system utilizing residual benefits of nutrients

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Keywords: Arjun, Mung bean, Intercropping, Zinc use efficiency.

1. Background

Soil fertility is one of the most important factors influencing crop growth, productivity and sustainability of agricultural systems. Intensive cropping and imbalanced use of fertilizers have resulted in the depletion of several essential nutrients from soil. Although the application of macronutrients such as nitrogen, phosphorus and potassium has increased over the years, micronutrient deficiencies have become a major constraint to crop production (Alloway, 2008). Among the micronutrients, zinc plays a vital role in plant growth and development. It is involved in enzyme activation, protein synthesis, photosynthesis and regulation of plant growth hormones. Deficiency of zinc not only reduces crop yield but also affects the nutritional quality of agricultural produce. In India, a large proportion of soils are deficient in available zinc due to factors such as high soil pH, low organic matter content, calcareous nature of soils and excessive application of phosphorus fertilizers (Arunachalam *et al.*, 2013).

2. Materials and Methods

The field experiment was conducted during the summer season under an Arjun (*Terminalia arjuna* L.)-mung bean intercropping system under semi-arid conditions at the research farm of Kalam Agricultural College, Kishanganj. The experiment was laid out to study the effect of different modes of zinc application on crop performance, zinc uptake and apparent recovery of zinc. Mung bean (*Vigna radiata* L.) was grown as the intercrop between rows of Arjun trees following recommended agronomic practices. The experiment consisted of eight treatments of zinc application and was laid out in a Randomized Block Design (RBD) with appropriate replications. Zinc was applied in the form of zinc sulphate heptahydrate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) through soil and foliar application at different growth stages of mung bean. The treatments were T₁ – Control (without Zn application), T₂ – Basal soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 5 kg Zn ha⁻¹, T₃ – Soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 5 kg Zn ha⁻¹ + foliar spray of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 0.5% at maximum vegetative growth stage, T₄ – Soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 5 kg Zn ha⁻¹ + foliar spray of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 0.5% at initiation of flowering, T₅ – Soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 5 kg Zn ha⁻¹ + foliar spray of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 0.5% at pod formation stage, T₆ – Soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 5 kg Zn ha⁻¹ + foliar spray of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 0.5% at maximum vegetative growth stage + 0.5% at initiation of flowering, T₇ – Soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 5 kg Zn ha⁻¹ + foliar spray of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 0.5% at maximum vegetative growth stage + 0.5% at pod formation stage, T₈ – Foliar application

of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ thrice @ 0.5% at maximum vegetative growth stage, @ 0.5% at initiation of flowering and @ 0.5% at pod formation stage.

3. Results and Conclusion

Different modes of zinc application significantly influenced grain yield, straw yield and harvest index of mung bean under the Arjun (*Terminalia arjuna* L.)–mung bean intercropping system. Grain yield ranged from 765.3 kg ha^{-1} in the control (T_1) to 872.3 kg ha^{-1} in treatment T_6 , where soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 5 kg Zn ha^{-1} was combined with foliar sprays at the maximum vegetative stage and initiation of flowering. This represents an increase of approximately 14% over the control. Treatments receiving combined soil and foliar application of zinc (T_3 – T_7) generally recorded higher grain yield than either soil application alone or foliar application alone. Straw yield followed a similar trend, with the highest value ($3402.3 \text{ kg ha}^{-1}$) observed in T_6 , while the lowest ($3255.3 \text{ kg ha}^{-1}$) was recorded in the control treatment.

Zinc concentration in grain, straw and root increased significantly with zinc application. Grain Zn concentration increased from 20.9 mg kg^{-1} in the control (T_1) to 35.8 mg kg^{-1} in treatment T_6 , which recorded the highest value. Similarly, straw Zn concentration increased from 29.5 mg kg^{-1} in the control to 40.5 mg kg^{-1} in T_6 . Root Zn concentration also increased markedly with zinc application, with the maximum value (105.4 mg kg^{-1}) observed in T_6 . Zinc application significantly improved grain nutritional quality. Grain protein content increased from 21.5% in the control to 24.9% in T_6 , indicating better nitrogen metabolism and protein synthesis due to adequate zinc supply. Zinc uptake by grain, straw and total biomass increased significantly with zinc fertilization. Grain Zn uptake increased from 16.0 g ha^{-1} in the control to 31.3 g ha^{-1} in treatment T_6 . Similarly, Zn uptake in straw increased from 96.2 g ha^{-1} in the control to 137.9 g ha^{-1} in T_6 . Total biomass Zn uptake also increased from 112.2 g ha^{-1} in the control to 169.2 g ha^{-1} in T_6 .

Among the treatments, soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 5 kg Zn ha^{-1} combined with two foliar sprays of 0.5% ZnSO_4 at the maximum vegetative stage and initiation of flowering (T_6) recorded the highest grain yield, straw yield, zinc concentration in grain and straw and zinc uptake. This treatment also resulted in higher protein content and lower phytic acid content in grain, which significantly reduced the phytate–zinc molar ratio, indicating improved zinc bioavailability.

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2.51 Soil Nutrient Availability and Uptake in Safed Musli as Influenced by Enriched Compost and Humic Acid

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Keywords: Safed Musli, Enriched compost, Humic acid, Nutrient uptake, Nutrient availability.

1. Background

Intensive cropping and indiscriminate use of chemical fertilizers have resulted in soil nutrient depletion, declining productivity and environmental degradation, necessitating integrated approaches for sustainable agroecosystem management (Tejada *et al.*, 2009). In this context, efficient soil, water and nutrient management through organic amendments plays a critical role in maintaining soil health and resource use efficiency. Enriched compost, derived from organic residues and enriched with NPS nutrients, enhances soil fertility, improves soil structure, increases water holding capacity and stimulates microbial activity thereby ensuring sustained nutrient release and improved nutrient cycling. Additionally, humic acid, applied as a foliar spray, functions as a bio-stimulant by promoting root proliferation, enhancing nutrient uptake efficient, improving chlorophyll synthesis and regulating plant physiological processes (Calvo *et al.*, 2014). The integration of enriched compost and humic acid represents an effective strategy to enhance soil quality, optimize nutrient dynamics and improve crop performance. Therefore, the present investigation was undertaken to assess the combined effects of enriched compost and foliar application of humic acid of nutrient availability and its uptake by Safed Musli, with an emphasis on promoting sustainable productivity and resource conservation in agroecosystems.

2. Material and Methods

The experiment was conducted in a randomized block design with nine treatments and three replications on clayey Inceptisol (pH 8.11). Treatments included application of NPS compost and vermicompost at specified doses, along with foliar sprays of humic acid at 60 and 90 DAP.

Soil samples (0-20 cm) were collected before sowing and after harvest, processed and analysed for chemical properties. Available nitrogen by alkaline KMnO₄ method (Subbiah and Asija, 1956), available phosphorus by Olsen's method (Watanabe and Olsen, 1965), available potassium by neutral ammonium acetate extraction (Jackson, 1973) and sulphur by CaCl₂ extractable method (Chesnin and Yien, 1951) were analysed. Plant samples were collected at harvest, proceed and analysed for nutrient content using standard digestion and analytical methods. Nutrient uptake was computed based on concentration and dry matter yield. The recorded data were statistically analysed using ANOVA to evaluate treatment effects on soil properties and nutrient dynamics under different organic nutrient management practices.

3. Results and conclusion

The treatment comprising NPS compost @ 4.5 t ha⁻¹ along with two foliar sprays of 0.5 % humic acid (at 60 and 90 DAP) consistently recorded highest total nutrient uptake with nitrogen (14.28 kg ha⁻¹), phosphorus (4.60 kg ha⁻¹), potassium (15.68 kg ha⁻¹) and sulphur (2.38 kg ha⁻¹), remaining statistically at par with NPS compost @ 3.0 t ha⁻¹ with humic acid and selected vermicompost based treatments. These treatments were significantly superior to the absolute control, indicating enhanced nutrient availability and uptake efficiency under organic nutrient

management. Available nutrient status showed a similar trend, with highest available nitrogen ($266.83 \text{ kg ha}^{-1}$), phosphorus (30.04 kg ha^{-1}) and sulphur (13.10 mg kg^{-1}) recorded under the same treatment, remaining at par with other integrated organic treatments. This highlights the role of enriched compost and humic substances in improving nutrient retention, mineralization, and bioavailability. Overall, application of NPS enriched compost along with two foliar sprays of 0.5 % humic acid (at 60 and 90 DAP) significantly improved nutrient availability and nutrient uptake in Safed Musli.

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2.52 Feedstock-Driven Variability in Biochars Produced under Uniform Pyrolysis and Its Implications for Soil Health, Climate Mitigation, and Carbon Crediting Potential

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Keywords: Biochar, Pyrolysis, Soil Health, Carbon Sequestration

1. Background

Biochar, a carbon-rich product of biomass pyrolysis, has gained significant attention as a multifunctional material capable of addressing soil degradation, enhancing agricultural productivity, and contributing to climate change mitigation through long-term carbon sequestration. Global evidence demonstrates that biochar properties are strongly feedstock-dependent even under standardized thermal conditions (Lehmann and Joseph 2015). In this study, eleven biochars (B1–B11) were produced from a diverse range of locally available feedstocks using identical slow pyrolysis conditions to isolate and quantify the effect of feedstock variability on biochar characteristics relevant to soil health and climate mitigation.

2. Material and Methods

The feedstocks included agricultural residues such as rapeseed stover (B1), maize stover (B2), rice straw (B7), rice chaff (B8), and wheat straw (B9); woody materials including apple prunings (B3), elm wood (B4), pear wood (B5), willow wood (B6), and implied poplar shavings; as well as chinara leaves (B10) and walnut shells (B11). A drum-in-kiln setup was used, consisting of an inner 150-liter coal tar drum reactor within a brick kiln. Pyrolysis was carried out at a controlled moderate temperature of 450–550 °C, monitored via thermocouple, with airflow regulated through a bottom ventilation hole to maintain uniformity. After carbonization, the biochars were cooled, collected, and micronized to <2 mm particle size for characterization. Physico-chemical, mineralogical (XRD), and microstructural (SEM-EDS) analyses were performed following established characterization protocols (Enders *et al.* 2012).

3. Results and conclusion

Physico-chemical analysis revealed that all eleven biochars were distinctly alkaline, with pH values ranging from 8.80 (chinara leaves, B10) to 10.45 (rice straw, B7). This alkalinity, typical of biochars produced at moderate temperatures due to the concentration of base cations as carbonates and oxides, positions them as potential liming agents for acidic soils (Yuan and Xu 2011). Electrical conductivity (EC), an indicator of soluble salt content, varied widely from 2.29 dS m⁻¹ (pear wood, B5) to 7.58 dS m⁻¹ (elm wood, B4), suggesting differences in salinity risk upon soil application. Nutrient profiles further highlighted feedstock-driven differences. Nitrogen (N) content ranged from 0.09% (pear wood, B5) to 0.75% (wheat straw, B9), with straw-based biochars (B7, B8, B9, B2) generally retaining higher N levels. Phosphorus (P) was low overall but reached 0.47% in rice straw (B7) and 0.37% in maize stover (B2). Potassium (K), the most variable macronutrient, peaked at 3.82% in maize stover (B2) and 3.21% in elm wood (B4), while remaining below 0.4% in apple prunings (B3), pear wood (B5), and walnut shells (B11). These patterns align with the inherent mineral composition of herbaceous versus woody feedstocks, where agricultural residues often concentrate more ash-derived nutrients.

XRD analysis revealed distinct mineralogical fingerprints that varied systematically with feedstock identity. Calcite was a recurring phase across several biochars, particularly in leaf

and wood-derived samples, contributing to their strongly alkaline character. Quartz and aluminosilicate minerals including albite and illite were characteristic of cereal straw biochars, consistent with the high silica phytolith content of graminaceous feedstocks. Graphitic carbon phases were detectable in certain stover and hardwood biochars, suggesting a comparatively higher degree of carbon structural ordering with implications for stability and recalcitrance in soil. Periclase was associated predominantly with wood and pruning-derived biochars, while phosphate-bearing mineral phases were identifiable in rapeseed stover biochar, broadly consistent with its elevated bulk phosphorus content. Walnut shell biochar was mineralogically distinct, exhibiting mica-type phases not observed in the remaining samples. Collectively, XRD confirmed that the ash-associated crystalline fraction carries a qualitatively unique mineralogical signature for each feedstock class.

Scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS) confirmed high carbon content in all samples, ranging from 65.1 wt% (wheat straw, B9) to 92.6 wt% (apple prunings, B3). Oxygen levels varied inversely (6.7–26.8 wt%), indicating differences in residual oxygenated functional groups that support cation exchange and sorption capacity. Straw-based biochars displayed elevated silicon and aluminum signals (e.g., wheat straw B9: Si 3.1%, Al 1.1%; rice straw B7: Si 1.8%), consistent with quartz and silicate phases detected by XRD. Calcium and potassium were detectable in most samples, with higher Ca in rapeseed stover (B1: 2.0%), wheat straw (B9: 2.4%), and chinara leaves (B10: 2.5%). Phosphorus appeared at low but measurable levels (0.2–0.5%) in several samples. The high carbon matrix with dispersed minerals suggests a porous structure typical of biochar, offering potential for water retention, microbial habitat, and pollutant sorption.

Collectively, these results demonstrate that biochars produced from different feedstocks—even under uniform pyrolysis conditions—exhibit substantial and consistent divergence in pH, EC, nutrient composition, mineralogy, porosity, and elemental structure. These variations dictate their optimal applications. Herbaceous and straw-derived biochars, with higher nutrient contents and alkaline mineral phases, are suitable for soil fertility enhancement, pH correction, and short-term agronomic benefits. Woody biochars, especially those with elevated carbon content and graphite-like phases (apple prunings, elm, walnut shells), offer enhanced carbon sequestration longevity and thus greater relevance for carbon crediting systems emphasizing permanence criteria. Biochars with zeolitic or aluminosilicate phases may contribute to nutrient retention, ammonium adsorption, and long-term soil health benefits.

Importantly, the climate-mitigation potential varies across feedstocks: char stability is greatest in carbon-rich woody materials, while nutrient-rich crop-residue chars offer co-benefits through fertilizer replacement and potential reduction in nitrous oxide emissions. This spectrum of properties supports a situation-specific utilization strategy in which biochar should be selected according to targeted agroecosystem functions—soil amelioration, nutrient cycling improvement, liming, or long-term carbon storage.

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2.53 Integrated Farming System Approach for Nutritional Security and Economic Empowerment of Rural Livelihood of District Jammu

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Keywords: Integrated Farming System (IFS), Small and marginal farmers, Livelihood enhancement, Nutritional security, Sustainable agriculture

1. Background

In India, 85 % of the land holding are small and marginal. The per capita availability of agriculture land has been decreased from 0.638ha in 1950-51 to 0.271ha by the end of the century. This situation is further alarming among Scheduled Caste (SC) farmers (Kumar and Narayanagowda, 2017). Declining trend in size of land holding under climate change scenario possess a serious challenge to sustainability and profitability of farmer as well farm. Jammu district of UT of J&K comprises of more than 24 % Schedule Caste population. The traditional monoculture production system adopted by these farmers has been explorative and the natural resources like soil and water were subjected to immense pressure beyond carrying capacity. This suggests an urgent need of integrated farming system where the various components of the farming system may be integrated to improve productivity and profitability as well as resource conservation.

Keywords: Integrated farming system, Monoculture, Profitability, Sustainability.

2. Material and Methods

The participatory research programme based on IFS model was conducted for four consecutive years from 2019-2023 under Schedule Caste Sub Plan Programme of OFR, AICRP-IFS in district Jammu of UT of J&K. A total of 150 beneficiary SC farmers with predominant farming system of Crop+ Dairy were identified in two villages i.e. Dabbar & Sheikhpur (Arnia & Bishnah blocks) of Jammu district with average holding size of 0.45 ha to improve their livelihood, nutritional security & income of existing farming system through holistic approach i.e. high yielding varieties, crop diversification, mushroom cultivation, backyard poultry & Nutritional Kitchen Gardening (NKG). The interventions were made in crop module i.e. Replacement of Basmati 370 rice variety with short-duration Sharbati rice with balanced fertilizer doses to optimize cropping calendar, Vegetable pea was introduced in place of *Rabi* crops and Okra (Ladyfinger) was introduced in summer season in existing Rice based cropping systems for higher profitability and as better nutrition. In livestock module, round-the-year availability of green fodder was ensured, balanced nutrition through feed supplements and animal health kits were provided to milch animals not only improve their health but also increase the milk production by clean milking. Furthermore, poultry component is added to diversify livestock income sources. Nutritional Kitchen Gardens (NKG) & fruit plants were also established to improve household-level nutrition and Mushroom cultivation was added as a low-cost, high-return enterprise.

3. Results and Conclusion

Schedule caste farmers of Dabbar & Sheikhpur villages show a significant increase in gross household income due to better crop combinations and integrated livestock practices. Introduction of poultry and mushroom units provided round the year income, reducing dependency on seasonal

agriculture. Kitchen gardens and vegetable diversification helped address household nutritional deficiencies. The shift to short-duration crops and year-round fodder supply contributed to more efficient use of natural resources. The results from 0.45 ha Crop+ Dairy farming system indicated a positive economic impact on agricultural performance of the SC farmers over the observed period. As depicted in Table, before the interventions, cost was ₹60,000 per year, which gradually increased to ₹69,250 by the impact year. Despite this rise in costs, the gross return improved significantly from ₹168,910 at the benchmark stage to ₹224,616 (increased by about 32.9%) in the impact year. Consequently, the net income saw a substantial increase from ₹108,910 to ₹155,366, reflecting a growth of approximately 42.6%. Additionally, the Benefit-Cost (B:C) ratio improved from 2.81 before the intervention to 3.20 in the impact year, indicating enhanced economic efficiency and profitability. These trends suggest that the intervention successfully contributed to increased returns and better financial outcomes for farmers over time. It is concluded that Schedule caste farmers with minimal additional investment per household of Dabbar & Sheikhpur villages not only boosted income but also enhanced sustainability, nutrition, and resilience of farming systems

Table1: Economics of Crop + Dairy Farming System (Area: 0.45 ha)

Parameters	Benchmark (Before intervention)	Low cost-based intervention period (years)			Impact year (2022-2023)
		2019-2020	2020-2021	2021-2022	
Cost of cultivation (₹/year)	60000	66000	66000	67000	69250
Gross Return (₹/year)	168910	200910	204800	204025	224616
Net income (₹/year)	108910	134910	138800	137025	155366
B: C ratio	2.81	3.04	3.10	3.04	3.2

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2.54 Integrated farming System Model for Sustainable farm income of Small and Marginal Farmers Under Irrigated Conditions of Jammu Region

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Keywords: Farmers, Integrated farming system, Profitability, Sustainability

1. Background

Indian agriculture is currently facing a crisis due to declining profitability, shrinking landholdings, high input costs, and environmental degradation, all worsened by climate change. To address these challenges and enhance farmer income, Integrated Farming System (IFS) offers a sustainable solution by integrating crops, livestock, horticulture, poultry, and fisheries, while promoting resource recycling and reduced input dependence (Walia & Kaur, 2020). Overuse of chemical inputs, especially in dominant systems like rice–wheat, has degraded natural resources and biodiversity. IFS offers a pathway to sustainable productivity, diversified income, and rural revitalization aligned with the goal of doubling farmers' income.

2. Material and Methods

A field experiment was carried out in 2017-23 at Research farm of AICRP-IFS, Chatha SKUAST-J, UT of Jammu & Kashmir, India under irrigated & Sub-tropical climatic conditions. One ha Integrated Farming System (IFS) model comprising of cropping systems (Rice-wheat-green manuring, Rice-potato-blackgram, Rice-mustard-greengram and Berseem + oat-maize + sorghum with hybrid napier on bund) in 0.52 ha + horticulture (Guava as main crop, Lemon & mango (Amarpali) as boundary crop and broccoli, Knol Khol, Palak, Cauliflower, Radish, turmeric & fodder as intercrops) in 0.32 ha + Dairy (2 cows, 1 buffalo heifer) including 2 m³ bio-gas and vermicompost unit in 0.08 ha + fish cum poultry in 0.1 ha + mushroom (button & dhingri).

3. Results and Conclusion

Rice Equivalent Yield (REY) ranged from 244.3 to 176.1 t/ha/year and may probably be due to the price fluctuation of Rice, while cultivation costs rose steadily, peaking at ₹570,299/ha in 2022–23. Highest gross returns (Rs. 880912) were realized in 2022-23, whereas highest net returns were recorded in 2021-22 (Rs. 321499). The Sustainable Yield Index (SYI) ranged from 0.853 to 0.801 which showed that the integrated farming system is sustainable in nature due to better resilience and resource efficiency. Labour use remained stable, suggesting consistent employment generation

Integrated Farming Systems (IFS) offer a sustainable solution to enhance smallholder farmer income by efficiently utilizing resources like soil, water, livestock, and crops. The IFS model developed at SKUAST-Jammu, which includes dairy, vermicompost, and biogas, generated high returns (₹3.05 lakh/ha/year), reduced input costs by 40%, and created 482 man-days/ha/year of employment. It promotes self-sufficiency, entrepreneurship, and ecological sustainability. Future research should prioritize IFS for resilient, business-oriented farming.

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Theme 3:

Livestock, fodder systems, Fisheries and Allied sectors under climate change



3.1 Climate-Smart Vacuum Feeding Strategies for Rainbow Trout in Recirculating Aquaculture Systems

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Keywords: Climate change, Feed efficiency, Rainbow trout, RAS, Vacuum feeding

1. Background

Feed management remains one of the most important determinants of aquaculture sustainability, accounting for a major share of operational costs and contributing significantly to waste generation. Under climate change scenarios, inefficient feeding not only increases production costs but also exacerbates water quality deterioration, especially in intensive systems. RAS are eco-friendly, water efficient, highly productive and climate-resilient solutions of intensive farming systems (Nesar Ahmed et al, 2021). However, RAS performance is highly dependent on precise feed management to maintain optimal water quality and fish health. Vacuum feeding systems represent an emerging feeding technology designed to deliver feed more efficiently while minimizing losses. Moreover, the use of vacuum spraying of thermolabile liquid components on the extruded pellets will allow to obtain highly digestible feed (Ageets V et al, 2019). Integrating vacuum feeding within RAS has the potential to improve feed conversion efficiency, reduce organic waste loads, and enhance overall system resilience to climate change.

2. Material and methods

This review is based on a systematic examination of scientific literature focusing on feed management in recirculating aquaculture systems (RAS), vacuum feeding technologies. Published studies were selected based on their relevance to cold-water aquaculture systems. The collected literature was critically analysed and synthesized to evaluate the role of vacuum feeding as a climate-smart feed management strategy in RAS.

3. Results and Conclusion

Recirculating aquaculture systems (RAS) provide a highly controlled production environment, allowing continuous water treatment and tight regulation of critical parameters such as total ammonia nitrogen (TAN), dissolved oxygen, and suspended solids, which are essential to fish health and productivity. In intensive systems, excess feed and organic waste can rapidly elevate TAN and degrade water quality, leading to stress and reduced performance if not managed effectively. Efficient feeding strategies that match fish appetite help minimize uneaten feed and organic load, thereby supporting stable water quality and reducing peaks in toxic nitrogenous compounds. While specific studies on vacuum feeding are emerging, appetite-based or automated feeding controls in RAS have been shown to improve feed utilization and prevent waste accumulation that contributes to TAN fluctuations. Integration of advanced feeding technologies such as vacuum feeding is therefore a promising climate-smart strategy to enhance feed efficiency, environmental performance, and resilience in rainbow trout RAS production.

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3.2 Constraints Faced by Integrated Agri-Aquaculture Farmers in the Subtropical Region of Jammu

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Keywords: Aquaculture, Environmental, Sustainability, Subtropical

1. Background

Aquaculture has emerged as the most rapidly expanding food production system over the last two decades (FAO, 2018) and is increasingly recognized as a viable and profitable approach in the food sector. Integrated agri-aquaculture-based enterprises play a significant role in poverty reduction, risk minimization in production and the enhancing household nutritional security by ensuring a regular supply of high-quality protein, creating income and employment opportunities and improving overall farm sustainability (Little *et al.*, 2016). Integrated agri-aquaculture (IAA), in particular, offers substantial potential for enhancing farmers' income through efficient utilization of land and water resources. Despite technological advancements and institutional support, the performance of IAA at the field level often remains below its potential due to various constraints faced by farmers. Farmers practicing IAA encounter a range of environmental, social and disease constraints that hinder the effective adoption of improved IAA practices. Understanding these constraints from the farmers' perspective is essential for designing need-based extension interventions and policy measures aimed at strengthening IAA development.

2. Materials and Methods

The present study was carried out in the Jammu region of Jammu and Kashmir. Jammu and Samba districts were purposively selected as they lie in the subtropical agro-climatic zone of the region. A total sample of 20 integrated agri-aquaculture practising farmers was randomly selected from these two districts for the investigation.

3. Result and Conclusion

The Table 1 indicates that among environmental constraints, change in temperature was reported as the most severe problem, affecting 75 per cent of the respondents. This indicates that temperature fluctuations pose a serious threat to fish survival and productivity. Poor quality of water was the next major constraint, reported by 45 per cent of the farmers, suggesting issues related to pollution or unsuitable water parameters. Under disease and health problems, non-availability of timely medicines emerged as the most important constraint, reported by 65 per cent of the farmers. Regarding social constraints, traditional beliefs and taboos were reported by 50 per cent of the respondents, indicating resistance to scientific fish farming practices.

Table1: Constraints faced by the integrated agri-aquaculture practising farmers regarding

S. No.	Constraints*	Frequency (N=20)	Percentage (%)
A.	Environmental Constraints		
1.	Water scarcity	2	10
2.	Excess rainfall	5	25
3.	Poor quality water	9	45
4.	Change in temperature	15	75
B.	Disease and Health Problems		
1.	Fish frequently suffer from disease	11	55

2.	Timely medicines	13	65
3.	Fish mortality	10	50
C.	Social Constraints		
1.	Social conflicts with neighbour	8	40
2.	Traditional beliefs and taboos	10	50
3.	Loss of fish due to Theft	9	45

Multiple Responses*4. References:**

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3.3 Microscopic Architecture of the Exocrine Pancreatic Duct System in Gurez sheep (*Ovis aries*)

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Keywords: Gurez, Digestion, Duct System, Exocrine, Pancreas.

1. Background

In Gurez valley, sheep and goats account for around 70% of household livestock, mainly reared for mutton and wool as by-product (Shaheen et al 2017). Compared to the exotic breeds and crossbreds, Gurez breed of sheep is well adapted to the harsh winters of the Gurez valley and are known for their sturdiness, disease resistance and fecundity. Pancreas of mammals is a unique gland as it consists of both exocrine and endocrine portions (Yuan et al 2021). Pancreas is a major accessory digestive organ that secretes digestive enzymes into the duodenum.

2. Materials and methods

The current investigation was undertaken at the Division of Veterinary Anatomy and Histology, F.V.Sc. and A.H., SKUAST-K, Shuhama. The pancreas of apparently healthy Gurez sheep were gathered from slaughter houses in the Gurez valley, regardless of sex. For histological studies, tissue pieces of about 2mm were collected from different lobes of the gland and kept in small vials containing fixatives like Neutral buffered formalin. The tissue specimens were processed by routine alcohol –xylene schedule and paraffin blocks were prepared (Luna, 1968). Sections of about 5–7-micron thickness were obtained, cleared in xylene and rehydrated in descending grades of alcohol and subsequently used for staining. Statistical analysis was performed on the mean values of the micrometric parameters to compare the various regions of the pancreas using one way analysis of variance followed by critical difference test (Snedecor and Cochran 1967). A probability of $P < 0.05$ was considered as statistically significant.

3. Results and conclusion

The duct system within the exocrine pancreas of Gurez sheep was initiated by the centroacinar cell found in the lumen of the pancreatic acini. Emerging from the acini, the duct system branched into intercalated, intralobular, interlobular, and the main pancreatic ducts. Intercalated and intralobular ducts were located within the lobule, while interlobular and main pancreatic ducts were situated in the interlobular connective tissue. The centroacinar cells exhibited an indistinct cell boundary, oval nuclei with the cytoplasm devoid of any granules unlike the acinar cells. The intercalated ducts served as a connection between the secretory acini and the intralobular ducts, characterized by a lining of simple squamous to simple low cuboidal epithelium. Due to the compact nature of the pancreatic parenchyma in sheep, acini were closely positioned to intralobular ducts. The intralobular ducts were lined by simple low cuboidal to tall cuboidal or occasionally low columnar epithelium. The interlobular ducts were found in the connective tissue between the lobules with the epithelium ranging from simple columnar to simple to stratified cuboidal and showed presence of goblet cells. Medium and large-sized islets, surrounded by blood vessels, were frequently observed in the walls of interlobular ducts. Occasionally, acini could also be seen in the lamina propria of these ducts. The primary ducts of pancreas were expansive, featuring a large lumen and exhibited a lining of columnar epithelium, ranging from simple tall columnar to pseudostratified columnar epithelium with abundant goblet cells in the lining epithelium. The

cellular height of the lining epithelium of the ducts progressively increased from intercalated to interlobular ducts, accompanied by a gradual enlargement of the luminal size and the connective tissue envelope surrounding the ducts. Larger ducts, due to their increased size, exhibited mucosal folding compared to the smaller ducts.

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3.4 Farm Diversification as a Climate Change Adaptation Strategy: Evidence from Integrated Crop–Livestock Systems

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Keywords: Crop–livestock integration, Farming system diversification, Integrated farming system

1. Background

Climate change poses a serious challenge to agricultural sustainability through increased climatic variability, extreme weather events, and resource degradation. Small and marginal farmers are particularly vulnerable due to their dependence on climate-sensitive cropping systems. In this context, diversification of farming systems, especially through integration of crops with livestock enterprises, has emerged as an important climate change adaptation strategy that enhances resilience, stabilizes farm income, and ensures food security. The present study was undertaken to assess the extent of crop and livestock diversification across different farming systems and examine the role of diversification in enhancing climate resilience

2. Material & Methods

The present study was conducted in three villages of Jammu district namely Chak Bana, Kothi Morh and Chak Marja which comprised three major farming systems, namely FS-I (Crop + Dairy), FS-II (Crop + Dairy + Goatry), and FS-III (Crop + Dairy + Poultry), each represented by 10 farm households. In crop enterprises both kharif and rabi crops were included and incase of livestock dairy, poultry and goatry were included simultaneously. Crop and livestock diversification were quantified using the Simpson Index (SI) and Herfindahl Index (HI). Higher SI values indicate greater diversification, while lower HI values reflect reduced enterprise concentration. Descriptive analysis was used to interpret diversification patterns in relation to climate change adaptation.

3. Results and Conclusion

The results of the study revealed a balanced representation of farming systems across the study area (Table 1), indicating widespread adoption of integrated farming practices. Among the systems, FS-II (Crop + Dairy + Goatry) exhibited the highest crop diversification (SI=0.53; HI=0.46) as well as the highest livestock diversification (SI=0.60; HI=0.39) (Table 2). In contrast, FS-I recorded comparatively lower diversification indices, particularly for livestock enterprises. The inclusion of goatry in FS-II significantly enhanced enterprise diversity, thereby reducing dependency on a single income source. FS-III (Crop + Dairy + Poultry) showed moderate levels of diversification, suggesting its potential to provide income stability under climate-induced production risks.

Table 1: Statistics of Farming Systems in the Study Area

Farming System	Enterprises	Frequency
FS -I	Crop + Dairy	10
FS -II	Crop + Dairy + Goatry	10
FS -III	Crop + Dairy + Poultry	10

Table 2: Crop and Livestock Diversification Index

Farming system	Crop Diversification index		Livestock Diversification Index	
	SI	HI	SI	HI
FS -I	0.50	0.49	0.42	0.57
FS -II	0.53	0.46	0.60	0.39
FS -III	0.49	0.50	0.44	0.55

Overall, the findings indicate that IFS enhance diversification and livelihood resilience. FS-II (Crop + Dairy + Goatry) emerged as the most diversified system in both crop and livestock enterprises, highlighting the crucial role of goatry in broadening income sources and reducing risk. FS-III also demonstrated moderate diversification, suggesting its suitability for income stability under climate variability, while FS-I showed relatively limited diversification potential.

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3.5 Overcoming Challenges to Sustainable Fodder Production in Bangladesh: An Agroforestry-Based Approach

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Keywords: Agroforestry, Livestock, Napier grass, and Nitrogen fertilization

1. Background

Bangladesh faces persistent fodder shortages driven by land scarcity, climate variability, and competing demands for food crops. The livestock sector, a critical pillar of rural livelihoods, depends largely on low-quality residues such as rice straw, which limits animal productivity (Huque and Sarker, 2014). Climate vulnerability further intensifies feed insecurity (Akter and Rahman, 2012; Ali *et al.*, 2019). Agroforestry offers a pathway to intensify production sustainably by integrating trees with forage crops, thereby improving land-use efficiency and nutrient cycling (Dagar and Tewari, 2017; Jose, 2009). Among tropical forages, Napier grass (*Pennisetum purpureum*) stands out due to its rapid regrowth, high biomass yield, and strong response to nitrogen fertilization (El Bassam, 2010; Islam *et al.*, 2024). However, tree canopy structure influences light availability and nutrient dynamics, which in turn affect forage performance (Pandey *et al.*, 2011; Cardinael *et al.*, 2017). Despite its potential, limited information exists on optimizing nitrogen rates for Napier under fruit tree-based systems in Bangladesh. This study therefore evaluated Napier growth, yield, and economic returns under mango (*Mangifera indica*), litchi (*Litchi chinensis*), and moringa (*Moringa oleifera*) systems compared with sole cropping, across four nitrogen levels (0, 50, 100, and 150 kg N ha⁻¹).

2. Materials and Methods

The experiment was conducted at Hajee Mohammad Danesh Science and Technology University, located in Agro-Ecological Zone 1 (AEZ-1). The soil of the experimental field was sandy loam with a pH of 5.6. The study followed a two-factor Randomized Complete Block Design with three replications. Factor A comprised four production systems: Mango + Napier (S1), Litchi + Napier (S2), Moringa + Napier (S3), and Sole Napier (S4). Factor B included four nitrogen levels: 0, 50, 100, and 150 kg N ha⁻¹. Napier cuttings were planted at a spacing of 60 cm × 80 cm. Organic manure, consisting of cow dung and compost, was applied uniformly during land preparation, while nitrogen fertilizer was applied according to the specified treatments. Data on plant height, leaf number, leaf length and breadth, collar diameter, tiller number, and fresh biomass yield were recorded at 30, 60, and 90 days after planting. Economic analysis was carried out by estimating gross return, net return, and benefit–cost ratio following Islam *et al.* (2004). Statistical analysis was performed using analysis of variance, and treatment means were compared using the least significant difference test at the 5% level of significance.

3. Results and Conclusion

The study found out that Nitrogen application, production system and economic returns clearly shown that the progressive increase in nitrogen rates to 150 kg N ha⁻¹ affects the overall yield and productivity of Napier grass. Fresh biomass yield increased substantially from 7.91 t ha⁻¹ without nitrogen to 13.68 t ha⁻¹ at 150 kg N ha⁻¹. These results confirm the strong significant interaction between nitrogen level and production system. The highest biomass yield (15.40 t ha⁻¹) was

achieved under the Moringa–Napier system with 150 kg N ha^{-1} , closely followed by Sole Napier at the same nitrogen rate (15.27 t ha^{-1}). On the other hand, the lowest yield (6.46 t ha^{-1}) occurred in the Litchi–Napier system without nitrogen application. These findings indicate that nitrogen use efficiency is maximized when combined with ecologically compatible tree species. The superior performance of Moringa + Napier systems under all nitrogen levels can be explained by the favorable microclimatic and edaphic conditions created by Moringa. Its sparse canopy ensures optimal light penetration, while nutrient-rich leaf litter accelerates nutrient cycling and improves soil organic matter, enhancing nitrogen-use efficiency (Saran *et al.*, 2017). In contrast, the low yields in Litchi-based systems reflect the suppressive effects of heavy shading and root competition, which exacerbate nutrient limitations, especially in the absence of external fertilizer inputs. This aligns with evidence from other agroforestry studies where complementary interactions between trees and forages improved resource capture and productivity (Atumo *et al.*, 2021).

From the economical point of view, the highest net return (USD 1,746 ha^{-1}) and benefit–cost ratio (3.73) were obtained from the Moringa–Napier system with 150 kg N ha^{-1} . The Litchi–Napier system at the highest nitrogen level also showed strong profitability (BCR 3.25), whereas Sole Napier under low nitrogen resulted in negative returns (BCR 0.78). Therefore, tree-based production systems demonstrated clear economic superiority over sole cropping, confirming the financial viability of integrated agroforestry systems, as supported by Islam *et al.* (2014).

Nitrogen fertilization and production systems significantly influenced Napier growth, yield, and profitability. The application of 150 kg N ha^{-1} maximized vegetative growth and biomass production. Therefore, integrating Napier grass with moringa under moderate-to-high nitrogen fertilization provides a sustainable strategy for improving fodder supply, farm income, and resilience in Bangladesh’s climate-vulnerable landscapes.

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3.6 Effects of Crossbreeding on Growth and Morphometric Traits of Sheep Genetic Groups in Jammu and Kashmir

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Keywords: Crossbreeding, Genetic conservation, Indigenous sheep, Morphometric traits

1. Background

Sheep husbandry is central to the rural economy of Jammu and Kashmir, where diverse agro-climatic conditions support indigenous breeds such as Karnah, Gurez, Poonchi, Changthangi and Bakerwal. These native sheep are well adapted to harsh environments, disease pressure and migratory systems. However, prolonged and unregulated crossbreeding with exotic fine-wool breeds, particularly Rambouillet and Merino, has altered their phenotypic and genetic structure. Morphometric studies have revealed clear inter-breed differentiation, emphasizing the need for breed-specific conservation strategies (N. N. Khan *et al.*, 2023). Recent evaluations of Gurez sheep provide updated baseline data on body weight and biometric traits, supporting sustainable utilization and conservation planning (Shanaz *et al.*, 2025).

2. Material methods

Field data were collected from indigenous sheep breeds (Karnah, Gurez, Poonchi, Changthangi, Bakerwal) and their crossbreds with Rambouillet and Kashmir Merino across Jammu, Kashmir, and Ladakh. Body weights from birth to adulthood and biometric traits (body length, height at withers, chest girth, ear length, tail length) were measured. Animals were categorized by sex, age (based on dentition), and genetic group. Least squares analysis was performed using the LSMLMW program, including fixed effects of genetic group and sex, with mean separation by Duncan's Multiple Range Test.

3. Results and Conclusion:

The analysis revealed significant ($P < 0.05$) differences among sheep genetic groups for body weight and morphometric traits under farmers' flocks in J & K. Crossbred sheep recorded higher mean adult body weight (32.8 ± 0.84 kg) compared to indigenous sheep (27.6 ± 0.72 kg). Similarly, crossbreds exhibited greater heart girth (78.4 ± 1.12 cm vs. 71.2 ± 0.96 cm), body length (69.5 ± 0.88 cm vs. 63.7 ± 0.79 cm) and height at withers (66.3 ± 0.91 cm vs. 60.8 ± 0.85 cm). Sex had a significant influence, with males outperforming females in most growth traits. The results indicate positive heterotic effects of crossbreeding on growth performance and body conformation under field conditions. However, indigenous sheep maintained consistent morphometric profiles reflecting their adaptation and genetic distinctiveness while crossbreeding enhances growth and body measurements, indiscriminate breeding may compromise indigenous genetic resources. A structured breeding programme integrating performance selection with conservation of native germplasm is essential for sustainable sheep improvement in Jammu and Kashmir.

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3.7 Exon IV Prolactin (PRL) gene polymorphism and its association with milk production traits in dairy cattle of Kashmir, India

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Keywords: Association, Exon IV, Genotypes, Milk traits and Prolactin gene

1. Background

Prolactin (PRL) is a polypeptide hormone that is synthesized and secreted from specialized cells of the anterior pituitary gland, extremely important in mammogenesis, galactopoietics, lactogenesis (Horseman *et al.*, 1997). It is also primarily responsible for the synthesis of lactose, lipids and all other major components of milk (Le *et al.*, 1994). These characteristics make PRL gene a strong candidate gene for milk traits. In bovines, PRL gene has been mapped to chromosome 23 at 43 cM close to the quantitative trait loci (QTL) about 10 kb in size, includes 5 exons coding for 199 amino acids and 4 introns (Camper *et al.*, 1984 and Hallerman *et al.*, 1988). It is most popular genetic marker used for the genetic characterization of *Bos indicus* cattle.

2. Material and methods

The study was undertaken on 120 dairy cows of two genetic groups Jersey and Crossbred HF cows (60 each) belonging to an organized farm MLRI, SKUAST-K. Daily milk records and milk samples (50ml) each were collected in sterile containers and were analysed for quality using Speedy Lab Milk Auto-analyser for the Fat, Protein, SNF, Lactose, Density and Ash parameters. 10 ml of blood was collected from jugular vein of each animal and genomic DNA was isolated by standard phenol-chloroform extraction method. Primer pair forward 5'CCAAATCCACTGAATTATGCTT 3' and reverse 5'ACAGAAATCACCTCTCTCATTCA3' were used for amplification of Exon IV (294 bp) for amplification (Brym *et al.*, 2005). The PCR products were digested with *Rsa* I (Thermo Scientific) and the restricted fragments were analyzed electrophoretically. The frequency of different genotypes and alleles were calculated by using Popgene 1.31 statistical software. To analyze the Hardy-Weinberg equilibrium of the population software Popgene version= 1.31 (Yeh *et al.*, 1999) was used. The following general linear model was used for obtaining the association followed by Tukey's test using SAS 9.3 statistical software. $Y_{ijk} = \mu + B_j + G_k + E_{ijk}$

Where Y_{ijk} is the observation of i^{th} animal of j^{th} breed with k^{th} genotype, Y_{ijk} is the milk yield/fat yield/ protein yield/ SNF/density/ash/lactose, μ the overall mean, B_j equals 1-2 (Jersey and Crossbred HF), G_k is the 1-3 (genotypes for selected genes), and E_{ijk} is the random error.

3. Results and Conclusion

A specific single band of lengths 294 bp was amplified in both the genetic groups. Exon IV region (294 bp) on digestion revealed three banding pattern and were designated as RR (single band of 294 bp), Rr (three bands 294/162/132 bp) and rr (two bands 162/132bp). In Crossbred HF cows, all the three patterns were present but in Jersey cows genotype rr was absent. The RR genotype was most prevalent in Jersey cows (0.40), and lowest in crossbred cows (0.26). The rr genotype was found only in crossbred HF cows (0.24). The frequency of R allele was highest in Jersey cows (0.70). The crossbred cows harbour the highest frequency of r allele (0.50). The non-significant ($P > 0.05$) Chi-square value for all the genotypes showed that the population was in

Hardy-Weinberg equilibrium. Genotype RR effects were found to be significant ($p < 0.05$) on all yield traits under in Crossbred HF and Jersey cows. The effect of genotype was found to be significant ($p < 0.05$) on protein %, fat % and density in Crossbred HF cows and non-significant ($p > 0.05$) in Jersey cows. The populations of Crossbred HF and Jersey cattle were polymorphic and R allele was commonly found. The effect of genotype was found to be significant ($p < 0.05$) on quality and yield of milk suggesting that Prolactin gene is associated with high yield and quality of milk.

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3.8 Molecular characterization of *HSPB6* Gene in Murrah buffalo (*Bubalus bubalis*) and its association with milk production traits in the sub-tropical climate of India

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Keywords: HSPB6 gene, Murrah buffalo, Heat stress, Marker assisted selection, Production traits

1. Background

The heat shock protein (HSP) is one of the most important macromolecules involved in thermoregulation under stress. Among them, *HSPB6* plays a unique role in protecting cells through its chaperone activity and stress-response regulation. This study was aimed to characterize the *HSPB6* gene molecularly in Murrah buffaloes and to evaluate its association with milk production traits in the subtropical climate of India.

2. Materials and Method

Milk production records of 789 adult animals for a span of 12 years were collected from the register maintained at Livestock Farm, Guru Angad Dev Veterinary and Animal Sciences University combined with 12 years meteorology data. Amplicons with sizes 578 and 720 base pair, respectively were created. Sequencing was done after amplification.

3. Results and Conclusion

Two single polymorphic loci (SNPs) were found in the *HSPB6* gene of Buffalo. Transversion at SNP 1 locus g.1123 A>C was found in the intronic region, and transition at SNP 2 locus g.1277 A>G was found in the coding region of Exon 2, which was non-synonymous and resulted in amino acid change from lysine (k) to glutamic acid at position 91. However, exon 1, intron 2, and the coding region of exon 3 were found to be monomorphic. Genotypic analysis revealed two genotypes in each SNP, AA and AC in g.1123A>C and AA and AG in g.1277A>G. Least square analysis showed a significant association of all genotypes with milk production traits. Hence, *HSPB6* can be used as a potential candidate gene to aid in better animal selection in breeding programmes.

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3.9 Revival of deceased high genetic merit valley-adapted Jersey germplasm- An *ART* approach for sustainable Dairying

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Keywords: Jersey, Ovary, IVF, embryos

1. Background

Raising profitable dairy in ecologically sensitive regions of the world demands genetic adaptation for sustainable genetic and economic gains. Kashmir valley with its temperate climate, mountainous terrain, lush green valleys, rich pastures and a distinct cold season for almost half-a-year period demands an extended adaptation interval for maximum productivity. The same is true for high producing exotic dairy cattle breeds which have been imported into the valley since decades. Jersey, an exotic dairy cattle breed, imported from Denmark in 1960s, has successfully adapted to the valley and has often been described as the most successful dairy cow breed of the region. The progeny achieved from these adapted cows through natural breeding and/or artificial insemination has been found to perform better than the counterparts imported/transported to valley from other parts of the country/world. Thus adaptation, both physical and gestational, was a major factor affecting the productivity. The loss of this highly adapted germplasm from diseases and death has long been felt as a matter of great concern, demanding tools and techniques for rescue and revival of this highly and peculiarly adapted germplasm. To overcome this critical bottleneck for advanced breeding programs, the present study envisages the application of assisted reproductive techniques (ARTs) for post-mortem oocyte retrieval followed by *in vitro* fertilization (IVF) (Shah *et al.*, 2015) embryo production and transfer to recipients. This study used high genetic merit sex-sorted Jersey semen and oocytes derived from post-mortem ovaries to produce high genetic merit Jersey embryos-both physically, genetically and gestationally adapted to unique Kashmir Valley ecology.

2. Materials and Methods

Ovaries were collected post-mortem from Jersey cows that died from accidental causes or non-infectious, non-notifiable conditions within 12 h of death and transported to the laboratory within 1–2 h in a pre-warmed thermos flask maintained at 30–35 °C. A total of 112 ovaries from 56 cows were processed individually to allow evaluation of cow-specific effects. Follicles measuring 2–8 mm were aspirated using an 18-gauge needle attached to a 10 mL syringe containing aspiration medium. Follicular contents were pooled per ovary, allowed to sediment for 10 min, and examined under a stereomicroscope. Grade A and B cumulus–oocyte complexes (COCs) were selected and washed three times in serum-free BO-IVM medium. Groups of 15–20 COCs were matured in 100 µL droplets of BO-IVM medium under mineral oil at 38.5 °C in a humidified incubator (5% CO₂, 21% O₂, balance N₂) for 22 h. Cryopreserved sex-sorted Jersey semen straws were thawed and used for *in vitro* fertilization (IVF). Presumptive zygotes were denuded using 0.5 mg/mL hyaluronidase for 2–3 min and washed in BO-IVC medium. Embryos were cultured in 50 µL droplets of BO-IVC medium under mineral oil at 38.5 °C in a tri-gas atmosphere (5% O₂, 5% CO₂, 90% N₂). Cleavage was assessed at 48 h post-insemination, and blastocyst development was evaluated on Days 7–8 according to International Embryo Transfer Society (IETS) criteria.

3. Results and Conclusion

A total of 112 ovaries were collected post-mortem from 56 Jersey cows, yielding 847 cumulus–oocyte complexes (COCs). Morphological grading showed that 62.33% (528/847) were Grade A/B, while 37.6% were Grade C/D. Following in vitro maturation (IVM), 412 of the 528 Grade A/B oocytes ($78.03 \pm 2.0\%$) achieved nuclear maturation, as indicated by cumulus expansion and polar body extrusion. A total of 402 matured oocytes were subjected to IVF using sex-sorted semen, resulting in a cleavage rate of $45.02 \pm 5.3\%$ (181/402) and a blastocyst rate of $29.28 \pm 3.8\%$ (53/181). Most Day 7–8 blastocysts were of high morphological quality, with 73.58% classified as IETS Grade 1.

These findings demonstrate that post-mortem ovaries from naturally deceased Jersey cows can serve as a viable oocyte source for in vitro embryo production (IVEP), particularly under slaughter-ban conditions where abattoir ovaries are inaccessible. Such opportunistic recovery may represent an important strategy for preserving valuable dairy genetics that would otherwise be lost following sudden mortality events. Integrating post-mortem oocyte recovery with assisted reproductive technologies, including embryo cryopreservation and the use of sex-sorted semen, could therefore complement existing breeding tools such as artificial insemination and multiple ovulation and embryo transfer programs (Martínez-Rodero *et al.*, 2021).

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3.10 Hydroponics Fodder: A Possible Way to Ensuring Supply of Nutritious Fodder in Urban Areas of Western Uttar Pradesh

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1. Background

India leads the globe in both total cattle population and milk output, however per capita availability is limited because of the country's low productivity. The country's need for feeds and fodder has increased as a result of the growth in the livestock population and the use of an intensive manner of animal husbandry. India has the most cattle and produces the most milk, but just 5% of the country's cropland is used for growing fodder. However, Uttar Pradesh has the highest livestock population in India, with approximately 67.8 million animals followed by Rajasthan (56.8) (20th Livestock Census, 2019). In state, there is major problem of low quality crop residues for forage requirement of livestock which is not enough for maintenance of animal health and productivity. Uttar Pradesh's urbanisation rate of 22.27% lags behind the national average of 31.16%.6 (Survey report 2023). Now a days, around 4.4 Crore (22%) of Uttar Pradesh's population lives in urban areas. There is no any alternate option to providing palatable and nutritious green fodder, they are totally depending on dry crop residue and other concentrates. Urban livestock farmers and dairy units in Uttar Pradesh face significant challenges in accessing high-quality green fodder year-round due to land scarcity, fluctuating climate, and forcing farmers to purchase costly feed.

2. Methodology

Hydroponics uses minimal water, limited space and controlled environment technology to produce with nutrient-rich green fodder within cities. It is a method of sprouted grains or growing crops without soil, using just water or a nutrient-rich solution. However, pure water alone can be used to generate hydroponic fodder and the use of nutrient-rich solutions is not necessary. For a brief period of time, the fodder plant's development can be sustained by the metabolism of the nutrient stores in the seeds. The grains are sprouted in a controlled atmosphere over a short amount of time roughly eight days. Hydroponic fodder cultivation is a useful substitute technique for sustainable farming of livestock in urban and semi urban areas of several parts of India. However, many farmers in Haryana, Uttar Pradesh and Bihar discovered that using homegrown or regionally sourced seeds in a low-cost shade net system, the cost of milk production using hydroponic fodder was lowered. Accordingly, the feed cost/kg milk was lowered by 25–30% and net profit was increased when fodder was grown in low-cost hydroponic systems. Finally, the greatest solution is producing fodder without soil in a small space using a high-tech or inexpensive technology, and it is harvested within 8-10 days only.

3. Results and Conclusion

It is becoming more significant as a means of ensuring year-round, high-volume supply of green feed for animals. For effective livestock production, farmers can use hydroponics on small- or large-scale using inexpensive equipment and year-round green feed additives. Through a capacity-building initiative, livestock producers will get education and awareness about the value of hydroponics and green feed for sustainable livestock production. It provides a clever alternate solution for combating land and fodder shortage in urban areas of Uttar Pradesh.

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3.11 Climate Change and Livestock Vulnerability: Seasonal Forcing of Mortality Patterns in a Goats

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Keywords: Goat, Mortality, Season, Disease, Pneumonia

1. Background

Climate change is projected to increase livestock mortality through heat stress, disease spread, and feed shortages. Understanding current patterns of mortality and their climatic drivers is essential for developing effective adaptation strategies. This study analyzes mortality records from a goat farm to quantify the association between season, year, age, and specific causes of death, providing a baseline for predicting future climate-related impacts.

2. Materials and Methods

A retrospective analysis was conducted on mortality data from a goat herd (n=90 deaths with specified cause). Causes of death were categorized into Enteritis, Pneumonia, Snake Bite, Plant Poisoning, and Other. Seasonal (Spring: Mar-May, Summer: Jun-Aug, Autumn: Sep-Nov, Winter: Dec-Feb) and annual distributions were analyzed. A chi-square test of independence was performed to assess the association between season and the primary causes of death (Enteritis and Pneumonia). A binary logistic regression model was constructed to predict the likelihood of death from infectious causes (Enteritis/Pneumonia) versus accidental causes (Snake Bite/Plant Poisoning), with season and age group as predictor variables.

3. Results and Conclusion:

Enteritis (40%) and Pneumonia (31%) were the predominant causes of mortality. The seasonal distribution of these causes is shown in Table 1. A significant association was found between season and cause of death ($\chi^2=21.4$, $df=3$, $p < 0.001$). Pneumonia deaths were heavily concentrated in Winter (50% of all pneumonia cases), while Enteritis showed peaks in Spring (28%) and Autumn (33%). Mortality was highest in animals under one year old (30%), primarily from Enteritis and Pneumonia. Logistic regression revealed that deaths occurring in Winter were significantly more likely to be from infectious causes (Pneumonia) compared to accidental causes (Odds Ratio=5.2, 95% CI: 1.4–19.8, $p=0.015$). A distinct spike in pneumonia cases was observed in 2023, suggesting a potential outbreak event. This study confirms a strong seasonal pattern in goat mortality, with cold stress driving pneumonia outbreaks and seasonal transitions linked to enteritis. While seasonal effects did not reach statistical significance, Age was a highly significant predictor. For each additional year of age, the odds of dying from Enteritis decreased by 19% (OR=0.81, $p=0.005$), confirming that Enteritis is primarily a disease of young animals. This study confirms a strong seasonal pattern in goat mortality, with cold stress driving pneumonia outbreaks (Winter OR=5.2) and age being the primary determinant of enteritis risk (19% reduction in odds per year of age). The findings suggest that predicted increases in climate variability could exacerbate pneumonia risks, while enteritis control must remain focused on young stock management. These results underscore the need for climate-adaptive management practices, including improved winter shelter, targeted nutrition for young animals, and vigilant grazing management, to enhance livestock resilience in a changing climate.

Table 1: Distribution of Major Causes of Death by Season

Cause of Death	Spring	Summer	Autumn	Winter	Total
Enteritis	10	5	12	9	36
Pneumonia	9	1	4	14	28
Snake Bite	4	4	1	0	9
Plant Poisoning	2	4	3	0	9
Other	3	2	0	3	8
Total	28	16	20	26	90

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3.12 Effect of Dietary Incorporation of Silkworm Pupa Meal on Growth and Egg Production of layers under Deep litter System

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Keywords: Silk worm pupae meal, Alternate protein, Poultry

1. Background

Growing human population demands sustainable and cheap food resources. Eggs provide quality protein at cheap price. The major component of poultry production is feed, which accounts 65-70% of total inputs. Among poultry feed components, protein source is most expensive and reduces profit from the enterprise (Banday et al 2023). Silk worm pupae are agro-industrial by product having crude protein upto 50-80%. Silkworm pupa meal (SWPM) can be used as an alternate protein source for poultry for preparation of cost-effective feed (Sheikh et al 2018). Present study was conducted with the aim to determine effect of replacing animal protein by silk worm pupae meal in layers in deep litter housing system.

2. Material and Methods

This study was conducted at Experimental Poultry Shed, Division of LPM, SKUAST, Jammu. The total duration of experiment was 72 weeks. To study the effect of dietary incorporation of Silkworm pupa meal in layers, 150 chicks of 8-week age were randomly divided into five groups (Control, T1, T2, T3, T4, T5) each having three replicates. Control group was provided with basal diet, the treatment groups were fed as, T1- Basal diet + 10% meat cum bone meal replacement with Silkworm pupae meal (SWPM), T2- Basal diet + 20% meat cum bone meal replacement with SWPM, T3-Basal diet + 10% meat cum bone meal replacement with ethanol treated SWPM and T4-Basal diet + 20% meat cum bone meal replacement with Ethanol treated SWPM.

3. Results and Conclusion

Results revealed that birds provided with Basal diet + 10% meat cum bone meal replacement with Silkworm pupae meal (SWPM) (T1) showed higher body weight during growth phase and birds provided with basal diet + 20% meat cum bone meal replacement with ethanol treated SWPM (T4) showed higher egg production compared to other groups. The birds of group T3 attained sexual maturity early than other groups. Overall, incorporation of silkworm pupa meal in poultry diet had beneficial effect on body weight, sexual maturity and egg production.

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3.13 Cold Stress Tolerance in Alfalfa (*Medicago spp.*): Integrating Morphological, Physiological, and Transcriptomic Insights

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1. Background

Alfalfa (*Medicago sativa* L.), also known as the "Queen of Forages," is considered one of the major forage legume crops globally owing to its high biomass yield, nutritional value, and adaptability to different environments. However, despite its tolerance to various environmental stresses, abiotic stresses, especially cold stress, pose a major constraint to its growth, productivity, and quality, especially in temperate and high-altitude regions of Ladakh and Kashmir Valley. Hence, it is imperative to assess genotypic variability and identify traits related to cold stress tolerance in alfalfa

2. Material and Methods

The present study was conducted on 45 alfalfa genotypes of *Medicago sativa*, *Medicago falcata*, and *Medicago varia* from Italy, Croatia, and Ladakh. Evaluation of field conditions was done in three locations, namely MAR&ES, Kargil; HMAARI, Leh; and MLRI, Mansbal (Jammu & Kashmir, India). Evaluation of morphological characteristics was done for assessing variability and performance. Physiological characteristics such as canopy temperature, relative water content (RWC), and membrane stability index (MSI) were also conducted for assessing performance. However, evaluation of biochemical characteristics such as chlorophyll content, proline content, and DAB assay for hydrogen peroxide content was also done and simultaneously, evaluation of forage quality characteristics such as neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), *in vitro* dry matter digestibility (IVDMD), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV), and crude protein content was also done. Additionally, the transcriptome analysis of selected tolerant and susceptible genotypes after application of cold stress (4°C for 48 hours) was done for finding differentially expressed genes (DEGs).

3. Results and Conclusion

Significant variation was found among all genotypes for all morphological traits, indicating high levels of genetic diversity among the genotypes. The highest coefficient of variation was found for florets per inflorescence (35.70%), followed by seed yield per plant (28.87%). Based on the performance for green forage yield, dry matter yield, and seed yield per plant:

- Genotypes AUS-ALF-1, AUS-ALF-13, AUS-ALF-19, ALF-CRO-10, AUS-ALF-9, AUS-CRO-9, and AUS-ALF-17 performed better under Kashmir Valley conditions.
- Genotypes ALF-AUS-13, ALF-AUS-21, ALF-CRO-10, ALF-AUS-7, ALF-AUS-1, ALF-CRO-9, and ALF-AUS-12 showed better performance in the cold arid region of Ladakh.

The results for physiological and biochemical analysis showed significant variation among the genotypes. In the tolerant genotypes, high values for relative water content, membrane stability, chlorophyll content, and proline accumulation were found, indicating high levels of stress tolerance. In forage quality analysis, significant variation was found among the genotypes.

Genotypes AUS-ALF-13, ALF-CRO-4, ALF-IT-5, and AUS-ALF-5 showed better forage quality with high digestibility and nutritional values. However, the expression analysis showed 644 genes were differentially expressed, out of which 325 genes were upregulated and 319 genes downregulated under cold stress. Notably, genes *MSGO680035588.01*, *MSGO680035598.01*, *MSGO380015311.01*, and *MSGO780040231.01* were significantly upregulated in tolerant genotypes, suggesting their role in cold stress tolerance.

Significant genetic variability was noted among alfalfa genotypes for morphological, physiological, biochemical, and forage quality traits. Some of the genotypes were noted as excellent performers under both Kashmir Valley and Ladakh conditions. The combination of physiological, biochemical, and transcriptomic studies has also offered better insights into the mechanisms of cold stress tolerance. The genotypes and genes identified here would also be effectively utilized in future breeding programs for the development of cold-tolerant, high-yielding, and nutritionally enriched alfalfa cultivars.

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3.14 Comparison of Mesenchymal Stem Cells and Fetal Fibroblasts as Donor Nuclei for Handmade Cloning in Sheep

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Keywords: Handmade cloning, Sheep, Mesenchymal stem cells, Fetal fibroblasts, Donor cells

1. Background

Handmade cloning (HMC) has emerged as an efficient alternative to conventional somatic cell nuclear transfer; however, its success remains limited by incomplete nuclear reprogramming, which is strongly influenced by donor cell type (Li *et al.*, 2024). Selecting an optimal donor nucleus is therefore critical to improving cloning efficiency. Mesenchymal stem cells (MSCs), due to their multipotent nature and greater epigenetic plasticity, may offer advantages over differentiated somatic cells, such as fetal fibroblasts (FFs). The present study was undertaken to compare the developmental competence and embryo quality of reconstructed embryos using MSCs and FFs as donor nuclei in ovine handmade cloning.

2. Materials and methods

The study was conducted under controlled laboratory conditions. Ovaries were collected from a local abattoir, and cumulus oocyte complexes (COCs) were aspirated and subjected to in vitro maturation. A total of 312 oocytes were selected for zona removal and manual enucleation using the handmade cloning technique (Khan *et al.*, 2018). Successfully enucleated cytoplasts were reconstructed using either mesenchymal stem cells or fetal fibroblasts as donor nuclei. Reconstructed embryos were aggregated using phytohemagglutinin, followed by electrical fusion and chemical activation. A total of 156 embryos were generated in each group (MSC-HMC and FF-HMC). Embryos were cultured in vitro under standard conditions. Developmental parameters, including fusion rate, cleavage rate, and blastocyst formation, were recorded. Embryo quality was assessed based on morphological grading and differential staining for total cell number (TCN) and inner cell mass (ICM) allocation. Statistical analysis was performed using one-way ANOVA, and differences between groups were evaluated using Student's t-test with significance set at $p < 0.05$.

3. Results and conclusion

Donor cell type significantly influenced the developmental competence of embryos produced through handmade cloning. Enucleation efficiency was slightly higher in the MSC group (93.1%) compared to the FF group (92.2%) ($p > 0.05$). Fusion rate was also higher in MSC-derived embryos (88.6%) than in FF-derived embryos (87.5%) ($p > 0.05$). Cleavage rates were recorded at 82.4% in MSC-HMC embryos and 81.3% in FF-HMC embryos ($p > 0.05$). Blastocyst formation rate was significantly higher in embryos reconstructed using MSCs (36.7%) compared to FFs (35.6%) ($p < 0.05$). Moreover, MSC-derived blastocysts exhibited improved quality, with higher total cell number (124.6 ± 3.2 vs 119.8 ± 2.9) and increased ICM cell allocation (38.5 ± 1.7 vs 35.9 ± 1.5) compared to FF-derived blastocysts ($p < 0.05$). The proportion of Grade I blastocysts was also greater in the MSC group (28.3%) than in the FF group (27.2%). It may be concluded that mesenchymal stem cells serve as a superior donor nucleus source compared to fetal fibroblasts in ovine handmade cloning, leading to improved blastocyst yield and embryo quality. These findings emphasize the importance of donor cell selection in optimizing cloning efficiency in sheep.

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3.15 Impact of Climate Change on Wetlands of Kashmir Valley, J&K

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Keywords: Climate change, wetlands, ecosystem

1. Background

Wetlands are highly productive ecosystems that provide essential services such as water purification, flood regulation, biodiversity conservation, and livelihood support. The Kashmir Valley hosts important wetlands including Dal Lake, Wular Lake, Hokersar, Manasbal, Anchar Lake, and Shallabugh, which are vital for ecological balance and socio-economic sustainability.

In recent decades, these wetlands have become increasingly vulnerable to climate change and anthropogenic pressures. Rising temperatures, erratic precipitation, declining snowfall, and extreme weather events have altered hydrological regimes. Simultaneously, urbanization, pollution, and encroachment have accelerated wetland degradation. This study assesses the impact of changing climatic patterns on wetland structure, hydrology, and biodiversity in Kashmir.

2. Materials & Methods

The study was conducted in major wetlands of the Kashmir Valley, with focused analysis on Hokersar, Shallabugh, Anchar Lake, and Wular Lake. A combination of field surveys and secondary climatic data was used. Field assessments included wetland area, vegetation status, water quality (nutrients and dissolved oxygen), and soil properties (moisture and organic matter). Long-term data on temperature, precipitation, and snowfall trends were analyzed using IMD and related datasets. Socio-economic surveys were conducted to capture local perceptions of environmental changes. Comparative analysis of historical and present conditions was carried out to evaluate climate-induced impacts.

3. Results and Conclusion

The findings indicate a steady rise in temperature and irregular precipitation patterns, along with reduced snowfall in the region. Wetlands showed a decline in water spread area and vegetation health, particularly in Hokersar, Anchar Lake, and Wular Lake, largely due to hydrological changes and encroachment. Water quality analysis revealed increased nutrient concentrations and reduced dissolved oxygen, indicating eutrophication. Soil analysis showed declining moisture and organic matter. Biodiversity was adversely affected, with noticeable declines in fish populations and disruption of migratory bird habitats.

Local communities reported reduced water availability, declining fisheries, and increased drought-like conditions. Overall, climate change was found to act as a key driver of wetland degradation, intensifying existing anthropogenic stresses. Wetlands in the Kashmir Valley are undergoing rapid ecological degradation characterized by shrinking area, declining water quality, and biodiversity loss. Climate change, combined with human pressures, is significantly altering their structure and functioning. Urgent measures such as integrated wetland management, climate adaptation strategies, regulation of anthropogenic activities, and restoration efforts are essential. Strengthening monitoring systems and promoting community participation will be critical for ensuring long-term sustainability and resilience of these fragile ecosystems.

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3.16 Bayesian Probabilistic Risk Assessment of Livestock Productivity under Climate Variability in Kashmir Valley

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Keywords: Bayesian inference, livestock productivity, climate stress, risk assessment, Kashmir Valley

1. Background

Livestock systems in the Kashmir Valley constitute a vital component of rural livelihoods and the regional economy. In recent years, the region has experienced significant climate variability, including fluctuations in temperature, irregular precipitation patterns, and an increased frequency of extreme weather events. The present study applies Bayesian methods to better understand and quantify uncertainty in livestock productivity under climate variability in the Kashmir Valley. The specific objectives are to model uncertainty using Bayesian inference and to estimate the probability of productivity risks under varying climatic stress conditions.

2. Materials and methods

The present study is based on secondary data obtained from the *Digest of Statistics, Union Territory of Jammu and Kashmir, 50th Edition (2024–25)*. Livestock productivity variables include Milk (lakh tonnes), Meat (lakh kg), and Wool (lakh kg), while climatic variables comprise maximum temperature, minimum temperature, morning relative humidity (M_RH), and evening relative humidity (E_RH). The study covers a time period from 2004 to 2024. A multivariate Bayesian regression framework is employed to examine the relationship between climatic variables and livestock productivity, allowing simultaneous modelling of multiple dependent variables and their interdependence. Uncertainty in livestock productivity is captured through the posterior predictive distribution. Risk is defined as the probability that livestock productivity falls below a critical threshold which is taken as the 25th percentile (lower quartile) of observed productivity.

3. Results and Conclusion

The results provide quantitative evidence of the effects of climatic variables on livestock productivity in the Kashmir Valley. The posterior mean estimates along with 95% credible intervals (CrI) allow probabilistic interpretation of these relationships. The baseline productivity levels, represented by the intercepts, are estimated at 18.63 (CrI: 16.5–20.8) for milk, 266.93 (CrI: 240–295) for meat, and 88.23 (CrI: 70–110) for wool, indicating the expected average production under typical climatic conditions. Maximum temperature exhibits a positive and credible effect on meat production, with an estimated coefficient of 12.5 (CrI: 2.0–25.0), suggesting that an increase in maximum temperature is associated with a substantial increase in meat output. In contrast, its effect on milk production is weak and uncertain (0.45; CrI: –0.10 to 1.05), while for wool production it shows a negative but non-credible effect (–4.2; CrI: –12.0 to 3.0), indicating potential but uncertain adverse impacts. These results indicate that higher evening humidity significantly enhances overall livestock productivity.

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3.17 Treated Sewage Water Irrigation for Climate-Resilient Fodder Oats: Effects on Soil Health and Nutrient Uptake

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Keywords: Climate resilience, livestock production systems, nutrient uptake, soil physicochemical properties, treated sewage water

1. Background

Water scarcity under changing climate scenarios is increasingly constraining fodder production, with agriculture accounting for 70-80% of global freshwater use and about 1.8 billion people projected to face absolute water scarcity by 2025. By 2030, global water demand is expected to exceed supply by nearly 40%, intensifying pressure on conventional resources (WWAP, 2024). Concurrently, global agriculture remains highly dependent on chemical fertilizers, with nutrient consumption exceeding 180 million tonnes annually and projected to approach 200 million tonnes by 2030. In this context, treated sewage water (TSW), generated in large volumes (~0.4 trillion m³ annually), provides a sustainable irrigation alternative by supplying water and essential nutrients such as nitrogen and phosphorus (Hashem *et al.*, 2021). Its use can reduce reliance on synthetic fertilizers while improving soil fertility through added organic matter and enhanced nutrient availability, along with promoting soil biological activity and nutrient cycling. In fodder oats (*Avena sativa* L.), improved soil fertility and efficient nutrient uptake are essential for high-quality forage production and sustainable livestock systems. Thus, TSW integration offers a promising approach for climate-resilient and resource-efficient fodder production under increasing water and nutrient constraints. The present study aims to assess the effect of treated sewage water irrigation on soil health and nutrient uptake in fodder oats (*Avena sativa* L.).

2. Materials and Methods

A field experiment was conducted in a split plot design with three irrigation sources- tube well water, alternate irrigation, and treated sewage water, assigned to main plots and four fertilizer levels (control, 50% RDF, 75% RDF, and 100% RDF) to subplots, with three replications. The experimental soil (clay loam) was characterized using standard procedures. Soil texture was determined by the International Pipette Method, while soil pH and electrical conductivity were measured using a pH meter and EC bridge, respectively. Available nitrogen, phosphorus, and potassium were estimated by alkaline permanganate, Olsen's, and flame photometer methods, respectively, and organic carbon by the Walkley and Black method.

3. Results and Conclusion

Treated sewage water irrigation significantly increased soil available nitrogen (184.58 kg ha⁻¹) and potassium (229.94 kg ha⁻¹) compared to tube well water, though it remained statistically at par with alternate irrigation. The highest available phosphorus (27.24 kg ha⁻¹) was also recorded under treated sewage water irrigation. This improvement can be attributed to the continuous addition of nutrients and organic matter through sewage water, which enhances nutrient availability and soil microbial activity. Soil pH, electrical conductivity, and organic carbon were not significantly influenced, indicating no adverse effect on soil health. Among fertilizer levels, 100% RDF recorded maximum available N (182.33 kg ha⁻¹), P (27.54 kg ha⁻¹), and K (245.04 kg ha⁻¹), remaining

statistically at par with 75% RDF, suggesting scope for fertilizer saving. Nutrient uptake was significantly higher under treated sewage water irrigation and 100% RDF, with N uptake ($179.02 \text{ kg ha}^{-1}$), P uptake (30.25 kg ha^{-1}), and K uptake ($135.74 \text{ kg ha}^{-1}$). Enhanced uptake reflects improved nutrient availability and efficient utilization, supporting the potential of treated sewage water as a sustainable input for climate-resilient fodder production.

The study concludes that treated sewage water irrigation enhances soil nutrient dynamics by significantly increasing the availability of nitrogen, phosphorus, and potassium, thereby promoting greater nutrient uptake in fodder oats (*Avena sativa* L.) without inducing adverse changes in soil physicochemical properties. The comparable performance of 75% RDF with 100% RDF indicates improved nutrient use efficiency and the potential for partial substitution of inorganic fertilizers. The observed improvements are attributed to the integrated supply of water, nutrients, and organic constituents through treated sewage water, which stimulate nutrient cycling processes. Thus, its adoption represents a viable, resource-efficient strategy for sustaining soil health and ensuring climate-resilient fodder production systems.

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3.18 Performance of Front Line Demonstrations of Oats Fodder in Mid hills of Jammu and Kashmir

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Keywords: FLDs, Fodder, Oats, mid hills, Rajouri

1. Background

In the hilly areas there is a huge shortage of green fodder especially in winter season and thus there is a great demand of fodder in the hilly areas. Oats as a fodder has the potential to fill the gap to some extent. Farmers of the district face severe shortage of fodder and lack awareness and knowledge regarding utilization of the fallow areas. Oat (*Avena sativa* L.), locally known as *Gandial* in Rajouri district and is one of the most important cultivated winter fodder crops. Oats fodder can grow well in wide range of soils with low inputs, fallow lands, low water supply and also having great future due to its aptitude to climate resilience. Oats fodder has become very popular in intermediate areas of Rajouri district of J&K UT *vis a vis* has improved the economic conditions of the small scale and marginal farmers. To overcome the problems, the present study was carried out at Krishi Vigyan Kendra (KVK), Rajouri initiated frontline demonstrations (FLDs) on fodder oats (*Avena sativa* L.) to popularize the scientific production technology of fodder oats in the district.

2. Materials and methods

The study was conducted during *rabi* 2021-22 to 2023-24 at Krishi Vigyan Kendra (KVK), Rajouri, J&K UT in the adopted villages of Nowshera, Doongi and Rajouri blocks of district Rajouri of Jammu and Kashmir Union Territory. Ten (10) villages were selected at random for front line demonstrations (FLDs) in Rajouri district. The improved technologies *viz.*, seed treatment, variety, seed rate, fertilizers, no. of cuts was adopted for front line demonstrations. A total of 140 FLDs were conducted in about 32.8 hectares area at different locations (Table 1). Locally cultivated varieties were used as local check. Before conducting the FLDs, the scientists gathered fundamental data on crop production techniques, acceptable high yielding varieties, seed rate, application of fertilizers and farmers' meetings to determine the current scenario in fodder oat production and as a result necessary improvements in the cultivation. Farmers on the other hand were permitted to carry out their own practices as a local check. Field days and farmers' meetings were conducted so that other farmers could learn about the benefits of the varieties and technologies on display. For comparison study, data on several parameters were gathered separately from both improved and farmers' practices.

3. Results and Conclusion

The yield of the oats fodder was higher in demonstrated fields than in local practice throughout *rabi* 2021-22 to 2023-24. Following the data analysis, it was shown that better technical intervention lead in a 29.78% higher oats fodder production of 297 q/ha as compared to 228 q/ha recorded with the farmers practice. This yield increase in demonstration plot might be due to recommended package and practices and other scientific interventions followed under the supervision and technical guidance of the KVK's scientists. The usage of improved and recommended variety of oats (Sabzar and Kent), proper seed treatment, recommended dose and proper time of fertilizer application under FLDs enhanced the yield of oats fodder as compared to

the farmers' practices. Oats fodder crop grown in demonstration plots accrued higher net returns (Rs. 40258/-) and B: C ratio (2.84) as compared to the farmers' practice amounting to Rs. 26842/- and 2.29, respectively. It may be concluded that oats varieties Kent and Sabzar could be well grown under the hills of Rajouri district for fodder production and to cope up with the scarcity of green fodder during the extreme winters in this border hilly district.

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3.19 Climate Change: Concerns and Adaptation Strategies in Kashmir

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Keywords: Climate, Strategies, Temperature tolerance

1. Background

Agriculture plays a crucial role in food security for the majority of people in India. The extremes of climate poses serious risks in terms of widespread droughts, flash rains, cyclones and enhanced incidences of malnutrition. The climatic concerns in future are likely to further aggravate the problem.

2. Materials & Methods

A controlled experiment was conducted using potted plants (e.g., bean plants) under three simulated climate conditions:

- Control Group – ambient temperature and regular watering
- Heat Stress Group – temperature elevated by $\sim 3\text{--}4^{\circ}\text{C}$
- Drought Stress Group – reduced watering frequency

Additionally, adaptation strategies were tested, mulching to conserve soil moisture, shade nets to reduce heat stress, plant height, leaf number, and soil moisture were measured over a 4-week period.

3. Results & Conclusion

Plants under heat stress showed a $\sim 25\%$ reduction in growth compared to control. Drought conditions resulted in wilting and $\sim 40\%$ lower biomass. Mulching improved soil moisture retention by $\sim 15\text{--}20\%$. Shade nets reduced temperature stress and improved plant survival rates by $\sim 18\%$. These results demonstrate that even small climatic variations can significantly affect plant productivity, but low-cost adaptation strategies can partially offset these impacts. The findings align with broader climate models, such as those from the Intergovernmental Panel on Climate Change, which predict reduced agricultural yields under warming scenarios. Adaptation strategies like water conservation, agroforestry, and climate-resilient crops are essential, especially in developing countries like India. Climate change poses significant risks to ecological and agricultural systems. However, localized, affordable adaptation measures—such as mulching and shading- can enhance resilience. Scaling such strategies is crucial for sustainable development and food security.

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3.20 Pelletization of Moringa–Napier Fodder for Enhanced Nutritional Quality and Climate-Resilient Livestock Systems

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Keywords: Crude protein (CP), Forage pelleting, Livestock nutrition, Moringa-Napier grass, Pellet Durability Index (PDI)

1. Background

Feed is the most expensive component of livestock production and directly influences animal productivity and profitability. In India, only about 8.4 million hectares are under forage crops, leading to a substantial deficit of green fodder (35.6%), dry fodder (10.95%), and concentrate feed ingredients (44%) (Anonymous, 2022). Ruminants rely on forage as a primary energy source through microbial digestion of structural carbohydrates in the rumen (Van Soest, 1994). However, fresh fodder has limitations such as high moisture content, low bulk density (50–130 kg/m³), poor storability, and high transportation cost, which are further aggravated under climate variability.

Forage pelleting converts loose fodder into compact, dense pellets, improving storage, transport, and feed utilization. It reduces wastage during surplus periods and ensures feed availability during lean seasons. Pelleting also enhances digestibility, reduces fiber and anti-nutritional factors, and allows incorporation of feed additives (Oyaniran *et al.*, 2018). *Moringa oleifera*, a protein-rich and drought-tolerant crop, combined with high-yielding Napier grass, offers a promising solution for improving fodder quality. Therefore, the present study aimed to develop Moringa–Napier pellets and evaluate their nutritional and physical properties as a sustainable and climate-resilient feeding strategy.

2. Materials and Methods

The experiment was carried out during 2023–2024 at the Agronomy Farm of ICAR–National Dairy Research Institute, Karnal (Haryana), India. The study followed a Randomized Block Design (RBD) with nine treatments and three replications, making a total of 27 experimental units. The treatments included different combinations of Moringa and Napier fodder, with and without binding agents:

T1: Moringa (20%) + Napier (80%)

T2: Moringa (30%) + Napier (70%)

T3: Moringa (40%) + Napier (60%)

T4–T6: Above combinations with molasses

T7–T9: Above combinations with guar gum

Pellets were prepared by grinding and mixing the fodder and then compressing it using a pellet machine. The best moisture levels for pellet formation were found to be 10% for Moringa and 16% for Napier. The pellets were tested for important nutritional parameters such as Crude Protein (CP), Crude Fiber (CF), and Ether Extract (EE). The tannin content was also measured to check for any anti-nutritional effects. Physical quality was evaluated using the Pellet Durability Index (PDI), which indicates how strong and stable the pellets are.

3. Results & Conclusion

Pelletization had a clear positive effect on both the nutritional quality and physical properties of the fodder. An increasing trend in crude protein (CP) was observed with higher inclusion levels of Moringa, confirming its role as a protein-rich component in the fodder mixture. The pelleting process further contributed to slight improvements in CP content, possibly due to concentration effects during moisture reduction, with CP values ranging from 14–16%. The crude fiber (CF) content decreased by about 4–5% after pelletization, indicating partial breakdown of fibrous components during processing and resulting in improved digestibility and feed intake. The ether extract (EE) ranged between 3.6–6.0%, reflecting adequate energy content without adversely affecting rumen health. Treatments containing 30–40% Moringa along with binders performed better in terms of nutritional quality, as binders improved pellet structure without altering feed composition.

The **pellet durability index (PDI)** was highest in T6 (60% Napier + 40% Moringa + molasses), reaching 97.83%, indicating strong and stable pellets suitable for handling and storage. The **tannin content** ranged from 0.21–0.35%, remaining within safe limits for livestock feeding. Overall, pelletization enhanced feed quality by increasing protein, reducing fiber, improving energy availability, and strengthening pellet durability, making it a suitable strategy for efficient livestock production.

The study clearly shows that pelletization of Moringa–Napier fodder is a useful method for improving feed quality and handling. Among all treatments, T6 (60% Napier + 40% Moringa + molasses) was the best, showing high protein content, lower fiber, good energy levels, and excellent pellet durability. Thus, pelleted fodder can serve as a sustainable and climate-resilient feeding option, especially in areas facing fodder shortages and climate stress. It can help reduce feed wastage, lower transport costs, and encourage value addition to improve livestock productivity.

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3.21 Quantifying Yield Gaps and Assessing the Impact of Frontline Demonstrations on Composite Fish Culture in Jammu District

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Keywords: Aquaculture, Composite fish culture, Frontline demonstrations, Technology index, Yield gap

1. Background

The fisheries and aquaculture sector in India has undergone a massive transformation with total fish production of 19.7 million tonnes for FY 2024–25, a 106% increase from 2013–14 levels. The sector is a vital engine for the economy, supporting the livelihoods of over 30 million people, particularly in coastal and rural communities. Inland fisheries have seen the most explosive growth (140% over the last decade), now contributing about 72% of total fish production (≈15MT). Composite fish culture, involving compatible species such as Catla, Rohu, and Mrigal with exotic carps has high production potential. The Jammu district, located in the subtropical southern part of the Union Territory of Jammu & Kashmir, serves as a vital agricultural hub characterized by varied topography and fluctuating climatic conditions. Fish farming plays an increasingly significant role in the district's economy, providing essential nutrition and employment; however, despite recent growth, current production levels remain insufficient to meet the rising local consumption demand. Therefore, the present study was undertaken to analyse yield gaps and assess the impact of FLDs on fish production and profitability in Jammu district. Frontline Demonstrations (FLDs) conducted by Krishi Vigyan Kendras (KVKs) serve as an effective extension tool to demonstrate improved technologies, reduce yield gaps and to enhance farmers' income.

2. Material and Methods

The present study was carried out from the year 2022-2026. In study, total 85 frontline demonstrations were conducted at 85 farmers' fish ponds covering an area of 8.5ha in blocks viz., *R S Pura, Bisnah, Suchetgarh, Meerain Saheb, Khour and Paragwal* of Jammu district to demonstrate production potential and economic benefit of improved technologies. A comparative evaluation was made between demonstration plots, where improved practices were adopted, and farmers' traditional practices. Key interventions included scientific pond preparation through liming and fertilization, recommended stocking density with proper species ratio, use of quality fish seed, and supplementary feeding along with water quality management. A detailed survey has been conducted with the help of a questionnaire followed by PRA for all the above said locations. The questionnaire was grouped in to some domain such as pond preparation, liming, manuring (pre-stocking management), stocking, feeding and post-stocking management, water quality monitoring and periodical/regular exchange, aeration facility, health monitoring & disease management, harvesting, handling, transportation and marketing of harvested material. Data were also collected on yield and economic returns and analyzed using standard indicators such as technology gap, extension gap, total yield gap and technology index. The Technology gap, Extension gap, Total yield gap and Technology adoption Index were calculated with help of formulas given below:

$$\text{Technology Gap} = \text{PY} - \text{DY}$$

$$\text{Extension Gap} = \text{DY} - \text{FY}$$

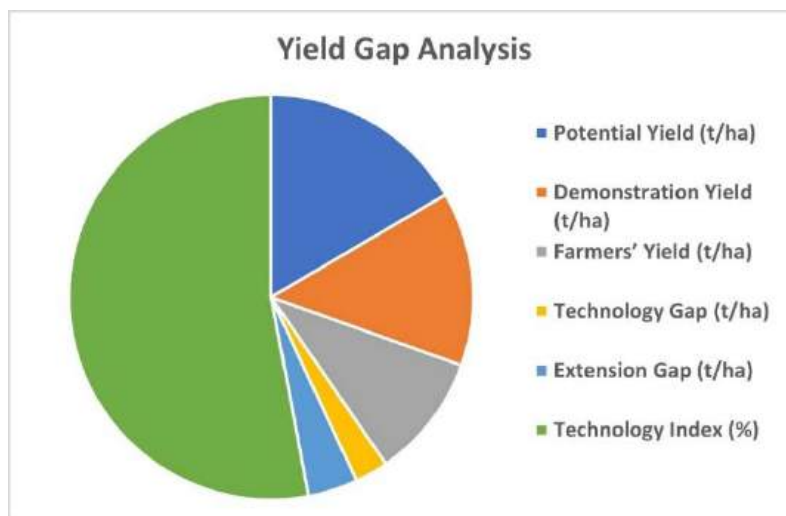
$$\text{Total Yield Gap} = \text{PY} - \text{FY}$$

$$\text{Technology Index (\%)} = \left[\frac{(\text{PY} - \text{DY})}{\text{PY}} \right] \times 100$$

Where PY: Potential Yield (Yield under ideal/research conditions), DY: Demonstration Yield (Yield under FLDs), FY: Farmers' Yield (Yield under traditional practices)

3. Results and conclusion

The results revealed a substantial improvement in fish productivity under FLDs compared to traditional practices. The average demonstration yield (4.2 t/ha) was significantly higher than farmers' yield (3.0 t/ha), indicating an increase of about 40–60%. However, the observed yield remained lower than the potential yield (5.0 t/ha), reflecting the existence of a notable technology gap. The extension gap, calculated as the difference between demonstration yield and farmers' yield, highlighted the need for stronger dissemination of improved practices. The technology index indicated moderate feasibility of the demonstrated technology under local conditions. Economic analysis showed that FLDs resulted in higher net returns and improved benefit-cost ratios due to increased production and better input utilization. Additionally, FLDs positively influenced farmers' knowledge, skills, and adoption behavior, particularly in areas such as stocking density, feed management, and pond maintenance. Despite positive outcomes, several constraints were identified which are limited access to quality fish seed, unavailability of desired species fish seed, high cost of feed inputs, poor pond management, inadequate technical knowledge among farmers and poor infrastructure. It is concluded that ensuring input supply, strengthening extension services, and conducting regular training programs are essential for reducing yield gaps and promoting sustainable aquaculture in Jammu district.



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3.22 Effect of Medicinal Herbs on Rumen Fermentation and Nitrogen Utilization in Goats

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Keywords: Digestibility; Dose-response; Goats; *In vitro* fermentation; Medicinal herbs; Rumen fermentation

1. Background

The growing concern over sustainability and environmental stress in livestock production systems has intensified the search for natural feed additives that can improve rumen efficiency without compromising animal health. Medicinal herbs, rich in bioactive compounds such as tannins, saponins, flavonoids, and essential oils, have shown potential to modulate rumen microbial ecology and fermentation pathways. These compounds can influence microbial populations by selectively inhibiting proteolytic and methanogenic microbes while supporting fibrolytic activity, thereby improving nutrient utilization. Such modulation of the rumen microbial ecosystem represents a targeted nutritional strategy to enhance fermentation efficiency and reduce metabolic inefficiencies.

Rumen fermentation is a complex microbial process, and its response to phytogenic additives depends not only on the type of herb but also on the level of inclusion. While moderate levels may enhance fermentation efficiency, excessive inclusion can disrupt microbial balance and reduce digestibility. Therefore, it is essential to evaluate both the functional and dose dependent effects of medicinal herbs under controlled conditions. The present study was undertaken to investigate how different inclusion levels of selected medicinal herbs influence *in vitro* rumen fermentation dynamics, digestibility, and fermentation stability in goats.

2. Material and Methods

The experiment was conducted at the Division of Animal Nutrition, Faculty of Veterinary Sciences and Animal Husbandry, SKUAST-Jammu. Eight medicinal herbs (*Azadirachta indica*, *Allium sativum*, *Cuminum cyminum*, *Emblica officinalis*, *Murraya koenigii*, *Terminalia arjuna*, *Trigonella foenum-graecum*, and *Curcuma longa*) were selected based on their phytochemical composition and potential effects on rumen microbial activity. The plant materials were processed by shade drying, oven drying at 40°C, and grinding to a uniform particle size of 1 mm.

An *In vitro* gas production technique was employed to assess fermentation characteristics. The basal substrate consisted of a wheat straw and concentrate mixture (60:40 ratio), with herbs incorporated at 3.0%, 3.5%, and 4.0% inclusion levels on a dry matter basis. Approximately 200 mg of substrate was incubated in calibrated glass syringes containing 30 ml of buffered rumen fluid prepared under anaerobic conditions.

The syringes were incubated at 39°C for 24 hours, and gas production was recorded at regular intervals to evaluate fermentation kinetics. Following incubation, residues were analyzed for *in vitro* dry matter digestibility (IVDMD) and *in vitro* organic matter digestibility (IVOMD) using standard procedures. The experiment followed a completely randomized design, and statistical analysis was performed using analysis of variance with significance declared at $p < 0.05$.

3. Results and Conclusion

The findings demonstrated that medicinal herbs showed differential effects on rumen fermentation depending on their inclusion levels. Lower inclusion (3%) consistently supported higher digestibility, suggesting improved microbial efficiency and substrate degradation. This response reflects a functional optimization of rumen microbial community under moderate phytogenic supplementation.

In contrast, higher inclusion levels (3.5% and 4.0%) produced inconsistent and, in some cases, reduced digestibility responses. This indicates the presence of a dose dependent microbial threshold, beyond which phytochemical activity may shift from stimulatory to inhibitory, thereby limiting fermentation efficiency.

Gas production followed a normal increasing trend with incubation time across all treatments, indicating that the inclusion of medicinal herbs did not disrupt overall fermentation kinetics. Additionally, rumen pH remained within the normal physiological range, reflecting stable fermentation conditions and absence of adverse effects on the rumen environment.

As a result, the study emphasizes that the effectiveness of medicinal herbs in ruminant nutrition is governed not only by their composition but also by their level of inclusion. The results underline the importance of optimizing dosage to achieve a balance between stimulatory and inhibitory effects of phytogenic compounds. These findings support the strategic use of medicinal herbs as natural feed additives for improving rumen fermentation efficiency and developing sustainable feeding practices in goats.

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3.23 Evaluation of Biochar based Fertilizers Blends for Improving Yield and Soil Fertility in Rice and Sweet Corn

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Keywords: Biochar, Fertilizer, Rice, Sweet corn, Yield

1. Background

Use of fossil fuels for industrial revolution led to an unprecedented increase in atmospheric CO₂ and other greenhouse gases. Build up of GHGs led to global warming and climate change. Excessive soil tillage further resulted in loss of soil organic carbon and soil health deterioration. This calls for global effort to adapt and mitigate the effect of climate change. Broad aspects of mitigation include shifting away from fossil fuels, improving energy efficiency, adopting regenerative agricultural practices, conservation of forests, conserving critical ecosystems. On one way the global community should reduce the emission of GHGs and on the other hand draw maximum CO₂ from atmosphere and store it for long term thorough C sequestration. One of the methods to sequester C for a long time through production and application of biochar to soil. Biochar is an aromatic carbon form, recalcitrant to microbial decompositions therefore helping in C sequestration, improving soil physical conditions, nutrient and water holding capacity. The present study was carried to assess the response of rice and sweet corn to application of biochar and biochar blends in respect of yield and soil fertility.

2. Material and methods

Biochar was prepared using rice chaff a waste product from rice seed processing mills. The biochar was prepared in the locally installed biochar kiln. A used drum placed in a kiln prepared from bricks and plastered with clay from inside and outside. The drum was heated using fuel wood and a temperature of 550- 600°C for 4-5 hours was achieved and monitored using thermocouple thermometer. The biochar was incubated with well decomposed farmyard manure in 1:1 ratio and 0.7% and 0.5% P on dry weight basis of biochar, for three months. The treatments included No treatment/no biochar (T₁), Biochar @ 1 kg/m² (T₂); Biochar @ 1 kg + Recommended dose of fertilizers (RDF) (T₃); Biochar 1 kg + 75% RDF (T₄); Biochar @ 1 kg /m² + 1 kg FYM + RDF (field application) (T₅); Pre – Blend (Biochar + FYM + Fertilizer (75 % RDF) @ 2 kg/m² (T₆); Pre - Blend (Biochar + FYM + Fertilizer (75 % RDF) @ 2 kg/m²+ biofertilizer (T₇), Recommended dose of fertilizers (RDF) (T₈).

3. Results and conclusion

The perusal of the data reveals that application of biochar (1kg/m²) alone resulted in significant yield reduction in sweet corn and rice yield when compared to RDF Application of biochar alone resulted in reduction in grain yield of rice and cob yield of sweet corn to the extent of 19% and 30%, respectively when compared to RDF. Field application biochar in combination with RDF resulted in 6.6% and 8.2 % increase in rice grain and sweet corn cob yield as compared to RDF alone. Field application biochar in combination with 1kg FYM/m² with 75% RDF resulted 8.5% and 6.5% increase in rice grain and sweet corn cob yield. Application of preincubated biochar with FYM and NP fertilizers (75% RDF) resulted in 16.8% and 19.0% increase in grain of rice and cob yield of sweet corn respectively, which was at par when biofertilizers (Azotobacter and PSB) were also added. Application biochar blends directly to the soil or after incubation resulted in non-signification change in EC but a significant increase in organic carbon, soil available N, P and K

after the harvest rice and sweet corn (Table 2). These finds corroborate the findings of Lebrun et al. 2023. The co-application of biochar with both inorganic and organic fertilizers increased crop yield by $179.6\% \pm 18.7$ (Bai et al 2022; Sun et al 2022.).

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3.24 Nutritional Prospectus of Top Feeds of District Samba of UT of J&K

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Keywords: Top feeds, Proximate, Fibre, Tannins, Condensed tannins, Maintenance, Production, Samba

1. Background

Top feeds are key feed resources for feeding ruminants during shortages, particularly in dry seasons. Improved livestock productivity as an outcome of cross-breeding policies and increased demand of livestock products due to increase in purchasing power and open trade scenario has resulted in an ever-widening gap in demand and supply of livestock feeds. Like other parts of the country, UT of Jammu and Kashmir is also in short of livestock feeds and fodders. The area under fodder production is reducing day by day indicating high pressure for cash crops production. As such, there is a dire need to explore new feed resources. Top feeds are key feed resources for feeding ruminants during shortages, particularly in dry seasons. They offer a sustainable, cost-effective, and nutrient-rich supplement to conventional feed for goats and cattle. The tree and shrub foliages not only provide a cheap source of nitrogen, energy and micronutrients, but have also many other advantages like their wide spread on-farm availability and easy accessibility to farmers, and above all the scope of adding variety to the diet. The top feeds can be harvested, sun dried and used in compounded protein supplements.

2. Material and Methods

The promising ten top feeds of District Samba viz *Butea monosperma*, *Carissa spinarum*, *Dendrocalamus strictus*, *Grewia optiva*, *Leucaena leucocephala*, *Melia azedarach*, *Morus alba*, *Psidium guajava*, *Zizyphus jujuba* and *Zizyphus nummularia* were selected for the present study. The selected top feeds were dried in shade and ground to pass 1 mm screen. The ground samples were stored in screw capped polycarbonate bottles. The proximate constituents were estimated as per the methods described by AOAC (2012), whereas, the fibre constituents were evaluated as per the methodology of Van Soest *et al.*, (1991). The total phenolics and tannin fractions were estimated as per the methods described by Makkar (1993) and Makkar and Singh (1995). The hydrolysable tannins were obtained by subtracting the condensed tannins from the total phenolics.

3. Results and conclusion

The crude protein content was highest in the *Leucaena leucocephala* (21.17%) and minimum in *Carissa spinarum* (5.18 %). Among the fibre constituents, *Butea monosperma* was having the highest neutral detergent fibre (65.40%), whereas, *Melia azedarach* was having the lowest NDF content (15.43%). Based on the proximate constituents it can be concluded that *Carissa spinarum* contained crude protein content to meet the nutritional requirements of ruminants for maintenance and minimum production, whereas, all other nine selected top feeds contained crude protein to meet the nutritional requirements for maintenance and high production. Further, on the basis of neutral detergent fibre content, it can be concluded that five selected top feeds viz. *Carissa spinarum*, *Leucaena leucocephala*, *Morus alba*, *Melia azedarach* and *Grewia Optiva* had NDF content for meeting the nutritional requirements of ruminants for high production; whereas, *Psidium guajava* had NDF content to meet the nutritional requirements for minimum production. The total phenolics content was highest in *Zizyphus jujba* (6.25 % DMB) and lowest in *Dendrocalamus strictus*

(0.97% % DMB). The proanthocyanidin (condensed tannin, % on DMB) varied from 0.26 in *Dendrocalamus strictus* to 4.25 in *Zizyphus nummularia*. Based on the tannin contents, it may be concluded that *Carissa spinarum*, *Zizyphus jujuba* and *Zizyphus nummularia* which contain optimum amounts of CT can promote beneficial effects on ruminants' health and productivity. Chemical composition and nutrient utilization of top feeds of shivalik range and District Poonch of Jammu and Kashmir have been evaluated (Sharma *et al.*, 2000; Ganai *et al.*, 2022, 2025)

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3.25 Long-term Impact of Integrated Pest Management Farmer Field Schools on Farmers' Attitudes, Knowledge, and Adoption: An *Ex-Post Facto* Analysis from North India

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Keywords: Knowledge, Attitude, Adoption, Application Pesticides and Average Pesticide Use.

1. Background

In India, Integrated Pest Management (IPM) was adopted by the Government of India as the main strategy of plant protection in 1985 and its activities were intensified only since 1993 (Peshin & Kalra, 2000). Farmer Field School (FFS) as an extension model for disseminating IPM technology was introduced in 1993 through Central Integrated Pest Management Centers (CIPMCs) in rice, cotton, and vegetable crops. The FFS was to facilitate farmers in acquiring knowledge of IPM practices and in developing a favourable attitude towards the adoption of IPM. IPM-FFS programmes have positive short and medium-term (three-year follow-up) effects for participating farmers in terms of knowledge gains, adoption of IPM practices, and reduced pesticide use, but these benefits fade over time. Therefore, we conducted an interstate ex-post facto study to analyse long-term impacts of IPM on farmers' knowledge, attitudes and adoption.

2. Materials and method

An *ex-post* facto (with/without) research design was employed to conduct an impact evaluation. The subtropics of Jammu and Kashmir (J&K) and Punjab were selected to draw the sample of villages. Under the IPMFFS, the CIPMCs of Jammu and Punjab have covered 71 villages (Jammu: 35; Punjab: 36) as part of the rice IPM programme between 2011 and 2020. Out of these, 24 villages were selected by random sampling from Jammu and Punjab, 12 each. Besides, a control group of 10 villages was selected in which no IPMFFS programme has ever been implemented in Jammu and Punjab. From each IPM village, 10 rice-growing farmers trained under the IPMFFS were randomly selected. From 10 non-IPM villages, 10 rice growers were randomly selected from each village after preparing a list of rice farmers in each village.

Thus, the total sample size was 340 rice farmers, 240 IPMFFS, and 100 non-IPM farmers.

3. Results and Conclusion

In Jammu, the mean knowledge and attitude score of the IPM farmers was 26.77 and 43.23, and that of the non-IPM farmers was 23.38 and 40.76, and the differences of 3.39 and 2.47 were statistically significant ($t=3.13$, $df=168$, $p=0.002$) ($t=4.00$, $df=168$, $p=0.000$). Where in the case of Punjab, the mean knowledge and attitude score of the IPM farmers was 28.54 and 39.92, and that of the non-IPM farmers was 27.30 and 39.26, and a difference of 1.24 and 0.66 was not statistically significant ($t=0.877$, $df=168$, $p=0.382$) (Table 1). Both the IPM-FFS-trained and control group farmers' mean attitude scores were unfavourable towards IPM practices, as they were below the mean attitude score obtained using the Tau-score.

The extent of adoption of resistant/ tolerance of rice, seed treatment, deep summer ploughing, recommended transplanting dates for basmati varieties and non-basmati varieties in Jammu (First to second fortnight of June) and in Punjab, non-basmati varieties of rice as recommended by PAU (Second fortnight of June) was higher among the IPM-FFS farmers as compared to the non-IPM farmers. In Jammu, the difference between IPM and non-IPM farmers was statistically significant in the case of seed treatment, deep summer and recommended transplanting dates for non-basmati varieties. Where

in the case of Punjab, there was only a significant difference in the recommended transplanting dates for non-basmati varieties of as recommended by PAU. Most of the farmers were unaware of the clipping of the seedlings and had not adopted the use of coir rope because of the labour involved in these practices. The average applications of pesticides were 2.30 in case of IPM farmers and 3.06 in case of non-IPM farmers and a difference of 0.76 was statistically significant. Where as in case of Punjab, the IPM farmers on an average had applied 1.935 kg/ha (a.i) and non-IPM farmers had applied 2.013 kg/ha (a.i). The IPM farmers had applied (4 %) less pesticides (a.i) than the non-IPM farmers. The average pesticides application were 8.09 in case of IPM farmers and 8.69 in case of non-IPM farmers and the difference was not statistically significant (Table 2)

Table 1: Mean knowledge and attitude score of the farmers about IPM practices

Jammu					Punjab			
	IPM (n=120)	Non-IPM (n=50)	Difference	t / (p-value)	IPM (n=120)	Non-IPM (n=50)	Difference	t / (p-value)
	1	2	(1-2)		3	4	(3-4)	
Mean knowledge score	26.77 ±6.42	23.38 ±6.00	3.39*	3.13 0.002	28.54 ±8.23	27.30 ±8.82	1.24	0.88 0.382
Mean attitude score	43.43 ±4.06	40.76 ±2.46	2.47*	4.00 0.000	39.92 ±8.23	39.26 ±8.82	0.66	1.02 0.310

Table 2: Adoption of IPM practices and pesticide use

Jammu				Punjab		
	IPM (n=120)	Non-IPM (n=50)	Difference (test)	IPM (n=120)	Non-IPM (n=50)	Difference (test)
Practice	1	2	(1-2)	3	4	(3-4)
Resistant/ tolerant varieties of rice (% farmers)	33	29	4 (z=0.60)	61	56	5 (z=0.70)
Seed treatment (% farmers)	32	14	18* (z=3.00)	53	60	-7 (z=1.00)
Deep summer ploughing (% farmers)	53	18	35* (z=5.20)	65	56	9 (z=1.30)
Recommended transplanting dates of basmati varieties (% farmers)	65	56	9 (z=1.30)	89	88	1 (z=0.50)
Recommended transplanting dates of non-basmati Varieties (% farmers)	64	40	24* (z=3.40)	68	84	-16* (z=2.60)
Mean pesticide use by weight (a.i) (kg/ha)	1.247 ±0.043	1.286 ±0.074	-0.039 (3 %)	1.935 ±0.056	2.013 ±0.084	-0.078 (4 %)
Mean pesticide applications (no.)	2.300 ±0.129	3.060 ±0.279	-0.760*	8.092 ±0.247	8.690 ±0.259	-0.598

The IPM-FFS programme has led to increased knowledge of IPM practices, but farmers also

reported negative attributes of these practices, which led to lower adoption of these practices. The reasons for this include farmers' low levels of education, limited exposure to media, and unfavourable attitude towards IPM practices, leading farmers to non-adoption of IPM practices. No long-term impact of IPM FFS on the difference in pesticide use between trained and other farmers was observed.

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Theme 4:

Agrobiodiversity, Horticulture, Agroforestry, and Ecosystem Services



4.1 Impact of Bio-Stimulants on *Solanum lycopersicum* L. and *Pisum sativum* L. under Fruit-based Agroforestry System

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Keywords: Bio-stimulants, Botanical extract, Fruit-based agroforestry, Humic acid, Protein hydrolysate

1. Background

Fruit-based agroforestry systems are increasingly recognized for their role in improving resource use efficiency, soil fertility, and farm profitability in hilly regions (Adane *et al.*, 2019). However, the productivity of intercrops in such systems is often constrained by nutrient competition and altered microclimatic conditions. Bio-stimulants, when applied in conjunction with recommended doses of fertilizers (RDF), have shown potential to enhance plant growth, yield, nutrient uptake and soil biological activity (Patrick, 2015). Despite their growing use, systematic evaluation of bio-stimulants under fruit-based agroforestry systems remains limited in the mid-hill regions of Himachal Pradesh. Therefore, the present investigation was undertaken to assess the influence of different bio-stimulants on growth, yield, quality attributes, soil properties, and economic returns of *Solanum lycopersicum* L. and *Pisum sativum* L. under agroforestry and sole cropping systems.

2. Materials and Methods

The field experiment was conducted during 2023–2024 at the experimental farm of the Department of Silviculture and Agroforestry, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP), India. The experiment was laid out in a factorial randomized block design (RBD) consisting of two main plot treatments, viz., fruit-based agroforestry system (AFS) and sole cropping, and eight subplot nutrient management treatments. The treatments included control (T₁), RDF (T₂), vermicompost (T₃), natural farming practices (T₄), farmyard manure (T₅), RDF + humic acid (T₆), RDF + botanical extract (T₇), and RDF + protein hydrolysate (T₈). Bio-stimulants were applied as supplements along with RDF. Growth, yield, quality parameters were recorded and analyzed using standard statistical procedures. RDF for tomato was N 104 kg/ha, P 76 kg/ha and K 54kg/ha where it was 26kg/ha N, 60kg/ha P and K 60 kg/ha for pea.

3. Results and Conclusion

The findings indicated that bio-stimulant application significantly influenced growth and productivity of both vegetable crops. In *Solanum lycopersicum*, the application of RDF + humic acid resulted in superior growth performance, recording maximum plant height (182.88 cm), number of primary branches (6.06), total branches (15.60), leaf area (15.49 cm²), root-shoot ratio (0.27), earlier maturity (37.00 days), higher number of pickings (8.66), prolonged harvest duration (26.66 days), and highest fruit yield (66.44 q ha⁻¹). Quality analysis of tomato fruits revealed improved nutrient composition under agroforestry, with the highest phosphorus (0.75%), potassium (0.25%), and total soluble solids (4.32 °Brix). In *Pisum sativum*, enhanced growth and yield attributes such as plant height (68.67 cm), pod length (10.10 cm), nodulation (25.10 nodules plant⁻¹), pods per plant (17.50), pod weight (6.26 g), 100-seed weight (35.85 g), harvest duration (29.33 days), and yield (57.21q ha⁻¹) were observed. However, maximum shelling percentage (49.55%), plant biomass (7.18 kg plot⁻¹), and yield performance under agroforestry conditions were recorded with RDF + protein hydrolysate treatment. The sole cropping recorded significantly

higher growth and yield parameters of *Solanum lycopersicum* L., including plant height (167.72 cm), number of primary branches (5.46), root–shoot ratio (0.23), leaf area (13.99 cm²), number of pickings (7.33), and fruit yield (56.79 q ha⁻¹). In contrast, quality attributes such as plant nitrogen (2.76%), phosphorus (0.75%), potassium (0.25%), and total soluble solids (3.79 °Brix) were superior under the fruit-based agroforestry system. Among nutrient management treatments, the combined application of RDF + humic acid resulted in maximum growth attributes, viz., plant height (179.08 cm), number of primary branches (6.05), branches per plant (15.60), root–shoot ratio (0.26), and leaf area (15.19 cm²). Yield attributes were also significantly enhanced under RDF + humic acid, recording the highest number of pickings (8.16), minimum time to maturity (37 days), extended harvest duration (26.66 days), and maximum yield (64.88 q ha⁻¹). Quality parameters such as phosphorus (0.95%), potassium (0.34%), and TSS (4.24 °Brix) were highest with RDF + humic acid, whereas maximum plant nitrogen content (3.96%) was observed with RDF + protein hydrolysate. In *Pisum sativum* L., the fruit-based agroforestry system significantly improved growth and yield traits, recording higher pod weight (5.04 g), 100-seed weight (32.40 g), yield (52.02 q ha⁻¹), and TSS (15.78 °Brix), while shelling percentage was maximum under sole cropping (43.76%). Among nutrient source treatments, RDF + protein hydrolysate proved most effective, resulting in maximum plant height (68.98 cm), plant biomass (7.16 kg plot⁻¹), pod length (10.10 cm), nodulation (25.03 nodules plant⁻¹), pods per plant (16.95), pod weight (5.99 g), 100-seed weight (34.10 g), shelling percentage (48%), harvest duration (29.16 days), and yield (57.20 q ha⁻¹). The same treatment also recorded the highest total soluble solids in pea seeds (17.56 °Brix). The combined application of humic acid and recommended dose of fertilizers (RDF) resulted in superior growth and yield performance of *Solanum lycopersicum* L. under open conditions, whereas *Pisum sativum* L. exhibited better performance under the fruit-based agroforestry system when supplied with RDF in combination with protein hydrolysates.

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4.2 Phenolics Signatures in Response to Salinity Stress provide Novel Insights into Physiological Basis of Salt Tolerance in Mango (*Mangifera indica* L.)

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Keywords: Mango, Mutation, Phenolic acid profiling, Rootstock, Salinity stress

1. Background

Mango (*Mangifera indica* L.) is mainly grown in semi-arid regions with sub-tropical and tropical climate. Salinity and sodicity are the most significant ecological factor that causes extensive crop yield loss in these regions. In India, approximately 6.74 m hectares of land is salt-affected and nearly 50% of the arable land is estimated to get affected with salt by the year 2050 (Kumar and Sharma 2020). Mango is highly sensitive to soil and water salinity and hence alkaline and saline soils should be avoided for its cultivation. Mango cannot tolerate high soil salt content (not more than 0.05%). Increase in root zone salinity severely impairs normal plant growth and development by increasing water stress, toxicity of specific ions like sodium or chloride and aggravating the production of reactive oxygen species leading to oxidative stress (Munns 2002). Higher levels of salinity has also been found to increase the production of secondary metabolites like pigments, phenolic compounds and flavonoids which play a major role in providing protection against oxidative damage in plants.

2. Materials and Methods

The effect of salt stress was evaluated on putative mutant seedlings (generated through gamma irradiation) of three polyembryonic mango genotypes viz., Bappakkai, Nekkare and Kurukkan. Total 200 putative mutants were selected and the treatments included watering them with 0 mM (Control-0.88 dS m⁻¹), 25 mM (EC- 2.7 dS m⁻¹), 50 mM (4.9 dS m⁻¹) and 75 mM (7.56 dS m⁻¹) NaCl+CaCl₂ (1:1, w/w) up to 88 days at a regular interval of four days. Several parameters like potassium and sodium content, total phenol content, relative water content (RWC), proline content, chlorophyll content, gas exchange parameters were determined along with phenolic acid profiling using Liquid Chromatography with tandem mass spectrometry (LC-MS-MS). Using SAS V9.3, the data were submitted to an analysis of variance (ANOVA), and results were considered significant at p<0.05. The statistics of various mean combinations was evaluated using Duncan Multiple Range Test (DMRT).

3. Results and Conclusion

Imposition of salinity stress resulted in a decrease in chlorophyll content, relative water content and gas exchange parameters while enhancing the levels of stress markers like Na⁺/K⁺ ratio, total phenols and proline. In total, thirteen phenolic acid compounds were identified including eight hydroxybenzoic acids and five hydroxycinnamic acids wherein hydroxybenzoic acid (majorly gallic acid) comprised more than 99% of total phenolic acids. In all the three genotypes, the concentration of protocatechuic acid, 2,4-Dihydroxy benzoic acid, gallic acid, chlorogenic acid and t-cinnamic acid increased with increasing level of salt stress indicating their potential role in mango salt tolerance. Bappakkai recorded higher K⁺, highest fold increase in proline content (+7.27 fold),

highest percent increase in chlorogenic acid (+510%), protocatechuic acid (+750%) and ferulic acid along with lower Na^+/K^+ ratio and lower reduction in the levels of caffeic and sinapic acid at higher level of salt stress suggesting that putative mutants of Bappakkai were better at tolerating salt stress as compared to the other two genotypes. Application of ferulic acid (FA) to Nekkare putative mutants increased the activity of enzymatic antioxidants, superoxide dismutase (SOD), catalase (CAT) and ascorbate peroxidase (APX). Further, quantitative real-time PCR analysis also revealed higher expression levels of SOD, CAT and APX in FA-treated Nekkare mutants under salinity stress. Bappakkai mutants were better at tolerating salt stress as compared to the other two genotypes. Our study confirms the genotype-specific attribute of phenolic compounds and their role in mango salt stress tolerance as well as the potential of exogenous application of phenolic acid in mitigating the salt stress in mango. The results of this study besides identifying distinct phenolic acid signatures in response to stresses like gamma irradiation and salinity, also confirm the potential of physical mutagenesis in breeding salt tolerant rootstocks in mango.

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4.3 Fire Frequency Effects on Forest Fuel Heterogeneity in Indian North Western Himalayas

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Keywords: Fire frequency, Fuel load, Fire management, Himalayan ecosystems

1. Background

Fire has been an intrinsic component of the earth's natural environment for centuries, governed by the interaction of three essential elements like fuel, heat and oxygen. As a major ecological disturbance, fire plays a decisive role in regulating vegetation structure, species composition and ecosystem dynamics. The frequency and intensity of fire events strongly influence forest fuel accumulation, distribution and heterogeneity, thereby shaping long-term ecosystem functioning and resilience. Globally, fire regimes have a profound impact on forest ecosystems. In 2015 alone, approximately 98 million hectares of forest about 3% of the global forest area were affected by fire, with the majority of burned areas occurring in tropical regions, where nearly 4% of total forest cover was impacted (GFRA, 2020). Increasing fire frequency worldwide has been largely attributed to persistent hotter and drier climatic conditions driven by climate change, compounded by human activities such as land-use change, agricultural expansion and inadequate forest management practices. According to the WWF International (2020), nearly 75% of wildfires globally are caused by anthropogenic activities. A notable 13% rise in global fire alerts was recorded in April 2020 compared to the previous year, highlighting the growing dominance of human-induced fire disturbances. In India, forest ecosystems are increasingly exposed to frequent fire events, with more than 36% of the country's forest cover estimated to be prone to recurrent fires. Nearly 4% of forest cover is classified as extremely fire-prone, while about 6% falls under very high fire-prone categories. As per the India State of Forest Report (ISFR, 2021), approximately 1,791 sq km of forest area (0.08% of total forest cover) is categorized as very highly fire-prone. Repeated fire incidents in these regions significantly alter forest fuel characteristics by influencing fuel load, continuity, moisture content and spatial heterogeneity. The Indian North-Western Himalayas, particularly Jammu and Kashmir, have experienced a notable increase in fire frequency in recent years. Between 2019–2020 and 2020–2021, 62 and 131 fire detections were recorded, respectively. Historical data reveal that 341 hectares of forest area were affected by fires in 2016, while in 2017, approximately 2,579 hectares were impacted across the region. Earlier records indicate 214 fire incidents in 2015 affecting 341.4 hectares, along with 470 and 278 incidents in 2014 and 2013, respectively. A sharp escalation was observed when fire incidents rose from 214 in 2016 to 775 in 2017. Rising temperatures and prolonged dry spells, coupled with insufficient rainfall, have been identified as major climatic drivers of these increasing fire occurrences. Importantly, over 90% of forest fire incidents in the region are attributed to man-made causes, including intentional burning, negligence and land-use pressures. Recurrent fires at short intervals prevent complete fuel recovery, leading to pronounced heterogeneity in forest fuel structure. Such heterogeneity affects fire behaviour, intensity and spread, creating complex feedback mechanisms that further influence forest composition, regeneration patterns and ecosystem stability in the North-Western Himalayan region.

2. Materials and Methods

The focus of the study was district Udhampur of Jammu and Kashmir, India. The base layers were prepared using toposheets. The forest fire maps were prepared using Landsat images (TM, ETM+ and OLI-TIRS). The normalised burnt area mapping was used to prepare forest fire maps based on the infrared composite image (band combination 7-4-1 in RGB for the Landsat ETM+) to generate the forest burned and unburned area maps for each month of the year between 2014 and 2024. The month-wise fire maps were merged to produce the year-wise map. All year-wise raster maps were converted to vector files and a unique value for burned and unburned areas was assigned and converted again to raster files. Finally, all the raster data of each year were combined to form fire frequency maps using map algebra in ArcGIS software. In the fire frequency map, all pixels were labelled according to the number of occurrences of fire between 2014 and 2024 as B1–B10. The unburned pixels were labeled as B0 and these are then categorised into different fire frequency classes: control, very low, low, moderate, high, and very high. Fuel characteristics including litter composition, biomass accumulation, and distribution are assessed across sites with different fire frequency classes.

3. Results and Conclusion

Results reveal a clear inverse relationship between fire frequency and litter biomass, with control plots exhibiting maximum litter (5.4 Mt/ha) and the very high frequency class recording the lowest (2.9 Mt/ha). Pine needles constitute the major portion (55%) of the fuel load, followed by leaf litter of broad leaved species (20%), bark and cones (15%), and smaller fractions of twigs, branches, grasses, and herbs. The findings highlight how repeated fire events significantly reduce surface fuel accumulation by suppressing organic matter build up and altering vegetation composition. It advocates for frequency-specific fuel management plans, promoting fire-resistant native species, safeguarding natural regeneration and deploying community-based early detection systems. These adaptive measures aim to enhance forest resilience and mitigate the cascading effects of frequent wildfires in climate-vulnerable mountain ecosystems.

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4.4 Effect of Rooting Hormone on Macro-Proliferation of Different Bamboo Species

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Keywords: Auxins, Growth and root parameter, Macro-proliferation, Rooting hormones

1. Background

Bamboo is the multifunctional and fastest-growing plant. Bamboo has played a crucial role in the daily life of millions of people in tropical countries, where it provides environmental, social and economic benefits (Ahmad *et al.*, 2021). Bamboos are an essential part of existence, not only in Indian culture but also across Southeast Asian culture. Bamboo has great potential to fulfill the basic needs of daily life and to develop entrepreneurs, due to which there is increase in bamboo farming and also increase in demand of saplings of different bamboo species. Therefore, there is necessity to mass propagate bamboo plants. Bamboo can be propagated through of seed (sexual) and vegetative (asexual) propagation. Seed availability of bamboo species is more infrequent. Most of the bamboo species flower and produce seeds just once in their lifetime, after growing for 3 to 150+ years, hence vegetative propagation method is most popular. Bamboo seedlings possess the capacity to proliferate and this potential of bamboo can be used for mass propagation using macro-proliferation method. In this method the seedlings of known age are allowed to grow for six months to one year in nursery and when the new shoots are observed growing from the rhizome, the seedlings are used for proliferation. The new rhizomes are separated from the seedlings using a secateur and are planted in a fresh polybag. By around three months, tillers develop, out of which some are retained in the nursery for future multiplication and remaining saplings are used for field planting. This cycle can be repeated every year for the production of planting stocks of known age for raising large scale plantations (Kumar, 1991). Further for better rooting and survival of the new rhizomes growth hormone treatments may play a good role (Vekatesh and Kariappa, 2021). Considering the above facts and demand from the farmers for known age plant this investigation programme entitled “Effect of rooting hormone on macro-proliferation of different bamboo species” has been designed to standardize a protocol for mass propagation of *Bambusa spp.* through macro-proliferation.

2. Materials and Methods

The investigation was carried out during February to June 2024 at Bamboo Resource Center, College of Forestry, Navsari Agricultural University, Navsari, Gujarat, India. The experiment was conducted in nursery conditions with factorial completely randomized design in which one year old seedlings of three different bamboo species viz., B₁: *B. nutans*, B₂: *B. tulda* and B₃: *B. polymorpha* were transplanted into polybags size 6 x 8 inch and treated with seven different levels of auxins concentrations i.e., G₁: Control, G₂: IBA 100 ppm, G₃: IBA 200 ppm, G₄: IBA 100 ppm + NAA 200 ppm, G₅: IBA 200 ppm + NAA 100 ppm, G₆: NAA 100 ppm and G₇: NAA 200 ppm. Fifteen cuttings of each treatment under each repetition were planted. Further, growth and root parameters, of three bamboo species were recorded along with survival percentage and multiplication rate. The data obtained from the experiment were processed and fed to the data sheet

in MS Excel and analysis using appropriate statistical software in FCRD (Factorial Completely Randomized Design). The standard error of mean [S. Em. ($\pm$)] was calculated in each case and Critical Difference (CD) at 5 per cent level of probability was worked out to compare the treatment means (Panse and Sukhatme, 1985).

3. Results and Conclusion

In different auxin concentration, reduction in all parameters was noted maximum in G₄: IBA 100 ppm + NAA 200 ppm, G₅: IBA 200 ppm + NAA 100 ppm, G₃: NAA 200 ppm and G₆: NAA 100 ppm auxins levels as compared to G₁: control and G₂: IBA 100 ppm on macroproliferated plants. While among three different bamboo species, B₁: *B. nutans* performed the best for growth parameters viz., days taken for first sprout (9.21), number of sprouts per plant (1.79), number of leaves per macro-proliferated plants (9.67). However, basal diameter (2.86 mm) recorded the highest in B₂: *B. tulda* and shoot height (31.34 cm) was recorded in B₃: *B. polymorpha* at 120 DAT under different concentration of auxins levels. Moreover, in case of root parameters, survival percentage and multiplication rate; B₃: *B. polymorpha* performed the best for, root length (18.51 cm), number of rootlets (21.42), number of rhizomes (2.34), survival percentage (45.71 %) and multiplication rate (1.73) at 120 DAT under different concentration of auxins levels. Almost all the parameters showed positive response towards the no auxin's treatments. All parameters were performed better in control or untreated cuttings. However, different concentration of auxins showed adverse effect towards all parameters which concluded that there was no requirement of rooting hormones for large scale propagation of *Bambusa* spp. through macro-proliferation techniques.

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4.5 Factors Hindering Fruit Yield and Quality: An Insight from Samba District of J&K UT

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Keywords: Constraints, Climate change, Fruit cultivation, Horticulture

1. Background

Fruit cultivation plays a vital role in the agricultural economy and livelihood security of farmers in the Union Territory (UT) of Jammu and Kashmir (J&K). The region's diverse agro-climatic conditions are highly suitable for the cultivation of a wide range of fruit crops, which contribute significantly to farm income, employment generation and nutritional security. The horticulture sector contributes significantly to the economy of UT of J&K and is a major source of livelihood. About seven lakh families are directly or indirectly involved with the Horticulture Sector in the UT of J&K. The favourable agro-climatic conditions enhance the horticulture potential, thereby making it a major export industry in the UT of J&K. It produces a diverse range of fruits such as apple, walnut, almond, pear, mango, citrus, cherry, apricot, peach and plum etc. During 2024, the total area under fruit cultivation in J&K was 3,44,696.40 hectares (ha) with a production of 26,43,340 metric tonnes (MT). Samba District accounted for 5,653.50 ha area under fruit crops, producing approximately 12,560 MT of fruits reflecting its growing importance in subtropical areas (Digests of Statistics J&K 2024). Fruit cultivation in Samba District of J&K faces increasing challenges due to climate change and environmental stresses, which threaten orchard productivity and fruit quality. Rising temperatures and erratic weather patterns disrupt critical growth stages such as flowering and fruit set. Extreme heat results in flower drop, sunburn injury and uneven fruit ripening, while frost events damage buds and reduce yields. These changes, intensified by global climate change which also increase pest and disease pressure on fruit crops such as mango and citrus.

2. Materials and Methods

The present study was conducted in the Samba district of Jammu and Kashmir. Samba district is situated between 32° 34' 0 N latitude and 75° 70' E longitudes. About two third of the area of district Samba is rainfed. There are nine blocks in the Samba district and out of nine blocks, sample were taken randomly selected five blocks. The total sample size for the present study comprises of fifty farmers.

3. Results and Conclusion

The findings presented in the Table 1 indicates that adverse weather conditions such as unseasonal rains and hailstorms emerged as the most severe constraint, securing Rank I with the highest Weighted Mean Score(WMS) (3.08). The second constraint reported by the fruit growers were excessive rainfall that causes flower drop and fruit rot (WMS=2.92; Rank II). This was closely followed by irregular rainfall affecting flowering and fruiting (WMS=2.80; Rank III). Hailstorms and strong winds damaging fruit trees ranked IV with a WMS of 2.76. The constraint climate change leading to erratic fruiting behaviour was ranked VI (WMS=2.64), while salinity reducing lime crop productivity occupied Rank VII (WMS=2.60). Lower ranks were assigned to drought or water scarcity during fruit development (WMS=2.56; Rank VIII) and rising temperature affecting mango flowering (WMS=2.52; Rank IX). Overall, the results clearly demonstrate that extreme

weather events and rainfall variability constitute the most critical constraints affecting fruit cultivation. Thus, the present study suggests that to improve the productivity of fruit crops, farmers need to be educated about climate mitigating practices.

Table 1. Constraints reported by the respondent farmers regarding low fruit productivity

S No.	Constraints	Weighted Mean Square	Rank
1.	Adverse weather conditions like unseasonal rains and hailstorms	3.08	I
2.	Drought or water scarcity during fruit development	2.56	VIII
3.	Rising temperature affecting fruit flowering	2.52	IX
4.	Climate change leading to erecting fruiting behaviour	2.64	VI
5.	Irregular rainfall affects fruit flowering and fruiting	2.80	III
6.	Excessive rainfall causes flower drop and fruit rot	2.92	II
7.	Salinity reduces lime crop productivity	2.60	VII
8.	Unfavourable temperature affects fruit quality	2.68	V
9.	Hailstorms and strong winds damage fruit trees	2.76	IV

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4.6 Performance of *Hordeum vulgare* and Soil Properties under *Prunus domestica* based Agroforestry System in Sirmaur district of Himachal Pradesh, India

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Keywords: Agroforestry, Benefit- cost ratio, Growth, Harvest index, Yield

1. Background

Prunus domestica is a stone fruit belongs to the family Rosaceae. It is also known as “Aloo Bukhara” in India. It is one of the important and broadly cultivated crops of temperate regions of the world. Santa Rosa variety of *Prunus domestica* is the major *Prunus domestica* cultivar grown over 90% of the total area under *Prunus domestica* cultivation in Himachal Pradesh (Kumar *et al.*, 2018). *Hordeum vulgare* is one of the initiator crops of ancient world agriculture and was one of the first domesticated cereals. The crop is considered as poor man’s crop and better adaptable to problematic soils under marginal lands. It comprises nearly 350 species, of which *Hordeum* includes 32 species encompassing both wild and cultivated types.

2. Materials and Methods

The present field experiment was conducted from October 2022 to April 2023 in four villages namely Batoli, Bari Bhun, Muchhari and Mangarh located in the Sirmaur district of Himachal Pradesh. The study aimed to evaluate the growth of *Hordeum vulgare* and assess the soil physico-chemical properties under a *Prunus domestica* based agroforestry system. The experiment was laid out in a Randomized Block Design (RBD) with three replications. Growth parameters such as plant height (cm), panicle length (cm), number of fertile spikelets, number of sterile spikelets, number of grains per panicle, grain weight per panicle (g) and 1000-grain weight (g), along with yield parameters including grain yield (q/ha), straw yield (q/ha), biological yield (q/ha), and harvest index (%), were analyzed at four different distances from the tree base, namely D1 (1 m), D2 (2 m), D3 (3 m) and control.

3. Results and Conclusion

It was observed that the growth and yield of the *Hordeum vulgare* crop were higher under control condition compared to those under tree canopies. The highest plant height (89.87 cm) and harvest index (32.05%) were recorded in control condition at Mangarh. The maximum benefit cost ratio (BCR) (2.89) was observed for *Prunus domestica*-*Hordeum vulgare* based agroforestry system. Soil physico-chemical properties were analyzed at different soil depths under both control conditions and beneath the trees. The parameters studied included soil pH, organic carbon (%), nitrogen, phosphorus, and potassium. The results indicated that organic carbon, nitrogen, phosphorus, and potassium contents were highest at the 0–15 cm soil depth under agroforestry system.

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4.7 Weed Management in Organically Grown Basmati Rice-Vegetable Pea-Sweet Corn Cropping System

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Keywords: Basmati rice, Green manure, Intercropping, Weed biomass, Rice equivalent yield

1. Background

Basmati rice-based cropping systems are emerging as profitable and diversified alternatives to conventional rice-wheat rotations in the irrigated subtropical belt of Jammu region. Integration of cereal-legume-vegetable sequences enhances cropping intensity, resource use efficiency, and farm income. Basmati rice-370 is highly valued worldwide for aroma and grain quality (Mushtaq *et al.*, 2024). Weed infestation is a major constraint, causing yield losses of 9–51%, which may increase to 62.6–75.8% in uncontrolled conditions (Neelapati *et al.*, 2025). Vegetable pea and sweet corn are particularly vulnerable due to slow initial growth and weak competitiveness, with potential yield losses up to 85%. Organic weed management combining green manuring, intercropping and manual weeding offers sustainable weed suppression, improves soil health, and enhances system productivity and profitability (Hasam *et al.*, 2021). This study aimed to evaluate the integrated effects of *Sesbania* green manuring, intercropping and hand weeding on weed dynamics, productivity, and economics of the Basmati rice-vegetable pea-sweet corn cropping system under subtropical Jammu conditions.

2. Materials and Methods

Field experiments were conducted during 2022–23 and 2023–24 at AICRP-Weed Management Research Farm, SKUAST-J, Chatha, Jammu (32°40' N, 74°82' E, 332 m above mean sea level). *Sesbania* (*Sesbania aculeata*) green manure was incorporated at 45 days before transplanting rice. Basmati rice (cv. Basmati-370) was transplanted during *Kharif*, vegetable pea (cv. PS-10) was grown during *Rabi* with radish or green onion intercrops, and sweet corn (Hybrid Sugar-75) was planted during *Zaid* with blackgram or *Sesbania* mulch. The experiment followed a split-split plot design with main plots (rice), subplots (pea), and sub-sub plots (sweet corn). Nutrients were applied through vermicompost according to recommended doses. Weed density and biomass were recorded at 30, 60 DAS/DAT and at harvest using 1 m² quadrats. Data were square-root transformed ($\sqrt{x + 1}$) and analyzed using ANOVA (Snedecor and Cochran, 1994).

3. Results and Conclusion

Basmati rice: Dominant weeds were *Echinochloa* spp., *Alternanthera philoxeroides*, *Ammannia baccifera*, and *Cyperus* spp. Two hand weedings at 20 and 40 DAS recorded the minimum weed density (6.50–5.83 No./m²) and biomass (5.04–7.20 g/m²). *Sesbania* green manure + hand weeding resulted in the highest grain yield and rice equivalent yield (REY) of **13.95 t/ha**, with net returns of **Rs. 435,088/ha** and a B:C ratio of **2.15**, due to effective weed suppression and improved soil fertility.

Vegetable pea: Major weeds were *Anagallis arvensis*, *Vicia sativa*, *Phalaris minor*, and *Cyperus rotundus*. Two hand weedings reduced weed density (21.95–29.25 No./m²) and biomass (22.80–31.20 g/m²). Intercropping with radish further enhanced system productivity due to additional radish yield, resulting in **REY 14.15 t/ha**, net returns **Rs. 445,719/ha**, and B:C ratio **2.23**.

Sweet corn: Dominant weeds included *Solanum nigrum*, *Amaranthus viridis*, *Imperata cylindrica*, and *Cyperus rotundus*. Sesbania mulch at 40 DAS minimized weed density (75.45 No./m²) and biomass (118.15 g/m²). Intercropping with blackgram resulted in slightly higher REY (13.90 t/ha), net returns (Rs. 432,936/ha), and B:C ratio (2.14) due to additional pulse yield. Overall, Sesbania green manure incorporation before transplanting followed by one mechanical weeding at 30 DAT in basmati rice, vegetable pea intercropping with radish and sweet corn intercropping with blackgram were found most remunerative, recording the highest REY (13.95, 14.15 and 13.90), net returns (Rs.) (435088, 645750 and 432936) and B:C ratio (2.15, 2.23 and 2.14) under the respective cropping sequences. Hence, in Jammu, basmati rice with Sesbania green manure and one weeding, vegetable pea intercropped with radish, and sweet corn intercropped with blackgram gave the highest yield and profitability.

Table 1: Effect of different weed management practices on rice equivalent yield (REY) and economics

S.no	Treatments	REY (t/ha.)	Total cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
Basmati rice (Main-plot)						
1.	Sesbania green manure before transplanting fb1 mechanical weeding at 30 DAT	13.95	202247	637335	435088	2.15
2.	Sesbania green manure before transplanting fb Hand weeding at 30 DAT	13.90	202198	635122	432924	2.14
3.	Two hand weeding at 20 and 40 DAT	13.78	202458	629595	427136	2.11
	SEm±	0.02				
	L.S.D (p=0.05)	0.06				
Vegetable pea (sub-plot)						
1.	Intercropping with radish	14.15	200030	645750	445719	2.23
2.	Intercropping with green onion	13.44	205816	614827	409011	1.99
3.	Two hand weeding at 20 and 40 DAT	14.05	201056	641685	440628	2.19
	SEm±	0.03				
	L.S.D (p=0.05)	0.10				
Sweet corn (sub-sub-plot)						
1.	Intercropping with sesbania and kept as mulch at 40 DAS	13.86	202700	633255	430554	2.12
2.	Intercropping with blackgram	13.90	201901	634837	432936	2.14
	SEm±	0.02				
	L.S.D (p=0.05)	NS		-		

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4.8 Evaluation of Indian Bean Genotypes against Pod Borer, *Helicoverpa armigera* in relation to Plant Morphological Characters

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Keywords: Indian bean, correlation, genotypes, morphological characters, pod borer

1. Background

Indian bean (*Dolichos lablab* L.) Syn. *Lablab purpureus* L., *Lablab niger* Medik is an important pulse crop having great potentiality for protein and yield. In India, it has an area of 23.86 mha (Anonymous, 2009) while in Gujarat, it occupies an area of 8901 mha with production of 7218 MT. The major insect pests damaging the crop are aphid, jassid, whitefly, pod borer, spotted pod borer and pod bug which attack buds, flowers and pods. Of which, pod borer *Helicoverpa armigera* (Hubner) is a major pest and is one of the major constraints in production. So, the present study was undertaken with the objective of screening Indian bean genotypes against pod borer *H. armigera* in relation to morphological characters.

2. Materials and Methods

The field experiment was conducted at Navsari Agricultural University, Navsari to screen 114 Indian bean genotypes against pod borer damage in relation to plant morphological characters. Pod borer damage was assessed by counting total pods and bored pods from top, middle and bottom part in each tagged plant (2/ genotype). The experimental trial was laid out in randomized block design using two replications. Significance of pod damage in each entry was assessed using ANOVA. Morphological parameters like growth habit (branching or erect), leaf characters (length, breadth, area and colour), trichome and leaf waxy coating (presence/absence), stem or shoot characters (height and colour), flower colour, pod characters (colour, shape, length, width and area), number of seeds per pod and pod yield in total picking were compared with pod damage on the basis of correlation coefficients. Non measurable parameters were compared on the basis of numerical ratings.

3. Results and Conclusion

I. Screening of Indian bean genotypes on the basis of pod borer damage

None of the genotypes remained free from pod borer attack indicating lowest pod damage in NIB-46 (0.96 %) (Tolerant reaction) while it remained highest in Gujarat papdi-1 (40.46 %) (Susceptible reaction).

II. Relationship of pod borer damage with plant morphological characters

- 1. Growth habit:** Resistant entries NIB 46, 28, 103, 86 and 25 possessed erect and semi erect growth habits indicating lower pod damage (0.96, 3.40, 3.70, 4.00, 4.1 %) while highly susceptible Gujarat papdi-1, NIB-15 and NIB-12 possessed spreading growth habit indicating significantly higher pod damage (40.46, 34.02 and 33.99 %). Correlation between pod damage and growth habit was highly significant ($r=0.2878$).
- 2. Leaf width:** Significantly higher leaf width (10.28, 9.46, 9.24, 9.19, 9.16 and 9.13 cm) were noticed in NIB-17A, 5B, 29, 11, 18 and 4, respectively wherein pod damage was low (9.8, 7.10, 9.9, 6.5, 7.7 and 12.7 %) while, it was lower in NIB-42A (6.29 cm) indicating high pod damage

- (20.3%). The correlation between pod damage and leaf width was significant ($r=-0.2302$)
3. **Leaf area:** Significantly higher leaf areas (100.22, 89.89, 88.04, 87.35, 84.74, 83.37 cm²) were observed in NIB-17A, 5B, 40, 11, 18, 72, respectively. These entries recorded 9.8, 7.10, 16.4, 6.5, 7.7, 11.4 per cent pod damage, respectively. While genotypes NIB-76, 42A and 70 and Gujarat papdi-1 recorded significantly lower leaf area (45.86, 44.68, 48.53, 49.84 cm²) and had significantly higher pod damage (15.2, 20.3, 16.9, 40.46 %). Correlation between pod borer damage and leaf area was significant ($r=-0.2030$).
 4. **Leaf vein colour:** Resistant NIB-46 possessed purple leaf veins which in turn indicated 0.96 per cent pod damage while, highly susceptible Gujarat papdi-1 possessed light green leaf vein which in turn indicated 40.46 per cent pod damage. Correlation between pod damage and leaf vein colour was highly significant ($r=-0.2212$).
 5. **Leaf trichome:** NIB-1, 6, 7, 19, 20, 21A, 22, 25, 26, 48 and 56 possessed trichomes on leaf surface wherein comparatively lower pod damage was observed (10.8, 12.5, 4.8, 6.7, 6.2, 8.8, 8.1, 4.1, 10.9, 13.2 and 10.7 %) while, highly susceptible Gujarat papdi-1, NIB-12 and 15 were devoid of leaf trichomes. Correlation between pod damage and trichome was significant ($r=-0.1904$).
 6. **Stem colour:** NIB-46, 86 and 25 possessed purple stem indicating significantly lower pod damage (0.96, 4.00, and 4.07 %) while highly susceptible Gujarat papdi-1 possessed green stem which in turn indicated highest pod damage (40.46 %). Significant correlation ($r=-0.2194$) was exhibited between pod damage and stem colour.
 7. **Flower colour:** NIB-46, 86 and 25 possessed purple flowers which in turn recorded significantly lower pod damage (0.96, 4.00, and 4.07 %) while susceptible Gujarat papdi-1, NIB-15 and 12 possessed white flowers had significantly higher pod damage (40.46, 34.02, and 33.22 %). Correlation between pod damage and flower colour was significant ($r=-0.1926$).
 8. **Pod colour:** Genotype NIB-46 possessed purple pods which in turn recorded significantly lower pod damage (0.96%). Whereas Gujarat papdi-1 and NIB-15, 12 and 93 possessed light green pods which had significantly higher pod damage (40.46, 34.02, 33.22 and 32.99 %). The correlation between pod damage and pod colour was highly significant ($r=-0.2460$).
 9. **Pod shape:** NIB-46 possessed straight pods indicating significantly lower pod damage (0.96%) while, Gujarat papdi-1, NIB-15 and NIB-12 possessed curve pods which indicated significantly higher pod damage (40.46, 34.02, 33.22 and 32.99 %). Correlation between pod damage and pod shape was highly significant ($r=0.3046$).
 10. **Pod width:** Significantly higher pod width (3.10, 2.52, 2.47, 2.47, 2.44, 2.26, 2.23, 2.21, 2.19 cm) was observed in NIB-1, 102, 5B, 17A, 18, 38, 100, 51 and 52 which indicated significantly lower pod damage (10.8, 7.00, 7.10, 9.8, 7.7, 16.0, 13.6, 7.2 and 11.1 %). While significantly lower pod widths (0.90, 0.91, 0.93, 0.95, 0.97, 0.98, 0.98, 0.98, 0.98, 0.98, 0.98, 0.98, 0.98 cm) were observed in susceptible entries NIB-82 (20.4%), 53 (25.1%) and Gujarat papdi-1 (39.78%). Correlation between pod damage and pod width was significant ($r=-0.1965$).
 11. **Pod area:** Significantly higher pod areas were recorded in NIB-1 (29.40 cm²) and 17A (24.09 cm²) indicating pod damage of 10.8 and 9.8 per cent, respectively. Genotypes which had significantly lower pod areas were NIB-82 (3.59 cm²) and Gujarat papdi-1 (3.66 cm²) indicating higher pod damage (20.4 and 39.78 %). Correlation between pod damage and pod area was significant ($r=-0.1762$).

12. No. of seed per pod: Higher seeds (5.75, 5.35, 5.00, 4.95, 4.95, 4.95, 4.88, 4.88, 4.88, 4.80, 4.75, 4.75, 4.60, 4.68/ pod) were observed in NIB-72, 46, 10, 35, 54, 45, 92B, 95B, 106, 86, 42C, 81, 13 and 96 which in turn had lower pod damage (11.40, 0.10, 8.30, 6.80, 6.10 %). While higher pod damage was observed in Gujarat papadi-1 (40.46 %), NIB-15 (34.02 %) and NIB-12 (33.22 %) which showed 3.8, 3.8 and 4.4 seeds per pod, respectively. Correlation between pod damage and No. of seeds per pod was significant ($r = -0.1902$).

13. Pod yield: In resistant entries NIB-46, 28, 103 and 86, pod yields were 240, 307.5, 106.2 and 313.7 g per plant, respectively which indicated pod damage of 0.96, 3.40, 3.70 and 4.0 per cent, respectively while, susceptible Gujarat papdi-1, NIB-15 and 12 indicated pod yields of 126.25, 337.5 and 107.5 g per plant which indicated pod damage of 40.46, 34.02, 32.99 per cent, respectively. Correlation between pod damage and pod yield was non-significant ($r = -0.0782$). It may be concluded that growth habit ($r = 0.2878$) and pod shape ($r = 0.3046$) indicated significant positive relationship with pod damage. Gujarat papdi 1, NIB-15 and NIB-12 displayed spreading type characters and were more prone to pod damage while resistant NIB-46, 28, 103, 86 and 25 possessed erect and semi erect growth habits. Resistant NIB-46 possessed straight pods indicated lowest pod damage (0.96%). Leaf width, area, vein colour, trichome, stem colour, flower colour, pod colour, width, area and number of seeds per pod displayed significant negative relationship with the pod damage. Characters like plant height, leaf length, leaf colour, waxy coating, pod length and pod yield failed to induce significant resistance or susceptibility in the entries.

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4.9 Carbon Stock Assessment of Himalayan Conifers: A Step Towards Climate Resilience and Sustainability

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Keywords: Carbon stock, *Cedrus deodara*, Climate change, *Pinus wallichiana*

1. Background

Climate change is a pressing global concern, often threatening ecosystems and disrupting environmental stability. Forests play a crucial role in mitigating these effects, functioning as primary carbon reservoirs and representing the largest carbon sink on the planet. Through the process of carbon sequestration, forests regulate the global carbon cycle, thereby reducing atmospheric CO₂ levels. *Pinus wallichiana* is a strong demander of light that grows at lower elevations (1,700-2,400 msl) and predominately occurring in southern most aspects. It is 50-meter-tall tree with a straight trunk and short, downward-curving branches. Longer branches form a dome-like crown in solitary trees. Young tree bark is smooth, but it becomes fissured with age. Smooth branches in properly spaced whorls. *Cedrus deodara*, is a pure crop and an associate of *Pinus wallichiana*, which is largely present on gentle slopes with an elevation ranging from (1,830-2,424) msl. It is a huge evergreen, dioecious tree with crowns that develop rounded or broad and flat with horizontal or slightly rising or descending branches that are not whorled but arise irregularly from the stem. The species thrives in well-drained, light, loamy soils and is native from Tibet to Afghanistan.

2. Materials and Methods

Above ground biomass was estimated by measuring tree diameter at breast height (DBH) using a caliper and total height with Ravi's multimeter. The form factor (f) was calculated using a Spiegel relaskope following the Pressler (1854) and Bitterlich (1984) formula, $f = \frac{2}{3h}$, where h is the total height. Tree volume (V) was then determined using Pressler's formula, $V = f \times h \times g$, with basal area (g) calculated as $g = \pi r^2$. Stem biomass was obtained by multiplying the specific gravity of wood with the calculated volume. Belowground biomass was estimated using the equation by Cairns *et al.* (1997): $BGB = \exp\{-1.059 + 0.884\ln(AGBD) + 0.284\}$. Branch biomass was calculated by categorizing branches based on diameter, recording fresh and dry weights, and applying the formula $Bdwi = \frac{Bfwi}{1+Medbi}$ (Chidumaya, 1990), with total branch biomass computed as $Bbt = n_1bw_1 + n_2bw_2 + n_3bw_3$. Understorey and herbaceous biomass were measured using 1 × 1 m quadrats, with collected samples oven-dried at 65±5°C to constant weight. Leaf biomass was determined by removing, weighing, and oven-drying leaves from five branches (Chapman, 1964). Litter biomass was calculated from collected litter using the formula:
$$\text{Total dry weight (kg/m}^2\text{)} = \frac{\text{Total fresh weight (kg)} \times \text{Subsample dry weight (g)}}{\text{Subsample fresh weight (g)} \times \text{Sample area (m}^2\text{)}}.$$
 Finally, total carbon stock was estimated by multiplying the total biomass by 0.5, following the IPCC (2006) default carbon conversion factor.

3. Results and Conclusion

Cedrus deodara exhibited higher basal area, height, diameter, volume, biomass, and carbon stock compared to *Pinus wallichiana*, reflecting its greater production and carbon sequestration

potential. Total biomass ranged from 369.18–403.2 t ha⁻¹ and carbon stock from 184.59–201.6 t ha⁻¹ in *Cedrus deodara*, exceeding the values recorded for *Pinus wallichiana*. Forest floor biomass and carbon were also slightly higher in *Cedrus deodara* stands. These results highlight the species' robustness in capturing and retaining carbon, establishing it as a major carbon sink in Himalayan forests. As a slow-growing conifer, *Cedrus deodara* ensures long-term carbon storage, emphasizing its ecological importance in climate change mitigation. Thus, conserving conifer-dominated forests, particularly *Cedrus deodara* and *Pinus wallichiana*, through sustainable management and afforestation is vital for reducing carbon loss and enhancing ecosystem resilience.

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4.10 Optimization of Potting Media for Germination and Early Seedling Development of *Terminalia chebula* Retz.

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Keywords: Agroforestry, Potting Media, Vermicompost, Germination

1. Background

Forest restoration and agroforestry development depend largely on the availability of high-quality planting stock. Standardization of nursery practices is, therefore, essential to ensure vigorous seedling production, better field establishment, and long-term sustainability of plantation programmes. Among important medicinal and multipurpose tree species, *Terminalia chebula* Retz. holds significant ecological, economic, and therapeutic value. The species is widely used in traditional medicine and is a key constituent of the Ayurvedic formulation Triphala. Despite its importance, limited research has focused on optimizing potting media for enhancing its germination and early seedling growth under nursery conditions. Potting media influences seed-soil contact, aeration, moisture retention, microbial activity, and nutrient availability, all of which directly affect germination behavior and seedling vigor. Organic amendments such as farmyard manure (FYM) and vermicompost improve soil structure and nutrient status, thereby promoting better root development and biomass accumulation. Considering the importance of producing robust seedlings for agroforestry and forest restoration, the present study was undertaken to evaluate the effect of different potting media combinations on germination and growth parameters of *Terminalia chebula* Retz. under nursery conditions.

2. Materials and Methods

The experiment was conducted at the Experimental Farm of the Division of Silviculture and Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), Chatha. The experiment was carried out using a Completely Randomized Design (CRD) with two replications. The investigation focused exclusively on evaluating the effect of potting media on germination and early seedling growth. Ten potting media treatments were prepared using soil, sand, farmyard manure (FYM), and vermicompost (VC) in different proportions. The treatments included: M₁ (Soil alone, control); M₂ (Soil + Sand); M₃ (Soil + Sand + FYM - 1:1:1); M₄ (Soil + Sand + FYM - 1:1:2); M₅ (Soil + Sand + FYM - 1:2:1); M₆ (Soil + Sand + FYM - 1:2:2); M₇ (Soil + Sand + VC - 1:1:1); M₈ (Soil + Sand + VC - 1:1:2); M₉ (Soil + Sand + VC - 1:2:1); and M₁₀ (Soil + Sand + VC - 1:2:2). The media were thoroughly mixed and filled into polybags before sowing the seeds. Healthy seeds were sown under uniform nursery conditions. Irrigation and cultural operations were maintained consistently across treatments. The observations included germination percentage, mean germination time, and coefficient of velocity of germination. Growth parameters were recorded at regular intervals and included collar diameter, shoot length, primary root length, number of leaves, fresh and dry weight of shoots and roots.

3. Results and Conclusion

Potting media significantly influenced germination behavior and seedling growth of *Terminalia chebula* Retz. under nursery conditions. Media enriched with organic amendments recorded higher germination percentage compared to the control (soil alone). Among all treatments, vermicompost-based mixtures particularly M₉ and M₁₀ showed superior performance with higher germination percentage, reduced mean germination time, and greater coefficient of velocity of

germination, whereas FYM-based treatments improved germination over control but remained comparatively less effective than vermicompost amended media. Soil alone exhibited lower germination percentage and slower emergence. Seedling growth attributes were also markedly affected by potting media composition, with vermin compost enriched treatments consistently producing taller seedlings with significantly greater collar diameter and longer primary roots. These treatments recorded higher fresh and dry biomass of shoots and roots and improved total seedling weight, indicating superior vigor and transplanting potential. Among all treatments, M₁₀ (soil + sand + vermicompost in 1:2:2 ratio) exhibited the best overall growth performance. FYM-based media performed moderately well but remained inferior to vermicompost based mixtures in terms of biomass accumulation and overall seedling vigor, while control seedlings recorded the lowest values for most growth parameters. Overall, the incorporation of vermicompost significantly enhanced seedling vigor, root development, and biomass production, demonstrating that potting media composition plays a critical role in influencing germination and early growth. Soil + sand + vermicompost mixtures, particularly at higher vermicompost proportions, proved most effective in producing vigorous and high-quality planting stock, and their adoption can substantially improve nursery efficiency and support large-scale plantation and agroforestry programmes involving these valuable medicinal species.

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4.11 Efficacy of Different Pre-Sowing Treatments on Germination and Growth of Karonda (*Carissa carandas* L.) Seeds

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Keywords: Germination, Growth, Karonda and Minor fruit

1. Background

Karonda is an important minor indigenous underexploited fruit crop of India. It has recently attained importance as an arid zone horticulture crop because of its hardy nature and its nutritious fruits. Karonda (*Carissa carandas* L.) is an important, minor underexploited fruit crop has origin in India. It is popularly known as “Bengal currant” or “Christ’s Thorn”. It belongs to family Apocynaceae with chromosome number $2n=22$. Karonda is suitable for growing throughout subtropical and tropical climatic zones of India having commercial and medicinal value. In India it is cultivated in Punjab, Kashmir, Uttar Pradesh, Rajasthan, parts of Gujarat and West Bengal. The dried fruits are good source of iron (39.10mg/100 g), pectin and contain fair amount of vitamin C. Fruits are used in preparation of jelly, jam, syrup, pickle, murabba and chutney (Kumar *et al.*, 2007). Karonda is best suited as a live protective fence due to the presence of axillary spines and formation of profuse leaves on crowded branches. It has excellent potential to be used for horticultural plantations in marginal and wastelands, owing to its hardy and xerophytic nature with wide adaptability to saline sodic soils with pH up to 10. Fruits are generally harvested at immature stage for vegetable purpose, while fully ripen fruits are consumed fresh or processed. The unripe fruits yield milky white latex which can be used in preparing chewing gum and rubber. The unripe fruits of karonda are medicinally used as an astringent. The ripe fruit is sweet, cooling, appetiser and antiscorbutic and is useful in controlling burning sensation, skin diseases, scabies, pruritus (Imran *et al.*, 2012) and particularly suitable for tarts and puddings. It is also used in curing anaemia. Though the fruits are being used for different purposes, it has not yet been exploited on a commercial scale. There exists a great variation in size, shape and colour of the fruits. Based on the fruit colour, three types of fruits are available i.e. green, pink and white. Based on taste, it can be further grouped into two types i.e. sweet and sour. As the crop is highly cross-pollinated, large variability exists in natural population. Seeds are recalcitrant and are relatively high in moisture content and possess a characteristic feature of losing their viability within 4-5 weeks. Hence seeds of karonda should be sown just after extraction from fruits. The seed is quite hard and germination is low. Still the fruit crop is commercially propagated by seeds. Being, a minor fruit crop, very limited work is done in this crop. The objective of present study was to improve the seed germination to standardize the pre-sowing treatments for raising the crops.

2. Materials and Methods

The present experiment was conducted at Punjab Agricultural University, Regional Research Station, Gurdaspur during the years 2023-24 and 2024-25. Karonda seeds were extracted carefully from the freshly harvested fruits. The seeds were washed with water to remove the mucilaginous covering over the seed surface. The seeds were shade dried and then subjected to different seed treatments *viz.* gibberellic acid (250,500 & 1000ppm), potassium nitrate (1.0,1.5 & 2.0 %), thiourea (1.0,1.5 & 2.0%), water soaking (24,48 & 72 hours) and control (sown immediately after extraction without any treatment). The study has been done in completely randomized design with 3 replications. After treatments, seeds were sown in polythene bags of size of 20x25cm, previously

filled with potting mixture of soil, FYM and vermicompost (1:1:1). Watering of seeds was done as soon as they were sown in polythene bags. Weeding and watering were done at regular intervals whenever needed. For protection of young karonda seedlings from any fungal attack at nursery stage, Bavistin (Carbendazim 50% WP) was drenched twice during the course of experiment. The observations regarding seed germination and different root & shoot growth parameters were recorded.

3. Results and Conclusion

Karonda seeds treated with gibberellic acid 1000ppm recorded minimum days for germination with maximum germination percentage. Growth parameters like seedling height, number of leaves, seedling diameter, survival percentage, fresh weight & dry weight of seedlings, number of primary roots, number of secondary roots, fresh weight of roots, dry weight of roots, main root length, primary root length, secondary root length, main root thickness, leaf length, leaf breadth, fresh weight of leaf and dry weight of leaf were also significantly maximum in karonda seeds treated with gibberellic acid 1000ppm. It can be concluded that gibberellic acid 1000ppm treated karonda seeds sown immediately after extraction gave best results in terms of all germination and growth parameters.

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4.12 Tracing Genetic Footprints through Nursery Performance: Provenance-based Variability in *Dalbergia sissoo* Roxb.

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Keywords: Adaptive divergence, Ecological adaptability, Genetic variability, Provenance variation

1. Background

Dalbergia sissoo Roxb. (Shisham) is a premier multipurpose leguminous tree species widely distributed across the Indian subcontinent and extensively utilized in agroforestry, social forestry, riverine stabilization, and commercial plantations. Owing to its wide ecological amplitude—ranging from sub-Himalayan tracts to dry alluvial plains—the species exhibits considerable intraspecific variability. Such variability often represents adaptive divergence, where geographically separated populations evolve genetically distinct traits in response to localized environmental pressures. Provenance variation plays a critical role in determining growth performance, stress tolerance, biomass allocation patterns, and overall adaptability. Early-stage nursery evaluation under uniform environmental conditions provides a robust approach to uncover adaptive divergence and inherent genetic variability by isolating genetically controlled growth differences from environmental influences. The subtropical region of Jammu is characterized by hot summers, moderate winters, erratic rainfall distribution, and periodic moisture stress. These conditions demand selection of well-adapted planting material capable of sustained growth and establishment. The present investigation was, therefore, undertaken to assess provenance-based variability and adaptive divergence among selected provenances of *Dalbergia sissoo* at the nursery stage under subtropical conditions of Jammu, with the objective of identifying superior provenances for regional plantation programmes.

2. Materials and Methods

The nursery evaluation was conducted at the Experimental Farm of the Division of Silviculture and Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu), Chatha. The site represents subtropical climatic conditions typical of the Jammu region, characterized by hot summers and moderate winters. The experiment was laid out in a Completely Randomized Design (CRD) to minimize environmental variation and ensure unbiased comparison among provenances. Uniform nursery practices were maintained throughout the experimental period, including standardized potting mixture, irrigation schedule, weeding, shading, and plant protection measures. These uniform management practices ensured that observed differences among provenances were primarily attributed to genetic variation rather than environmental influences.

3. Results and Conclusion

The study revealed significant variation among provenances for most growth and biomass-related parameters, indicating substantial intraspecific genetic variability. Germination percentage differed among provenances, suggesting inherent physiological differences possibly linked to seed origin and maternal environmental effects. Marked differences were observed in seedling height and collar diameter, two primary indicators of early growth vigour. Certain provenances consistently exhibited superior height increment and stem thickness, reflecting enhanced photosynthetic capacity and resource utilization efficiency. Such traits are often associated with

improved field establishment and competitive ability. Since all provenances were grown under identical nursery conditions, the observed differences can largely be attributed to genetic factors rather than environmental variation. The present investigation confirms significant provenance-level variability in *Dalbergia sissoo* at the nursery stage, reflecting distinct genetic footprints shaped by ecological gradients. The findings emphasize the importance of provenance-based selection for afforestation, agroforestry, and plantation forestry programmes in subtropical regions. Identification of superior at an early developmental stage offers a cost-effective and scientifically robust approach to enhancing plantation success, productivity, and long-term ecological stability. Out six provenances, provenance 25B (UP) outperformed than the remaining. Overall, the study contributes to a better understanding of intraspecific genetic variability in *Dalbergia sissoo* and supports the development of climate-resilient, region-specific silvicultural strategies.

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4.13 Effect of Organic Amendments on Yield of Parthenocarpic Cucumber (*Cucumis sativus* L.) under Polyhouse Condition

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Keywords: Biodynamic, Cucumber, Dashparni, Silica

1. Background

Cucumber (*Cucumis sativus* L.), a member of the family Cucurbitaceae, is a warm-season vegetable cultivated globally under tropical and subtropical conditions. Cucumber is one of the fastest maturing vine vegetables and is extensively grown across the country. The adoption of parthenocarpic and gynoeious cucumber cultivars in controlled environments has shown promise in enhancing fruit yield and harvest index. These cultivars allow for more efficient use of limited growing areas, especially in protected cultivation systems. Organic inputs such as biodynamic preparations, silicon supplements and *Dashparni ark* improve soil fertility and strengthen plant resilience against biotic and abiotic stresses. These eco-friendly inputs enhance nutrient uptake, root growth, and photosynthetic efficiency. As a result, they help achieve stable and higher crop yields with better produce quality.

2. Materials and Methods

The experiment was conducted under polyhouse at Hi-Tech Unit, Rajasthan College of Agriculture, which is situated in Udaipur at 24°35'N latitude 74°42'E longitude at 585.5 meters above mean sea level. Cucumber var. Nagene cultivated during July - October, 2023 in *Kharif* season. The polyhouse was covered with aluminate sheet and ultra violet stabilized low density polyethylene sheet having 200-micron thickness with provision of foggers. The trial was laid out in Completely Randomized Design with three replications. The experiment was comprised of ten treatments comprising different combinations of organic sources such as biodynamic, silica and *Dashparni* for polyhouse cultivation of cucumber. Yield per vine was derived by multiplication of number of fruits per vine and average weight of fruit in each treatment and replication and expressed in kilograms. The yield per square meter was calculated by multiplying total yield per vine with number of plants accommodated in one square meter area *i.e.* 2.22 and expressed in kilograms. The yield per acre was calculated by multiplying yield per square meter with 4000 and divided by 1000 and expressed in tons.

3. Results and Conclusion

Yield per vine, yield per square meter and yield per acre of cucumber are most important and economic traits also significantly varied with application various treatments. Significantly utmost yield per vine (4.20 kg), yield per square meter (10.07 kg) and yield per acre (40.30 t) were recorded in treatment T₁₀ (BD 500 @ 75 g/ha + BD 501 @ 2.5 g/ha + Silica @ 1% + *Dashparni* @ 10%) followed by (3.93 kg) treatment T₉ (BD 501 @ 2.5 g/ha + Silica @ 1% + *Dashparni* @ 10%), whereas least performing treatment was treatment T₁ (Control) by producing minimum yield per vine (3.27 kg), yield per square meter (7.83 kg) and yield per acre (31.33 t). Yield increased due to application of Biodynamic compost and silica has been seen by various researchers in different crops. Highest yield due to application of BD 500 and BD 501 has been reported by Gaware *et al.* (2022). Application of Biodynamic provided the nutrients to the crop for its proper growth and development with the culmination of higher yield reported by Dutta *et al.* (2018).

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4.14 Ascorbic Acid Treatments Enhanced the Postharvest Quality of Peach (*Prunus persica* L. Batsch) under Low Temperature Storage Conditions

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Keywords: Ascorbic Acid, Postharvest Quality, Peach and Sensory Qualities

1. Background

Peaches (*Prunus persica* L. Batsch) are the utmost admired fruits in the world having high yield and quality with pleasant flavour, attractive colour, dietary value and medicinal properties. Peaches are excellent source of antioxidants enriched with phenolic compounds, carotenoids (provitamin A) and ascorbic acid content (Byrne, 2002). Low chilled peach cultivar 'Shan-i-Punjab' growing in the Punjab state of India get matured in the 1st week of May coincide with prevailing high temperature and relative humidity of the region which cause rapid fruit quality deterioration leading to postharvest losses that limits its storage potential. Physico-biochemical changes are continued to occur in climacteric fruit after harvest which causes high postharvest losses both during marketing and storage. The stored peach fruit quality depends upon diverse physico-biochemical alterations like transpiration, respiration that cause loss of sugars as well organic acids and cell wall degradation (Liguori *et al.*, 2004). Colour alterations and texture deterioration during storage immediately affect sensory qualities, which lowers the price of fresh fruit in the local market and restricts export and long distance transportation. Market glut during the harvesting season, create difficulty for getting compensable prices of peach enforced the farmers to sell at lower price. Therefore, it is important to keep fruit available in the market for an extended amount of time either by storing the fruits with the application of health safe chemicals and at controlled atmosphere. Therefore to meet the consumer demand for healthier options with ensuring human and environmental safety, the present study was planned in order to determine the effect of ascorbic acid treatments on postharvest quality management of peach fruit at low temperature storage conditions.

2. Materials and Methods

The current investigation was carried out at Punjab Agricultural University, Ludhiana during the years 2020-21 and 2021-22. Peach cultivar Shan-i-Punjab fruits, uniform in size and free from infections or physical injuries were harvested at physiologically mature stage during the month of May from Fruit Research Farm, Punjab Agricultural University, Ludhiana. Fruits were harvested in the early morning and shifted instantly to Postharvest Laboratory in the plastic crates. Afterwards, high quality fruits deprived from visual defects were randomly choose and divided into four different treatments. There were four replications in each treatment with factorial total randomized design. Ascorbic acid (AA) @ 0.5, 1.0 & 2.0 mM were prepared by dissolving in minimum quantity of alcohol and subsequent concentration achieved by mixing in the required distilled water. Fruits that had been treated with varying concentrations of ascorbic acid and tap water (control) for five minutes, then dried in the shade and after this these fruits were packed in three-ply corrugated fibre board boxes along with paper lining with 5% perforation for storage. Fruits were then kept in a cold storage area having 0-1°C and 90-95% relative humidity. After ten, twenty, thirty and forty days of storage, a lot of twenty fruits from each replication of each treatment

were taken for physico-biochemical examination and quality assessment. The statistical analysis software SAS version 9.3 (Windows) was used to collect and analyse the data. Two-way analysis of variance (ANOVA) was used to differentiate the means at $p \leq 0.05$ using the LSD test

3. Results and Conclusion

It was noted that fruits treated with 0.5 mM and 1.0 mM ascorbic acid during cold storage showed maximum sensory quality on the 20th day of storage, whereas fruit treated with 2.0 mM ascorbic acid had the greatest sensory quality on the 30th day of storage, after that a reduction in sensory quality was observed in all the treatments. At the storage edge, 2.0mM ascorbic acid treated fruits sustained highest sensory quality rating, while lowest in control. The fruits under control treatment had the fastest rate of inclination in ripening index, while the fruit treated with ascorbic acid (2.0 mM) had the slowest rate of inclination in ripening index. A decrease in soluble solids content (SSC)/ titratable acidity (TA) ratio was seen when the concentration of ascorbic acid treatment was increased. It was also noted that lowest average juice pH was recorded in freshly harvested fruits (zero day of storage) and highest average juice pH was noted at 40th day of storage. The rise in pH content at slower rate was observed in ascorbic acid 2.0mM treated fruits in contrast to the other treatments. During the early stages of storage in all treatments, the sugar content (total sugars, reducing sugars and non-reducing sugars) of peach fruits increased as ripening progressed. All sugar contents in ascorbic acid treated fruits increased more slowly than in control fruits, peaking on the 20th day of storage for both treated and untreated fruits except ascorbic acid 2.0mM treated fruits. Towards the storage edge, all sugars declined at faster rate in each treatment with minimum decline noted in ascorbic acid 2.0mM treated fruits as compared to other treatments. Under cold storage conditions, the peach fruit's surface lightness (L^* value) increased as ripening progressed. In contrast to control fruits, the ascorbic acid 2.0 mM treated peach fruit showed a slower increase in L^* value. Similarly, the colour values a^* and b^* coordinates progressively raised throughout the 40 days of cold storage, but the ascorbic acid treatment at 2.0 mM decreased the rise in colour pigments relative to other treatments. Total carotenoids content of peach fruit increased effectively with storage in all the treatments. Fruits treated with ascorbic acid at a concentration of 2.0 mM had the lowest total carotenoids content among the various ascorbic acid treatments. The control treatment fruits retained a higher percentage of carotenoid pigments compared to fruits treated with ascorbic acid. The spoilage percentage of peach fruits increased with storage duration. Peach fruits treated with 1.0 mM and 2.0 mM ascorbic acid showed no signs of deterioration after 40 days in cold storage. On the 40th day of storage, control fruits showed noticeably more fruit deterioration (Table 1). From the current two years study, it can be concluded that postharvest treatments of ascorbic acid (2.0mM) shown a strong capability for maintaining overall acceptability up to 30 days of cold storage and demonstrated the capacity to postpone the fruit ripening and maintain the qualitative characteristics of fruits.

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4.15 Tree Biometrics and Rhizosphere Microbial Population of *Gmelina arborea* (Kashmir Teak) Provenances

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Keywords: Carbon sequestration, Rhizosphere microbial population, Biomass production, Litter dynamics.

1. Background

Gmelina arborea Roxb., commonly known as Kashmir teak, white teak, or gambhar, is a fast-growing multipurpose tree species widely utilized in agroforestry, farm forestry, and plantation forestry across tropical and subtropical regions of India. Owing to its light weight yet durable timber, rapid juvenile growth, adaptability to varied edaphic and climatic conditions, and economic significance for both timber and fuelwood production, the species plays a crucial role in sustainable land-use systems and carbon sequestration strategies. However, the productivity and ecological performance of *Gmelina arborea* plantations are strongly influenced by genetic variability among provenances and their interaction with site-specific soil and microbial environments. Despite extensive utilization of the species, limited information is available on the comparative performance of different provenances in terms of tree biometrics, biomass accumulation, carbon sequestration potential, rhizosphere microbial population dynamics, litterfall production, and economic returns under agroforestry systems. The present study was therefore undertaken to evaluate the growth, soil, microbial, and economic responses of seven provenances of *Gmelina arborea* under uniform agroforestry conditions.

2. Materials and Methods

The experiment was conducted at the Agroforestry Research Station, Ghatika, Bhubaneswar, under the All India Co-ordinated Research Project on Agroforestry, Odisha University of Agriculture and Technology, Odisha, India, over a period of two years from June 2021 to June 2023. The experimental site is characterized by a tropical hot and humid climate, with an average annual rainfall of 1472 mm, mean maximum temperature of 32.7°C, a minimum temperature of 25.2°C, and red lateritic soils of loamy sand to sandy loam texture. The study was laid out in a Randomized Block Design with three replications, comprising seven provenances of *Gmelina arborea*: Chandaka (Odisha), Nuapada (Odisha), Nilgiri (Odisha), Rayagada (Odisha), Durgaprasad (Odisha), Jhargram (West Bengal), and Kahikuchi (Assam). One-year-old saplings were transplanted in 2015 at a spacing of 6 m × 4 m, following recommended silvicultural practices. Observations were recorded at 72 and 96 months after planting and the pooled data over two years were used for analysis.

3. Results and Conclusion

Tree biometric parameters, including tree height, basal girth, diameter at breast height (DBH), crown spread, and number of branches, exhibited statistically significant variation among provenances. Among the seven provenances, Jhargram consistently recorded superior growth performance, registering the highest tree height (6.30 m), basal girth (29.43 cm), DBH (10.24 cm), crown spread (1.98 m), and number of branches (13). In contrast, the Nilgiri provenance exhibited

the lowest values for most biometric traits, indicating comparatively inferior growth under the same environmental conditions. Biomass production varied significantly across provenances. The Jhargram provenance recorded the highest above-ground biomass (13.68 t ha^{-1}), below-ground biomass (3.81 t ha^{-1}), and total biomass (17.49 t ha^{-1}), while the Nilgiri provenance produced the lowest total biomass (13.14 t ha^{-1}). Carbon sequestration potential, calculated by assuming 50% of total biomass as carbon, followed a similar trend, with Jhargram sequestering the maximum carbon ($8.74 \text{ Mg C ha}^{-1}$) and Nilgiri the minimum ($6.57 \text{ Mg C ha}^{-1}$). These results highlight the role of provenance selection in enhancing biomass productivity and carbon storage in agroforestry systems. Soil physico-chemical properties also exhibited discernible variation among treatments. Soil pH across all provenances remained mildly acidic, ranging from 5.06 to 5.13. Available nitrogen content was highest under the Jhargram provenance ($173.49 \text{ kg ha}^{-1}$), suggesting improved nutrient cycling and nitrogen availability. Available phosphorus and potassium were highest under the Kahikuchi provenance, indicating localized nutrient enrichment. Soil organic carbon stock varied among treatments, with the highest value recorded under the Durgaprasad provenance ($316.80 \text{ kg ha}^{-1}$), reflecting differences in litter input, root biomass contribution, and microbial activity. Rhizosphere microbial population analysis revealed significant differences among provenances in terms of fungi, bacteria, and actinomycetes populations. The Jhargram provenance recorded the highest fungal ($69.70 \times 10^4 \text{ CFU g}^{-1} \text{ soil}$) and bacterial populations ($389.17 \times 10^6 \text{ CFU g}^{-1} \text{ soil}$), while the Chandaka provenance exhibited the highest actinomycetes population ($337.49 \times 10^6 \text{ CFU g}^{-1} \text{ soil}$). The enhanced microbial abundance under superior-performing provenances may be attributed to higher litterfall input, improved root exudation, favorable soil moisture regimes, and greater organic matter availability, collectively contributing to enhanced nutrient cycling and soil biological health. Litterfall dynamics revealed clear seasonal patterns, with maximum litter deposition occurring during the winter months. February recorded the highest monthly litterfall (58 g m^{-2}), followed by January (55 g m^{-2}). The total annual litterfall amounted to 188 g m^{-2} , underscoring the role of *Gmelina arborea* plantations in contributing organic matter to the soil and sustaining soil fertility through nutrient recycling. Overall, the study conclusively demonstrates that provenance selection plays a pivotal role in determining the growth performance, biomass production, carbon sequestration potential, soil nutrient dynamics, microbial population structure, litterfall production, and economic returns of *Gmelina arborea* plantations. Among the seven evaluated provenances, Jhargram (West Bengal) emerged as the most productive and economically viable for agroforestry systems in eastern India. The results emphasize the importance of integrating genetic selection with soil and microbial assessments to enhance productivity, sustainability, and climate mitigation potential of agroforestry-based land-use systems.

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4.16 Studies on Propagation Techniques in *Diospyros lotus* Linn. in Jammu Subtropics

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Keywords: *Diospyros lotus*, Growing media, GA₃, Seed scarification, Germination

1. Background

Persimmons (genus *Diospyros*, family Ebenaceae) encompass nearly 190 species distributed across warm temperate and subtropical regions, predominantly in Asia and North America. Among them, *Diospyros kaki*, *D. lotus*, and *D. virginiana* hold commercial prominence, with *D. kaki* being the most widely cultivated. *D. lotus* (date plum) serves as a key rootstock for persimmon cultivars and offers nutritional and medicinal benefits, including antioxidant and antidiabetic properties (Rauf *et al.*, 2017; Ojha *et al.*, 2023). Despite its value, propagation challenges—such as poor seed germination, slow seedling growth, and graft incompatibility—hinder large-scale production. This study standardizes pre-sowing treatments, growing media, and vegetative methods to enhance germination and vigour to obtain quality planting material for *D. lotus* under Jammu subtropics.

2. Materials and Methods

The study was conducted during 2024–2025 at the Experimental Farm of the Division of Silviculture and Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, under open-field nursery conditions to standardize seed and vegetative propagation techniques in *Diospyros lotus*. The investigation comprised two experiments laid out in a Completely Randomized Design (CRD) Factorial with three replications. In the first experiment, the effect of growing media and pre-sowing treatments on seed germination and seedling growth was evaluated. Five growing media were tested: M₁ (garden soil), M₂ (garden soil + sand, 1:1), M₃ (garden soil + sand + farmyard manure, 1:1:1), M₄ (garden soil + sand + vermicompost, 1:1:1), and M₅ (garden soil + sand + cocopeat, 1:1:1). Pre-sowing treatments included cold water soaking for 24 and 48 hours, GA₃ @ 300 ppm for 24, 48, and 72 hours, and H₂SO₄ scarification for 1, 2, and 3 minutes, along with an untreated control. Seeds were sown at 2 cm depth and maintained at 25–30°C. Observations were recorded on germination percentage, seedling height, collar diameter, primary root length, and fresh and dry biomass. The data were statistically analysed using analysis of variance (ANOVA) appropriate for factorial CRD, and treatment means were compared at the 5% level of significance. The second experiment assessed the effect of rooting hormones and seasons on semi-hardwood cuttings. Treatments comprised IBA and NAA at 25, 50, and 100 ppm, along with control, cuttings planted during spring (March–April) and rainy (July–August) seasons. Cuttings were treated using the quick-dip method and planted in nursery beds under recommended cultural practices. Observations included sprouting percentage, rooting percentage, number of shoots, root length, leaf area, and biomass parameters. Data were statistically analyzed using ANOVA, and treatment means were compared at the 5% level of significance.

3. Results and Conclusion

Among the growing media, M₃ (Garden soil + Sand + FYM, 1:1:1) was found superior, recording maximum seed germination (71.69%), seedling height (53.54 cm), and stem diameter

(12.44 mm). However, M₅ (Garden soil + Sand + Cocopeat, 1:1:1) produced the maximum primary root length (28.01 cm). Among pre-sowing treatments, GA₃ @ 300 ppm for 48 hours significantly enhanced seed germination (69.43%), seedling height (40.05 cm), stem diameter (10.54 mm), and primary root length (22.64 cm). The interaction effect of M₃G₃ (Garden soil + Sand + FYM, 1:1:1 + GA₃ @ 300 ppm for 48 hours) was found most effective, recording maximum seedling height (48 cm), fresh shoot weight (28.77 g), dry shoot weight (16.86 g), and total biomass (60.06 g fresh weight). The treatment combination M₅G₃ (Garden soil + Sand + Cocopeat, 1:1:1) + GA₃ @ 300 ppm for 48 hours recorded maximum primary root length (26.67 cm) and dry root weight (5.78 g). It can be concluded that the combination of Garden soil + Sand + FYM (1:1:1) along with GA₃ @ 300 ppm for 48 hours is most suitable for improving seed germination and seedling growth of *Diospyros lotus* under subtropical conditions of Jammu. In the second experiment, the study revealed that application of NAA @ 100 ppm during the spring season (March–April) significantly enhanced sprouting and rooting percentage, shoot number, root length, leaf area, and biomass of semi-hardwood cuttings compared to other treatments. Hence, NAA @ 100 ppm in spring was found to be the most effective treatment for successful vegetative propagation.

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4.17 Enhancing Soil Health and Carbon Stocks through Forest Tree-Based Agroforestry Systems in the Char lands of Bangladesh

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Keywords: Agroforestry, Biomass, Carbon Sequestration, Degraded lands and Soil health

1. Background

The low-lying riverine Char land of Bangladesh are formed by alluvial deposition and are characterized by fragile soils, frequent flood–erosion dynamics, and high livelihood vulnerability. Introducing forest tree–based agroforestry on these lands offers a nature-based pathway to stabilize soils, rebuild organic matter, and diversify incomes for char communities (Mohiuddin, 2022). Globally, meta-analyses show that agroforestry systems consistently increase soil organic carbon (SOC) relative to adjacent cropland or pasture, with notable gains concentrated in topsoil and humid/subtropical zones; the mechanisms include increased litter inputs, enhanced root biomass and rhizosphere activity, improved microclimate, and reduced erosion (Shi et al 2018). The tree species commonly used in agroforestry can both sequester substantial above and below-ground carbon and improve key soil properties that are especially valuable in chars where pedogenesis is shallow and erosion is frequent. On this basis, forest tree-based agroforestry is promoted as a climate-resilient land-use option that simultaneously enhances soil health, builds carbon stocks, and supports rural livelihoods (Ali *et al.* 2024). However, recent assessments of char-focused agroforestry initiatives underline both promising soil health gains, to realize carbon stock and livelihood co-benefits are needed. Considering these circumstances, this research was undertaken.

2. Materials and Methods

The study was conducted under a forest tree–based agroforestry system in the char land areas of the Tista River Basin, Bangladesh, over a research period spanning March 2018 to June 2021. Three forest tree species mahogany (*Swietenia macrophylla*), lombu (*Khaya* sp.), and gamari (*Gmelina arborea*) were established at an initial planting spacing of 4 m × 4 m, with thinning planned at later growth stages to regulate stand density. Seasonal intercrops were integrated within the system, where cauliflower (*Brassica oleracea*) was cultivated during the Rabi season and taro (*Colocasia esculenta*) during the Kharif season. The experimental design comprised seven treatments: T₁ consisted of mahogany combined with cauliflower and taro; T₂ included lombu with cauliflower and taro; T₃ involved gamari with cauliflower and taro; T₄, T₅, and T₆ represented sole stands of mahogany, lombu, and gamari, respectively; while T₇ served as the sole cropping system with cauliflower and taro. This treatment structure enabled comparative evaluation of integrated agroforestry systems against monoculture tree and crop systems under char land conditions.

3. Results and Conclusion

The comparative analysis of tree girth (diameter) increment reveals that integrating agricultural crops does not impede forest tree development; rather, it often enhances it. For both Mahogany (*Swietenia macrophylla*) and Lombu (*Khaya* sp.), girth increments were higher in agroforestry (AGF) configurations compared to sole stands. Lombu exhibited the highest overall growth rate among the three tree species, while Gamari (*Gmelina arborea*) was the only species to

show slightly better performance in a sole stand compared to within agroforestry system. The superior growth in AGF systems (particularly for Mahogany and Lumbu) likely stems from the "complementary effect," where trees benefit from the residual fertilizers and intensive management (such as weeding and irrigation) applied to the understory vegetable crops. On the other hand, in case of biomass and carbon stock outputs, the study highlights the high potential of forest tree based agroforestry systems for climate change mitigation through carbon storage. Lumbu (*Khaya* sp.) in treatment T₂ achieved the highest total biomass (9.01 kg/tree) and a carbon sequestration rate of 9.77 tons/ha. Agroforestry treatments (T₁, T₂, T₃) consistently yielded higher total biomass and carbon storage per hectare than their respective sole tree counterparts (T₄, T₅, T₆). The carbon storage for Lumbu-based systems (2662.9kg/ha) was nearly double that of Gamari-based systems (455.23 kg/ha), indicating that species selection is critical for maximizing sequestration in char lands. Moreover, the integration of trees led to a measurable improvement in the physico-chemical properties of the fragile char land soils. All treatments showed a significant increase in soil organic carbon (SOC) from initial levels. Notably, Treatment T₂ (Lumbu + Crops) increased SOC from 0.61 % to 1.05 %, representing a substantial gain in soil organic matter within three years. Available Phosphorus levels saw dramatic increases; for instance, in T₁, Phosphorus rose from 69.43 to 102.60 microgram/ g soil. Potassium levels also improved across all agroforestry plots, likely due to increased litterfall and reduced leaching. While the soil remained acidic, the agroforestry systems helped maintain slightly moderate pH levels compared to the initial state, creating a more stable environment for microbial activity. Forest tree-based agroforestry systems significantly enhance soil health and carbon sequestration compared to sole cropping systems. These systems represent a promising climate-smart land-use strategy for restoring degraded lands and ensuring sustainable agricultural productivity in climate vulnerable environments.

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4.18 Integrated Nutrient Management for Enhancing Germination and Seedling Growth of *Acacia nilotica* and *Acacia catechu* in Nursery

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Keywords: Integrated nutrient management, *Acacia nilotica*, *Acacia catechu*, Nursery, Seedlings, Vermicompost

1. Background

Forest nurseries play a crucial role in producing healthy planting stock required for afforestation, agroforestry development, and restoration of degraded ecosystems. However, declining soil fertility and improper nutrient management often result in poor seedling growth and low survival rates in plantation programmes. Integrated Nutrient Management (INM), which involves the combined application of organic and inorganic nutrient sources, has been widely recognized as an effective approach to improve soil fertility, nutrient availability, and plant growth. The use of organic amendments such as farmyard manure and vermicompost along with inorganic fertilizers improves soil physical, chemical, and biological properties and enhances nutrient uptake by plants (Jaisankar *et al.*, 2014). *Acacia nilotica* and *Acacia catechu* are important multipurpose tree species widely used in agroforestry systems, industrial plantations, and ecological restoration programmes. These species provide valuable products such as timber, tannins, gum, and medicinal compounds, while also contributing to soil fertility through nitrogen fixation. The present investigation was undertaken to evaluate the effect of integrated nutrient management on germination behavior, growth performance and seedling quality of *Acacia nilotica* and *Acacia catechu* under nursery conditions.

2. Materials and Methods

The experiment was conducted at the Experimental Farm of the Division of Silviculture and Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), Chatha, Jammu, India. The study was laid out in a Factorial Completely Randomized Design (CRD) with three replications. A total of fifteen integrated nutrient management treatments consisting of different combinations of inorganic fertilizers (N, P₂O₅ and K₂O) and organic sources such as farmyard manure (FYM) and vermicompost (VC) were evaluated along with a control (no treatment) treatment. Seeds of *Acacia nilotica* and *Acacia catechu* were sown in polybags under uniform nursery conditions and standard cultural practices were followed throughout the experiment. Observations were recorded on germination parameters including germination percentage, mean germination time, and coefficient of velocity of germination. Growth and seedling quality parameters such as seedling height, collar diameter, shoot length, primary root length, number of leaves, leaf area, fresh and dry biomass of shoots and roots, root:shoot ratio, sturdiness quotient, and seedling quality index were recorded. Soil properties and nutrient uptake characteristics were also analyzed to determine the effect of different integrated nutrient management treatments.

3. Results and Conclusion

Integrated nutrient management treatments significantly influenced germination behavior, seedling growth, and biomass production of both *Acacia nilotica* and *Acacia catechu* under nursery conditions. Treatments integrating organic and inorganic nutrient sources showed better performance compared to sole nutrient applications and significantly outperformed the control

treatment. The treatment (0.5 g N through vermicompost + 0.5 g N + 2.0 g P₂O₅ + 2.0 g K₂O kg⁻¹ soil) recorded the best overall performance in both species, resulting in higher germination percentage, faster germination rate, and significantly improved growth parameters such as seedling height, collar diameter, root development, and biomass accumulation. Seedlings raised under pre-said treatment also exhibited superior seedling quality indices and improved vigor compared to other treatments and the control. Similar improvements in seedling growth and biomass accumulation due to integrated nutrient management have also been reported in other tree species (Bhat *et al.*, 2020). The enhanced performance observed under this treatment may be attributed to the synergistic effect of organic and inorganic nutrient sources, which improve nutrient availability, soil structure, microbial activity, and nutrient uptake efficiency. Overall, the results highlight the importance of integrated nutrient management in producing vigorous and highquality nursery seedlings. The combined application of vermicompost with inorganic fertilizers, particularly treatment (0.5 g N through vermicompost + 0.5 g N + 2.0 g P₂O₅ + 2.0 g K₂O kg⁻¹ soil) proved most effective for improving germination and seedling growth of *Acacia nilotica* and *Acacia catechu*. Thus this nutrient management strategies should be adopted in these species to obtain their quality planting stock.

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4.19 Assessment of Morphological Traits of *Cordia myxa* Trees in Kathua District of Jammu

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Keywords: Correlation, DBH classes, Fruit yield, Regression

1. Background

Cordia myxa L., commonly known as Lasora or Indian cherry, is a multipurpose medicinal tree belonging to the Boraginaceae family. It is widely distributed in tropical and subtropical regions and holds significant nutritional and therapeutic value in Ayurvedic and Unani systems of medicine. Despite its medicinal and commercial importance, the species remains underutilized, particularly in terms of scientific evaluation of its growth and yield parameters. Diameter at Breast Height (DBH) is widely used as an indicator of tree growth, biomass accumulation, and productivity. However, limited information is available regarding the relationship between DBH classes and fruit yield attributes in *Cordia myxa*. Therefore, the present study was undertaken to assess morphological traits and evaluate their influence on fruit yield across different DBH classes in Kathua district of Jammu.

2. Materials and Methods

The study was conducted in four villages (Prangoli, Sohal, Saida and Badholi) of Tehsil Hiranagar, District Kathua (Jammu & Kashmir). A total of 50 trees were surveyed and categorized into five DBH classes: D1 (10–20 cm), D2 (20–30 cm), D3 (30–40 cm), D4 (40–50 cm) and D5 (50–60 cm). Five representative trees from each DBH class were selected randomly for detailed observations. Parameters recorded included tree height, diameter, number of branches, crown spread, leaf area per tree, number of fruits per bunch, bunch weight, and fruit yield per tree. Data were analyzed using one-way ANOVA at 5% level of significance. Correlation analysis was performed to determine the relationship between fruit yield and growth parameters. Multiple regression analysis was conducted to evaluate the combined effect of independent variables on fruit yield using SPSS software.

3. Results and Conclusion

Growth and yield parameters showed a clear increasing trend with higher DBH classes. The D5 class (50–60 cm) recorded maximum values for height (8.61 m), diameter (57.53 cm), number of branches (14.75), crown spread (7.47 m), leaf area per tree (7.13 m²), number of fruits per bunch (13.25), bunch weight (0.094 kg), and fruit yield (45.55 kg/tree). Fruit yield was significantly higher in D5 and was statistically at par with D4 class. Correlation analysis revealed that fruit yield was significantly and positively correlated with diameter ($r=0.979$), height ($r=0.979$) and crown spread ($r=0.945$). However, number of branches and leaf area per tree showed non-significant correlation with fruit yield. Regression analysis indicated that all independent variables collectively explained 97.3% variation ($R^2=0.973$) in fruit yield. Among all parameters, leaf area per tree alone significantly influenced fruit yield ($p < 0.01$), suggesting its strong predictive ability. It is concluded that fruit yield in *Cordia myxa* is directly proportional to DBH class, with larger diameter trees producing substantially higher yields. Leaf area per tree emerged as a reliable predictor of fruit productivity. Hence efforts need to be made to select trees based on leaf area for further propagation and tree improvement.

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4.20 Post-harvest Melatonin Application Enhances Quality and Shelf Life of Mango cv. Zardalu

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Keywords: Mango, Melatonin, Shelf life, Fruit quality, Gene expression

1. Background

Mango (*Mangifera indica* L.) is one of the most important tropical fruits cultivated widely in India. In Bihar, the cultivar 'Zardalu' of Bhagalpur has received a Geographical Indication (GI) tag for its unique aroma and bright yellow colour; however, its short postharvest life limits long-distance marketing. Rapid softening due to cell wall degrading enzymes such as polygalacturonase (PG), pectin methyl esterase (PME), and expansin accelerates quality deterioration. Melatonin, a naturally occurring indoleamine, has emerged as a potential postharvest treatment due to its antioxidant properties and regulatory role in ripening. The present study was undertaken to evaluate the effect of postharvest melatonin application on quality attributes, antioxidant system, and expression of softening-related genes in mango cv. Zardalu under ambient storage conditions.

2. Materials and Methods

The experiment was conducted using mature fruits of mango cv. Zardalu harvested from the Horticulture Garden of Bihar Agricultural University, Sabour. Fruits were dipped for 10 minutes in melatonin solutions at concentrations of 0.1 mM, 0.5 mM, and 1.0 mM, while distilled water served as control. Treated fruits were stored at ambient conditions (30±2 °C; 80±5% RH) and analyzed at two-day intervals up to 14 days. Sensory and physical parameters including weight loss, decay loss, and firmness were recorded. Biochemical analyses were performed to estimate total soluble solids (TSS), titratable acidity, TSS: acidity ratio, total sugars, ascorbic acid, total carotenoids, total phenols, total flavonoids (Zhishen *et al.* 1999), and antioxidant capacity (Apak *et al.* 2008) using standard protocols. Statistical analysis was performed using completely randomized design and means were compared using Duncan's Multiple Range Test 1 at P≤0.05.

3. Results and Conclusion

Postharvest melatonin treatment significantly improved the shelf life and quality of mango cv. Zardalu during ambient storage. Among treatments, 0.5 mM melatonin was most effective. At the end of 14 days storage, fruits treated with 0.5 mM melatonin exhibited minimum weight loss (15.43%) and decay loss (6.67%) compared to control (42.87% and 63.33%, respectively). Treated fruits maintained higher firmness (2.90 kg/cm²) relative to control (0.27 kg/cm²). Melatonin treatment helped retain higher TSS (18.77 °Brix), titratable acidity (0.17%), and total sugars (14.20%) compared to untreated fruits. Nutritional quality was significantly enhanced, as 0.5 mM treatment maintained higher ascorbic acid (19.90 mg/100 g), total carotenoids (11.27 mg/100 g), total phenols (184.00 µg GAE/100 g FW), total flavonoids, and antioxidant activity (450.47 µmol Trolox equivalent/100 g) at the end of storage. It may be concluded that postharvest dipping of mango cv. Zardalu in 0.5 mM melatonin effectively delays ripening by 3–4 days under ambient conditions, maintains physicochemical and nutritional quality, reduces decay, and suppresses

softening-related gene expression. This strategy offers a promising, eco-friendly approach to enhance marketability and storage life of this GI-tagged cultivar.

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4.21 Influence of Different Seed Sources with Respect to Sowing Time on Germinability of Indian Sandalwood (*Santalum album* L.) under Nursery Conditions in Jammu Sub-Tropics

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Keywords: Germination, Nursery, Seed source, Sowing time

1. Background

Sandalwood (*Santalum album* L.) is a highly valued evergreen hemi-parasitic tree known for its ecological, cultural and economic importance. Although traditionally confined to peninsular India, recent efforts have been made to introduce this species in northern regions. Successful plantation establishment largely depends on the availability of quality planting material, which in turn is influenced by seed source and nursery practices. However, limited information is available on the performance of different seed sources under varied sowing times in the sub-tropical conditions of Jammu. Therefore, the present investigation was undertaken to evaluate the influence of different seed sources with respect to sowing time on germination behaviour of sandalwood under nursery conditions.

2. Materials and Methods

The experiment was conducted during 2023 at the experimental farm of the Division of Silviculture and Agroforestry, SKUAST-Jammu, Chatha. The study was laid out in a Factorial Completely Randomized Design with two factors: seed source and sowing time at four and two levels respectively. Four seed sources viz., Karnataka (SS₁), Tamil Nadu (SS₂), Kerala (SS₃) and Himachal Pradesh (SS₄) were combined with two sowing times, spring (ST₁) and rainy season (ST₂), making eight treatment combinations with five replications. Seeds were soaked in 0.05% GA₃ for 24–36 hours and treated with fungicides before sowing on raised nursery beds (3 × 1 m) filled with sand, soil and FYM (2:1:1). Seeds were sown at 2 cm depth with 6 cm spacing within rows and 20 cm between rows. Observations on germination percentage, germinative energy, coefficient of velocity of germination, mean daily germination and mean germination time were recorded up to 45 days. The data were analyzed using R software.

3. Results and Conclusion

Sowing time and seed source significantly influenced germination parameters of sandalwood. Seeds sown in spring (ST₁) recorded higher germination percentage (47.50%), germinative energy (21.40%), coefficient of velocity of germination (3.12) and mean daily germination (0.53) along with reduced mean germination time (32.12 days) compared to rainy season sowing. Among seed sources, Karnataka (SS₁) seeds performed the best with maximum germination percentage (46.40%), germinative energy (21.20%), coefficient of velocity of germination (3.17) and minimum mean germination time (31.66 days), whereas Himachal Pradesh (SS₄) seeds showed the poorest performance. The interaction effect revealed that ST₁ × SS₁ produced the most favourable germination response, while ST₂ × SS₄ recorded the lowest values. It can be concluded that spring sowing using Karnataka seed source is most suitable for raising quality seedlings of *Santalum album* under the sub-tropical conditions of Jammu.

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4.22 Comparative Evaluation of Fruit Characteristics in *Terminalia chebula* Retz. Selections at Different Temporal Harvesting Windows for Promoting Agrobiodiversity

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Keywords: Cultivars, Fruit traits, Genotypic variation, Harvest timing, *Terminalia chebula*

1. Background

Medicinal plants play a vital role in traditional healthcare systems and are increasingly recognized for their therapeutic value due to the presence of diverse bioactive compounds (Ghorai, 2023). Among them, *Terminalia chebula* Retz. (Harad), a member of the Combretaceae family, is an important multipurpose medicinal tree widely used in Ayurvedic, Unani, and traditional medicine systems. The fruits of *T. chebula* contain several biologically active compounds such as tannins, flavonoids, amino acids, succinic acid, and β -sitosterol, which contribute to its antioxidant, antimicrobial, and digestive properties (Chattopadhyay and Bhattacharya, 2007). Owing to its high medicinal and commercial value, the species is extensively utilized in pharmaceutical and herbal industries. *Terminalia chebula* is widely distributed across the Indian subcontinent, particularly in the sub-Himalayan and subtropical regions, where it grows well in mixed and dry deciduous forests (Troup, 1921). However, considerable variability exists among different genotypic selections in terms of fruit size, weight, pulp content, and yield, which directly influence its commercial and therapeutic applications. Such variability among natural populations represents an important component of agrobiodiversity that can be utilized for the selection and conservation of superior genetic resources. In addition to genotypic variation, harvesting time plays a critical role in determining fruit development, yield, and quality. Therefore, evaluating fruit trait variability across different harvesting windows is essential for identifying superior selections and optimizing harvest timing. A comparative evaluation of fruit characteristics under different temporal harvesting windows can provide valuable information for selecting elite genotypes, promoting sustainable utilization, and conserving genetic diversity of this medicinally important species.

2. Materials and Methods

The experiment was conducted at the experimental farm of the Division of Silviculture and Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu, located in the subtropical region of Jammu and Kashmir. The study site experiences distinct seasonal variations with hot summers, cold winters, and moderate annual rainfall, providing suitable climatic conditions for the growth of *Terminalia chebula*. A plantation established in 2018 with a spacing of 4×6 m was used for the study. Four geographically distinct selections- Jammu Selection (Raj Hard), Kallar, Pragpur, and Palodi—were evaluated under a replicated experimental design. Each selection consisted of twelve trees arranged in two replications. The mean tree method was employed to obtain representative samples, and fruit samples were collected during three harvesting windows (September, October, and November) in 2022. This experimental setup enabled a systematic assessment of genotypic variation and harvesting time effects on fruit traits and yield of *Terminalia chebula* under subtropical conditions. Fruit traits were measured using standard methods to ensure accurate evaluation of *Terminalia chebula* selections. Fruit length and diameter were recorded with digital vernier callipers, while

fresh and dry fruit weights were determined using a physical balance. Fresh pulp content was measured after mechanical extraction, and dry pulp content was assessed after oven drying at 60 °C.

3. Results and Conclusion

The results revealed significant variation in fruit morphological traits among the different *Terminalia chebula* selections across the three harvesting months. In September, the Palodi selection demonstrated superior performance for most fruit traits, particularly fresh fruit weight, dry fruit weight, fresh pulp content and fruit diameter, while Jammu Selection exhibited the greatest fruit length. During October, Palodi and Jammu Selection maintained higher fruit weight and pulp content compared to the other selections, whereas Kallar generally recorded the lowest values for most traits. In November, Jammu Selection showed better performance for fresh and dry fruit weight, dry pulp content and fruit length, while Palodi maintained relatively higher fresh pulp content and Praggpur recorded a larger fruit diameter. Overall, the temporal analysis indicated that fruit development and yield-related traits varied significantly with harvesting time and genotype. The findings emphasize the importance of selecting appropriate harvesting windows and elite selections such as Palodi and Jammu Selection for improved fruit yield and quality. Furthermore, variability in fruit traits of these selections of *Terminalia chebula* could contribute to the conservation and promotion of agrobiodiversity of this species and future tree improvement programme.

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4.23 Floristic Diversity and Ethno-botanical Uses of Tree Species in the Campus of Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu, India

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Keywords: Biodiversity, Flora, Ethno-botany, Floristic inventory, Sub-tropical

1. Background

Tree diversity in human-managed landscapes, particularly university campuses, plays a crucial role in conservation of native and exotic flora while serving as living laboratories for botanical education. The sub-tropical region of Jammu harbors rich floristic diversity, yet systematic documentation of tree species in institutional campuses remains limited (Singh 2020). University campuses often act as refuge for plant species with significant ecological and ethno-botanical value, but such undocumented wealth faces threats from rapid urbanization. Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu (SKUAST-J) campus represents one such managed ecosystem where comprehensive inventory of tree species and associated traditional knowledge has been lacking. The present study was, therefore, conducted to document the floristic diversity and ethno-botanical significance of tree species within the SKUAST-Jammu campus.

2. Materials and Methods

The study was conducted at the main campus of SKUAST-J, Chatha, Jammu, located between 32°73' N latitude and 74°87' E longitude at an altitude of 326 m amsl. A comprehensive field survey covering the entire campus area of 578 acres was carried out from January 2023 to January 2024. All tree species encountered were photographed, collected, and identified using standard floras (Hooker 1872-1897) and online databases. Ethno-botanical data regarding local names and traditional uses were compiled through systematic review of existing scientific literature and ethno-botanical studies from the region. The documented species were categorized based on their families, and uses were classified into medicinal, timber, fodder, fuelwood, ornamental, religious/cultural, and edible categories. Floristic composition was analyzed by determining species distribution per family, while ethno-botanical data were analyzed by calculating percentage of species in each use-category.

3. Results and Conclusion

The intensive survey documented a total of 58 tree species belonging to 20 families within the SKUAST-J campus. Fabaceae emerged as the most species-rich family with 15 species, followed by Moraceae with 10 species. Ethno-botanical analysis revealed that a majority of species (62%, 28 species) possessed medicinal uses, with applications ranging from treatment of dysentery (*Mangifera indica*) to cardiac ailments (*Terminalia arjuna*). Timber value was recorded for 33% species (15 species), fodder value for 22% species (10 species), and ornamental significance for 27% species (12 species). Notably, 18% species (8 species) held profound religious and cultural importance, including *Aegle marmelos* (sacred to Lord Shiva) and *Elaeocarpus ganitrus* (used for rosaries). It may be concluded that the SKUAST-Jammu campus serves as a vital repository of tree diversity with substantial ethno-botanical significance, functioning as both a conservation site and

a living laboratory for botanical education. This baseline inventory provides a foundation for future monitoring and conservation initiatives, emphasizing the need to prioritize native, ethno-botanically significant species in campus landscaping programs.

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4.24 A Novel Colony Design for Wild Ground-Nesting Bees of family Halictidae genus Lasioglossum

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1. Background

The rearing and habituation of genus *Lasioglossum* is a challenge for ecologists (Richards, 2020). Unlike managed honey bees, the majorities of *Lasioglossum* bee species are solitary and do not form large colonies. A significant proportion of these wild bees are ground-nesting species that construct tunnels and brood chambers in soil. These nests require specific environmental conditions, including suitable soil texture, proper drainage, adequate moisture, and access to nearby floral resources (Nelson *et al.* 2022). Therefore, present invention relates to the development of an artificial colony design intended for habituation and rearing of *Lasioglossum* bees, which are an ecologically significant group of pollinators responsible for the fertilization of a wide range of agricultural crops and wild plant species.

2. Materials and Methods

Multiple sites were selected for colony installation aimed for restoration of bees under natural conditions. A novel colony design for genus *Lasioglossum* bees in the form of a rectangular wooden box partially filled with selected well drained loose clay to loam soil type. The wooden box is constructed with specific dimensions to provide stability, portability, and sufficient nesting space. A defined depth of soil is filled inside the box and maintained at a gentle slope (5-7), which plays a critical role in facilitating drainage and preventing water accumulation. The colony is placed in open environments near flowering plants to ensure easy access to floral resources, and mustard plants are grown in the surrounding area to provide a continuous and abundant supply of nectar and pollen. This integrated design creates a favorable microhabitat that encourages wild bees to establish nests, thereby enhancing bee restoration, recovery, pollination efficiency and ecological resilience.

3. Results and Conclusion

The colony design proposed consists of a wooden box made from durable and environmentally friendly wood, selected as the primary construction material due to its natural insulating properties, which help maintain stable internal temperatures and protect developing bee larvae from extreme environmental fluctuations. The dimensions of the box are carefully chosen, with a length ranging from 60 to 65 centimeters, a width of 30 to 32 centimeters, and a depth of 15 to 17 centimeters. These dimensions ensure that the colony provides adequate surface area for multiple nesting sites while remaining manageable and easy to install in different field conditions. The wooden structure allowed for easy fabrication using locally available materials, making the design accessible to farmers, researchers, and conservation practitioners. The soil is filled up to a depth of approximately 11.5 to 12 cm, sufficient enough to allow bees to excavate tunnels and brood chambers while also maintaining structural integrity. The soil is lightly compacted to resemble natural ground conditions, ensuring that it is neither too loose, which could lead to tunnel collapse, nor too compact, which would hinder excavation. This balance is essential for successful nest establishment and brood development. A distinguishing feature of the invention is the maintenance of a gentle soil slope ranging between 5 and 7 degrees. This sloping design is inspired by natural

nesting preferences of many *Lasioglossum* bees, which often select slightly inclined surfaces such as embankments or raised ground. The slope facilitates effective drainage of excess water during rainfall or irrigation, thereby preventing water stagnation and nest flooding. By reducing moisture accumulation, the slope significantly lowers the risk of fungal growth, larval mortality, and nest abandonment, which are common challenges in artificial nesting environments.

The soil used in the colony is selected from loam to clay types, as these soils provide the ideal combination of particle sizes required for stable tunnel construction. Loamy soils offer good aeration and drainage, while clay components contribute to tunnel strength and durability. The soil must be free from excessive organic debris, stones, or contaminants that could obstruct tunnel excavation. Importantly, soils prone to waterlogging or extreme dryness are avoided, as they negatively affect bee nesting success. The careful selection and preparation of soil are critical components of the invention, as they directly influence nest stability and brood survival.

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4.25 Effect of Sister Planting Methods and Plant Spacing on Growth, Yield, Quality and Pest Disease Incidence in Garden Pea (*Pisum sativum* L.)

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Keywords: Pea, Planting methods, Pest disease incidence, Spacing

1. Background

Pea (*Pisum sativum* L.) is an important cool-season leguminous vegetable crop cultivated widely for its tender green pods, which are rich in proteins, carbohydrates, vitamins and minerals. The productivity and quality of pea are largely influenced by agronomic practices such as planting methods, crop geometry and spacing, which directly affect growth behaviour, yield attributes and quality parameters. Inappropriate planting patterns and continuous mono-cropping often lead to poor crop performance and increased incidence of insect pests and diseases, particularly powdery mildew and leaf miner, which are major constraints in pea cultivation. These biotic stresses not only reduce green pod yield but also adversely affect marketable quality (Yadav *et al.* 2020). Several researchers have reported that intercropping systems and proper crop geometry significantly influence flowering behaviour, yield components, quality traits and pest-disease dynamics in vegetable legumes (Meena *et al.* 2022). However, the response of pea to different planting methods and spacings varies with crop combinations and environmental conditions. Therefore, the present investigation was undertaken to evaluate the effect of different planting methods and spacings on flowering behaviour, yield attributes, quality parameters and incidence of powdery mildew and leaf miner in pea.

2. Materials and Methods

The present investigation was carried out during the rabi season at the Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), Chatha, under subtropical agro-climatic conditions of the Jammu region. The experiment consisted of different planting methods involving sole cropping of pea and intercropping of pea with broad bean, winter maize and mustard, along with two spacings. The treatments were laid out in a factorial randomized block design with three replications. Standard agronomic practices were followed uniformly for all treatments throughout the crop growth period. Observations were recorded on days to 50 per cent flowering, days to marketable maturity, number of pods per plant, pod weight, shelling percentage, green pod yield and total soluble solids (TSS). In addition, the incidence of powdery mildew and leaf miner was recorded at appropriate crop growth stages. The recorded data were statistically analysed to test the significance of treatment effects.

3. Results and Conclusion

The results presented in Table 1 clearly indicated that planting methods and spacing had a marked influence on growth, yield, quality and pest-disease incidence in pea. Days to 50% flowering did not show significant variation among treatments however, the earliest flowering was recorded under T₁ (74.33 days), whereas relatively delayed flowering was observed under T₂ and T₆ (75.33 days). With respect to spacing, S₁ recorded earlier flowering (73.19 days) as compared to S₂ (76.76 days). Earliness in flowering under closer spacing may be attributed to better utilization of light and nutrients, leading to enhanced physiological activity, as also reported by Singh *et al.*

(2019). Days to marketable maturity varied significantly among treatments. T_1 recorded the minimum days to marketable maturity (102.33 days), while T_4 recorded the maximum duration (105.00 days). Early maturity under T_1 might be due to balanced vegetative growth and efficient translocation of assimilates towards reproductive organs. Similar trends have been reported by Yadav et al (2020) in garden pea. Yield attributing characters were significantly influenced by treatments. The maximum number of pods per plant (54.84) and highest pod weight (7.01 g) were recorded under T_1 , whereas the lowest number of pods per plant was observed under T_7 (37.18). Increased pod number and pod weight under T_1 resulted in higher yield. Among spacing treatments, S_1 recorded higher number of pods per plant (47.14) compared to S_2 (44.13), indicating the advantage of optimum plant population. Shelling percentage showed significant differences among treatments, with T_3 recording the highest shelling percentage (55.87%), while the lowest was observed under T_1 (52.56%). Slightly higher shelling percentage under S_1 (54.03%) suggested better seed filling, which may be attributed to favourable growing conditions. Green pod yield was significantly affected by treatments and spacing. T_1 produced the highest green pod yield (148.48 q ha⁻¹), which was significantly superior to all other treatments, while the lowest yield was recorded under T_7 (71.63 q ha⁻¹). Among spacing treatments, S_1 recorded higher yield (88.34 q ha⁻¹) compared to S_2 (82.85 q ha⁻¹). Higher yield under T_1 may be attributed to higher pod number, pod weight and better growth performance, in agreement with the findings of Meena *et al.* (2021). Quality parameter in terms of TSS content did not show significant variation due to treatments; however, numerically, the highest TSS was recorded under T_6 (11.66°Brix), whereas the lowest was observed under T_3 (10.66°Brix). Slightly higher TSS under S_2 (11.33°Brix) may be due to reduced inter-plant competition, leading to better accumulation of soluble solids. Incidence of powdery mildew differed significantly among treatments. The minimum powdery mildew incidence was recorded under T_1 (7.16%), while the maximum incidence was observed under T_7 (87.52%). Lower disease incidence under T_1 may be attributed to improved plant vigour and favourable microclimatic conditions, which suppress disease development, as reported by Sharma *et al.* (2022). Leaf miner incidence also varied significantly among treatments. T_1 recorded no leaf miner infestation (0.00%), whereas the highest infestation was recorded under T_7 (12.85%). Spacing did not significantly influence leaf miner incidence; however, numerically lower infestation was observed under S_2 (7.07%). Reduced pest incidence under favourable planting methods may be due to better aeration and plant health. Overall, T_1 in combination with S_1 proved superior by enhancing yield attributes, green pod yield and minimizing pest and disease incidence in pea.

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4.26 Tragacanth Gum Fortified with Sodium Nitroprusside: Alleviates the Quality Deterioration in Litchi Fruit through Regulation of Antioxidant Metabolism

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Keywords: Litchi, Tragacanth gum, Sodium nitroprusside

1. Background

Litchi (*Litchi chinensis* Sonn.) is also known as the queen of subtropical fruits, belongs to the Sapindaceae (soapberry) family. Litchi has a short postharvest life which restricts its transportation and marketability. Fruit has a very limited shelf life, typically remaining marketable for only 2–6 days under ambient conditions. The fruit has a thin, fragile pericarp and high moisture content, which makes it highly prone to rapid deterioration and postharvest losses (Marak *et al.*, 2024). In addition, litchi fruits quickly lose their characteristic bright red pericarp color after harvest when kept at room temperature. This discoloration occurs due to several factors, including excessive moisture loss from the pericarp, mechanical damage, chilling injury, pathogen infection, and enzymatic oxidation of phenolic compounds catalyzed by polyphenol oxidase (PPO) and peroxidase (POD) enzymes (Ali *et al.*, 2020). Among these causes, water loss from the outer pericarp plays a crucial role in browning, as dehydration of the pericarp tissues accelerates pigment degradation and leads to rapid loss of visual quality. Edible coating materials provide efficient alternatives to minimize after-harvest losses and maintain fruit quality longer. The present study aimed to investigate the coating impact on the ripening and senescence processes along with physico-chemical assays, membrane permeability, decay, cell wall-hydrolyzing enzymes and antioxidant enzyme activities during 20 days of low-temperature storage.

2. Materials and Methods

Mature, healthy, and uniformly red litchi fruits (cv. Dehradun) were harvested and immediately transported to the Postharvest Laboratory at PAU, Ludhiana. The fruits were then be sterilized with sodium hypochlorite, followed by treatment with an edible coating consisting of tragacanth gum (TG) enriched with sodium nitroprusside (SNP), and stored at 4 ± 1 °C. Physicochemical and enzymatic parameters of litchi fruits in each treatment will be measured at day 0 (initial value) and at 5, 10, 15, and 20 days of storage. The study was arranged in a factorial Completely Randomized Design (CRD) with three replications, and statistical analysis was performed using SPSS software (version 22.0).

3. Results and Conclusion

The results showed that TG + SNP 2mM was able to restrict loss in weight, flesh firmness, soluble solids content (SSC), titratable acidity (TA), lowered fruit decay, enhanced the activity of antioxidant defence enzymes like superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD) and efficiently delayed the activity of enzymes responsible for the degradation of the cell wall, notably polygalacturonase (PG), pectin methyl esterase (PME) and cellulase (CL) in coated fruit, corroborating the synergetic action of TGplusSNP. The combined coating protected fruits against excessive electrolyte leakage and cell wall-degrading enzymes better than pure TG and SNP. The results suggest that the TG + SNP 2mM formulation has the potential to maintain litchi fruit quality during low temperature storage and is most suitable for possible commercial applications in the litchi preservation industry.

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4.27 Soil physico-chemical properties under prominent Agroforestry systems in District Baramulla of Jammu and Kashmir, India

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Keywords: Agroforestry systems, Baramulla J&K, Carbon sequestration, Soil Physico-Chemical Properties

1. Background

Agroforestry represents a sustainable and climate-resilient land-use system that integrates trees, crops, and livestock to enhance productivity, ecological stability, and resource-use efficiency (Nair, 1998). By fostering complementary interactions among system components, agroforestry improves nutrient cycling, water use, and light interception, thereby strengthening agroecosystem resilience (Ajayiet *al.*, 2011). In regions like District Baramulla of Jammu and Kashmir, characterized by fragile mountain ecosystems, evaluating the impact of different agroforestry systems on soil health is essential for sustainable land management and long-term productivity.

2. Materials and Methods

The present study assessed soil physico-chemical properties under major agroforestry systems, namely agri-silviculture, horti-agriculture, and agri-horti-silviculture, prevalent in District Baramulla. Soil samples were collected from a depth of 0–30 cm and analyzed for key parameters including available nitrogen (N), phosphorus (P), potassium (K), soil organic carbon (SOC), pH, electrical conductivity (EC), bulk density, and soil carbon stock using standard laboratory procedures.

3. Results and Conclusion

The results revealed significant variation in soil properties across agroforestry systems, highlighting the influence of system composition on soil fertility. The agri-horti-silviculture system recorded the highest nutrient availability, with nitrogen (361.6 kg ha⁻¹), phosphorus (38.26 kg ha⁻¹), and potassium (38.85 kg ha⁻¹), along with maximum soil carbon stock (305.38 kg ha⁻¹). Soil organic carbon content was highest (1.85%) under the horti-agriculture system, indicating its strong potential for carbon enrichment. Soil pH across all systems ranged from slightly acidic to neutral, which is conducive for optimal nutrient availability. Electrical conductivity varied significantly among systems and decreased with soil depth, with the highest value (0.31 mS cm⁻¹) observed under agri-horti-silviculture. Bulk density and soil carbon stock were also highest in agri-horti-silviculture, followed by horti-agriculture, and lowest in agri-silviculture. Findings of this study demonstrates that diversified agroforestry systems, particularly agri-horti-silviculture, substantially improve soil physico-chemical properties by enhancing nutrient availability, increasing carbon sequestration, and improving soil structure. These findings underscore the importance of promoting integrated agroforestry systems in Baramulla as a sustainable strategy for improving soil health, ensuring agricultural productivity, and contributing to climate change mitigation.

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4.28 Adaptability and Propagation Efficiency of *Diospyros lotus* L. in Temperate Environments: A Case Study from Kashmir

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Keywords: Date plum, *Diospyros lotus* L., Germination, Rooting, Sprouting and Survival.

1. Background

The date plum persimmon, DPP (*Diospyros lotus* L.) commonly known as Amlook belonging to family Ebenaceae is a deciduous wild edible temperate fruit tree of significant nutritional and medicinal importance due to the presence of bioactive compounds such as phenolics and flavonoids. The species is underutilized in spite of its potential, and little is known about its chemical makeup and biology of propagation in temperate climates, especially in Kashmir. Large-scale agriculture, conservation, and sustainable use are all hampered by this ignorance. Persimmon propagation is constrained primarily by the inherently low rooting ability of cuttings from species commonly employed as rootstocks. Propagation is a critical aspect of plant cultivation and conservation. Understanding germination patterns, seedling establishment, and vegetative propagation techniques is essential for producing healthy seedlings, multiplying superior genotypes, and developing effective nursery protocols.

2. Materials and Methods

The present study entitled, “Propagation and Chemical Profiling of *Diospyros lotus* L. under temperate conditions of Kashmir” was undertaken to standardize the propagation techniques using organic media for the germination and seedling characteristics. The research involved a detailed study on seed propagation in nursery conditions, evaluating the impact of five distinct growing media [T₁: Only Soil; T₂: Only FYM; T₃: 2:1:1 (Soil: Sand: FYM); T₄: 2:2:1 (Soil: Sand: FYM); T₅: 2:1:2 (Soil: Sand: FYM)] in a Completely Randomized Design (CRD) with four replications and ten different concentrations (2000, 3000, 4000 ppm) of three rooting hormones: IBA, IAA, and NAA, along with a control on semi-hardwood cuttings of *Diospyros lotus* L. at Faculty of Forestry, Benhama, Ganderbal, SKUAST-K during the year 2023-2025..

3. Results and Conclusion

The results demonstrated that the growing medium had a highly significant influence on all parameters. The treatment T₁ (Only Soil), which served as the control, consistently yielded the lowest values for virtually all recorded parameters. This treatment resulted in the poorest germination percentage (32.50%) and the lowest seedling survival rate (50.00%). Seedlings in T₁ exhibited stunted morphological development, including the minimum shoot length (14.88 cm), root length (13.23 cm), shoot collar diameter (1.95 mm), number of leaves (6.50), leaf area (10.31 cm²), and total dry biomass (1.45 g). Consequently, the quality and vigour indices were also the lowest for T₁, with a Seedling Vigour Index-I of 913.53, Seedling Vigour Index-II of 47281.25, and a Dickson's Quality Index of 0.14. In stark contrast, the treatment T₅ (Soil: Sand: FYM, 2:1:2), which had the highest proportion of nutrient-dense FYM, emerged as superior, recording the highest germination percentage (75.00%) and seedling survival (66.54%). Seedlings in T₅ also exhibited optimal morphological development, including maximum shoot length (33.89 cm), root length (32.86 cm), shoot collar diameter (6.24 mm), number of leaves (23.75), leaf area (52.09 cm²), and total dry biomass (4.60 g). Concurrently, vegetative propagation was tested using semi-

hardwood cuttings treated with ten different concentrations (2000, 3000, 4000 ppm) of three rooting hormones: IBA, IAA, and NAA, along with a control, also laid out in a CRD. In stark contrast to the success with seeds, all treatments for vegetative propagation resulted in a complete failure of root initiation (0% rooting), despite achieving moderate shoot sprouting percentages (ranging from 71.7% to 78.3%) across different hormone treatments. This clearly indicates that semi-hardwood cuttings of *Diospyros lotus* are recalcitrant to rooting under the stated experimental conditions.

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4.29 Insights into the Role of Gamma-Aminobutyric Acid (GABA) on Improving Yield and Quality of Apple

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Keywords: Gamma-aminobutyric acid (GABA), Pre-harvest spray, Fruit yield and quality.

1. Background

Apple (*Malus domestica* Borkh.) is an important temperate fruit crop widely cultivated in the Himalayan regions of India for its economic and nutritional value. Improving fruit yield and quality is a major concern for growers due to environmental and physiological constraints.

Gamma-aminobutyric acid (GABA), a non-protein amino acid, plays an important role in plant metabolism and stress regulation. Exogenous application of GABA has shown potential in enhancing plant growth, yield and fruit quality in several horticultural crops. Therefore, the present study was undertaken to evaluate the effect of different concentrations of GABA on yield and quality of apple cv. Starkrimson.

2. Materials and Methods

The study entitled “Insights into the Role of Gamma-aminobutyric Acid (GABA) on Improving Yield and Quality of Apple” was conducted at Regional Horticulture Research Sub-station Bhaderwah during 2024–2025. Uniform and healthy trees of apple (*Malus domestica* Borkh.) cv. Starkrimson of similar age and vigour were selected for the experiment. The study was carried out to evaluate the effect of different concentrations of gamma-aminobutyric acid (GABA) on yield and quality of apple. The experiment consisted of five treatments, including Control (water spray) and four concentrations of GABA, i.e., 25 µM, 50 µM, 75 µM and 100 µM. The treatments were arranged in a Randomized Block Design (RBD). The required concentrations of GABA were prepared using distilled water and applied as foliar spray using a hand sprayer. All recommended orchard management practices, including irrigation, fertilization and plant protection measures, were followed uniformly for all treatments throughout the experimental period. Observations were recorded on yield and fruit quality parameters, including fruit weight, fruit size, yield per tree, total soluble solids (TSS) and titratable acidity at harvest. The recorded data were statistically analyzed using analysis of variance (ANOVA) to determine the significance of treatment effects.

3. Results & Conclusion

The results of the study revealed that different concentrations of gamma-aminobutyric acid (GABA) significantly influenced the yield and quality attributes of apple cv. Starkrimson. Among the various treatments, the application of 75 µM GABA showed superior performance compared to other concentrations and the control. This treatment resulted in improved fruit yield along with better fruit quality parameters such as higher fruit weight, increased total soluble solids (TSS) and improved overall fruit quality. The enhanced performance under 75 µM GABA may be attributed to its positive role in regulating physiological and metabolic processes in plants, thereby promoting better fruit development and quality.

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4.30 Diversity, Adoption Patterns, and Land Allocation of Agroforestry Systems in District Ganderbal, Kashmir Himalaya

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Keywords: Agroforestry diversity, Cropping patterns, Land allocation, Home gardens and Kashmir Himalaya

1. Background

Agroforestry is an important land-use system in the Himalayan region, integrating trees with crops and livestock to enhance productivity, ecological stability, and rural livelihoods. In the Kashmir Valley, farmers traditionally practice diverse agroforestry systems to optimize limited land resources while meeting household needs for food, fodder, fuelwood, and income. These systems contribute to soil conservation, biodiversity enhancement, and climate resilience in fragile mountain ecosystems. Given the prominent land use patterns, diverse landscapes, and productive agroforestry systems in the Kashmir Valley, there exists substantial potential for enhancing rural livelihoods through the development and integration of agroforestry-based opportunities. To effectively promote the adoption of agroforestry, it is essential to understand the psychological and socioeconomic factors that influence farmers' decisions. Thus the present study is designed to highlight the prominent agroforestry systems, their composition to seek the attention from practitioners, scientists and policy makers for its further development and strengthening.

2. Material and Methods

The study was conducted in district Ganderbal, Jammu and Kashmir, located at an elevation of 1650–3000 m above mean sea level. Agriculture is the primary livelihood in the district, with a large proportion of the population engaged in farming and horticulture. A multi-stage random sampling technique was used to select study sites. Four Community Development blocks Lar, Safapora, Wakura, and Ganderbal were randomly selected, followed by the selection of ten villages. A total of 112 households were surveyed through structured interview schedules and field observations to collect information on agroforestry practices, species composition, and land allocation. Seasonal observations during kharif and rabi seasons were conducted to document tree–crop combinations. Tree spacing, height, and diameter were measured using standard field instruments, while crop yields were recorded and converted to hectare basis. Cropping intensity was calculated using the standard formula: Cropping Intensity (%) = (Gross Cropped Area / Net Sown Area) × 100.

3. Results and Conclusion

The study identified four prominent agroforestry systems in district Ganderbal: homegardens, agrihortisilviculture, agrisilviculture (boundary plantation), and hortisilvipasture, each characterized by distinct combinations of woody perennials and crop components. Homegardens exhibited the highest species diversity and structural complexity, integrating timber species such as *Salix fragilis*, *Populus balsamifera*, *Ailanthus altissima*, and *Ulmus villosa* with fruit trees like apple, pear, plum, cherry, walnut, and grapevine, along with a variety of vegetables and root crops during both seasons. The agrihortisilviculture system combined multipurpose trees (*Populus deltoides*, *Salix alba*, *Robinia pseudoacacia*) with horticultural crops and seasonal agricultural crops, representing a diversified land-use strategy. Agrisilviculture systems mainly involved boundary plantations dominated by poplar and willow associated with cereal-based

cropping such as rice during kharif and oats or mustard during rabi. Hortisilvipasture systems integrated tree and fruit species with forage crops including *Trifolium*, *Lolium*, and *Festuca*, reflecting their importance in supporting livestock-based livelihoods. Similar agroforestry components have been reported earlier in the Kashmir Himalaya (Mughal & Bhattacharya, 2002; Rizvi *et al.*, 2021).

The adoption pattern showed that homegardens were practiced by the highest proportion of households (30.36%), though they occupied a relatively smaller land area (11.86%). Agrisilviculture systems accounted for 25.14% of the area with 25% household adoption, while agrihortisilviculture systems covered 28.32% of the area with 24.11% adoption. In contrast, hortisilvipasture systems had the lowest adoption (20.53%) but occupied the largest land share (30%), which generally requires larger landholdings (Sharma *et al.*, 2020).

Cropping intensity averaged 171.75%, with the highest value recorded in agrisilviculture systems (179.21%), indicating efficient land utilization through the integration of perennial trees with seasonal crops, consistent with observations reported by Dahiyat *et al.* (2022).

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4.31 Strengthening Livelihood Security and Ecological Sustainability through Agroforestry in the Northwestern Himalayas

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Keywords: Agroforestry, Livelihoods, Socio-economic analysis, Sustainability, Tree species preference

1. Background

Agroforestry plays a crucial role in improving rural livelihoods and ensuring ecological sustainability, particularly in fragile mountain ecosystems such as the Northwestern Himalayas. In regions such as Jammu and Kashmir, integrating trees with crops and livestock contributes to diversified farm income, soil conservation, and climate resilience. Understanding the socio-economic characteristics of farming communities and their preferences for agroforestry species is essential for developing suitable agroforestry models. The present study examines the livelihood contribution of agroforestry systems and the socio-economic profile of households in the Baramulla district of Jammu and Kashmir, highlighting the importance of context-specific interventions for sustainable rural development.

2. Material and Methods

The study was conducted during 2020–2021 in the Baramulla district of Jammu and Kashmir. A multi-stage randomised sampling technique was used to select respondents. Four blocks were selected, and a total of 180 households were surveyed from these blocks to ensure a representative sample. Primary data were collected through structured questionnaires, field observations, and farmer interactions. Information related to demographic characteristics, income sources, tree species preferences, and agroforestry practices was recorded. The collected data were analysed using descriptive statistics to examine socioeconomic patterns and the contribution of agroforestry to household livelihoods.

3. Results and Conclusion

The findings revealed that the majority of respondents were middle-aged farmers with low literacy levels, indicating the need for simple, readily adoptable agroforestry interventions. Agroforestry contributed significantly to household livelihoods, accounting for 63.65% of the total income derived from agricultural, horticultural, and forest-based products. Among forest tree species, Poplar and Willow were the most preferred by farmers, while Apple, Pear, and Walnut were identified as the most desirable fruit tree species for future plantation on farmland. The study also indicated that 87.22% of respondents belonged to the high-income category, suggesting that agroforestry systems have strong potential to enhance economic stability in the region. However, a small proportion of low-income households (2.22%) highlights the need for inclusive strategies to ensure equitable benefits. The study recommends the promotion of fruit tree-based agroforestry models, including agri-horti-silviculture, integrated mixed farming, and agri-horti-silvopasture systems suited to Himalayan conditions. Incorporating diverse fruit, fodder, and timber species based on farmers' preferences can improve ecological resilience while strengthening livelihood security. Overall, agroforestry emerges as an effective and sustainable livelihood strategy in the Northwestern Himalayas when socio-economic realities and local preferences are carefully integrated into planning and implementation.

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4.32 From Litter to Soil: Decomposition Pathways in Himalayan Conifer Forests

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Keywords: *Pinus wallichiana*, *Cedrus deodara*, litter, stand.

1. Background

Litter decomposition is a vital biogeochemical process that underpins nutrient cycling and carbon dynamics in terrestrial ecosystems. The plant litter—comprising fallen leaves, fine twigs, stems, and reproductive structures—accumulates on the soil surface and serves as a primary pathway for nutrient return to the soil among these components, leaves often constitute more than 70% of aboveground litterfall, which plays a key role in shaping soil structure, fertility, and microbial activity. The complex process of litter decomposition is governed by an interplay of climatic conditions, litter quality, and the composition and activity of decomposer organisms. Litter layers, while distinct from mineral soil, vary in composition across seasons and elevations, with some regions showing as little as 8% contribution from forest floor litter to total carbon storage. Nonetheless, these organic layers are critical components of the global carbon cycle (Aerts, 1997) and contribute significantly to greenhouse gas mitigation efforts through carbon sequestration. Thus, understanding the drivers and patterns of litter decomposition is imperative—not only for managing forest nutrient cycling and productivity but also for informing strategies aimed at optimizing carbon sinks in the face of global climate change.

2. Materials and Methods

For conduction of the present study, the experimental site consisted of two forest stands viz., *Pinus wallichiana* and *Cedrus deodara* at Mattan range of Lidder forest division in South Kashmir located in Mattan compartment 3L and Nagbal compartment 7L located in Mattan Forest range, Lidder Forest Division. The quadrates for the collection and decomposition were set up using a stratified random sampling method. After litter sampling, litter samples were collected (cleared and swept of any deposited debris) once from 1m × 1m demonstrated areas in each quadrate. In each quadrate, 9 bags containing litter were arranged on the forest floor for decomposition of the enclosed litter. Three bags from each quadrates were collected after an interval of (4, 8 and 12 months) for analysis.

3. Results and Conclusion

The study revealed that the litter mass loss (g) in Site-I (*Pinus wallichiana*) was recorded highest in third time interval i.e 12 months [1.33g] followed by second time quadrant i.e 8 months [1.11g] and the least mass loss was found in first time quadrant i.e 4 months [0.57g] The decay rate was recorded to be highest in the first interval {0.0141} followed by second time interval and third time interval {0.0133} and {0.0120} respectively. In Site-II (*Cedrus deodara*), average litter mass loss (%) was recorded highest in third time quadrant i.e 12 months[1.66g] followed by second time quadrant i.e 8 months [0.98g] and the least decomposition was found in first time quadrant i.e 4 months (0.53g). The decay rate was recorded to be highest in the first interval {0.0130} followed by second time interval and third time in third time interval {0.0126} and {0.0105} respectively. Overall, the highest litter mass loss and decay rate was recorded more in Site-I (*Pinus wallichiana*)

as compared to Site-II (*Cedrus deodara*). The results of the study reported that conifers decompose slowly than the broadleaved species and *Pinus wallichiana* surpasses *Cedrus deodara* in decay rate. The findings of our study are supported by the findings of Jugran and Tewari (2022) and Enez (2022) where slow decomposition of pine needles was also recorded.

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4.33 Economic Evaluation of Agroforestry Systems along the Altitudinal Gradient in Kashmir Himalayas

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Keywords: Agroforestry systems, Economic Altitude Indicators

1. Background

Agroforestry systems represent a vital land-use strategy that integrates trees, crops, and livestock to enhance ecological stability and economic resilience. In mountainous regions such as the Kashmir Himalayas, altitude plays a decisive role in shaping agricultural productivity, resource availability, and household income. Variations in elevation influence climatic conditions, soil fertility, and species composition, thereby affecting both the subsistence and commercial potential of agroforestry practices. The Kulgam district, with its diverse altitudinal gradients, provides an ideal setting to examine how these systems perform under differing ecological and socio-economic contexts. Understanding the economic viability of agroforestry across altitudes is crucial for guiding farmers, policymakers, and development agencies toward sustainable land-use strategies that balance livelihood security with environmental conservation.

2. Materials and Methods

The study was conducted in the Kulgam district of the Kashmir Himalayas, encompassing altitudinal zones between 1500 and 2100 meters above mean sea level. A multi-stage random sampling technique with a sampling intensity of 5% was applied, resulting in the selection of 212 households across three representative altitudes. Four major agroforestry systems hortisilvipasture, horticulture, agrihortisilviculture, and agrisilviculture were identified for comparative evaluation. Data were collected through structured household surveys, interviews, and field observations, supplemented by secondary sources. Economic performance was assessed using standard indicators including Net Present Value, Benefit-Cost Ratio, Internal Rate of Return, Equivalent Annual Income, and Land Expectation Value, applying a uniform discount rate across systems. Statistical analysis, particularly the Kruskal–Wallis test, was employed to determine significant differences in agroforestry product yields and income patterns across altitudes, thereby highlighting the influence of elevation on economic sustainability.

3. Result and Conclusion

The comparative evaluation of agroforestry systems across altitudinal zones in Kulgam revealed significant variation in economic performance. The hortisilvipasture system recorded the highest values (NPV=₹8,628,346; BCR=3.85; EAI=₹1,454,332; LEV=₹12,108,109), underscoring its superior profitability and sustainability. In contrast, the agrihortisilviculture system exhibited the lowest values (NPV=₹928,922; BCR=1.45; EAI=₹130,864; LEV=₹1,089,772), reflecting weaker viability. The Internal Rate of Return (IRR) was strongest in agri-silviculture (45.58%), indicating short-term efficiency despite lower overall returns. Production trends also shifted with elevation crop, timber, and fruit yields declined at higher altitudes, whereas fuelwood, fodder, and non-timber forest products increased. These findings are consistent with recent Himalayan agroforestry research, which emphasizes altitude as a critical determinant of both ecological productivity and household income strategies (Pant *et al.*, 2025). Similarly, studies in Himachal Pradesh confirm that mid-altitude agroforestry systems outperform both lower and higher zones in

terms of profitability and resilience (Kumar *etal.*, 2025). Overall, the study highlights that hortisilvipasture and hortiagriculture systems at mid-altitudes offer the most balanced combination of financial vigour and ecological adaptability, making them promising models for sustainable agroforestry development in mountainous regions.

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4.34 Optimizing Mulberry Cutting Development: Effect of Plant Growth Regulators and Rooting Media

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Keywords: Cocopeat, Growth regulators, Mulberry, Rooting media, Vermicompost.

1. Background

Mulberry (*Morus spp.*) is a multifaceted species of significant scientific and economic importance, offering a range of benefits. The mulberry leaves and fruits are rich in protein and vitamins are long being exploited as animal feed or food products in several countries. Several studies have shown antioxidant, antiviral, anti-inflammatory hypolipidemic, antihyperglycemic, neuroprotective (Pan and Lou, 2008) benefits of mulberry. Growing mulberry plants through cuttings planted in different media using different concentration of plant growth regulators leads to faster growth making it reliable method for large scale propagation. A factorial study was conducted under shade net house conditions to evaluate the impact of plant growth regulators (PGRs) and rooting media on mulberry cutting development.

2. Materials and Methods

The experiment for the research was conducted during the year 2023-2024 at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. The experiment was laid out by Factorial Completely Randomized Design with 18 treatments replicated thrice. Treatment consisted of different concentrations of growth regulators *i.e.* IBA (1000 ppm, 1500 ppm and 2000 ppm) and NAA (1000 ppm, 1500 ppm and 2000 ppm) and different rooting media *i.e.* Sand + FYM, Vermicompost and Cocopeat. The plants of mulberry which were healthy, moderate in vigour and disease free were selected for making cuttings. The cuttings of 15-20 cm in length with 2-3 buds were retained on cutting for planting by removing the leaves completely. Different concentrations of plant growth regulators were prepared and rooting media was sterilized before planting cuttings. Polybags of 9''x 4'' was filled with different rooting media. The cuttings were dipped for half a minute in different concentrations of IBA and NAA solutions prepared before planting.

3. Results and Conclusion

The impact of plant growth regulators and rooting media was evaluated for cuttings of mulberry by utilizing multiple concentrations of plant growth regulators and different rooting media. Among the treatment combinations, T₈ treatment (*i.e.* 2000 ppm IBA + Vermicompost) found with the maximum rooting percentage (*i.e.* 50.88% and 66.22% at 60 and 90 days after planting, respectively) and length of longest root (*i.e.* 98.1 mm and 138.1 mm at 60 and 90 days after planting, respectively). The results obtained from the study revealed that the growth regulators and rooting media have a significant effect on root development of mulberry cuttings. It may be concluded from the study that application of 2000 ppm IBA as growth regulator and in rooting media application of Vermicompost were found superior with significantly highest values of various characters of mulberry cutting such as maximum rooting percentage and length of the longest root.

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4.35 Dietary Diversity and its Impact of Health of Rural Women: A Study of Rural Samba District, Jammu & Kashmir

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Keywords: Dietary diversity, nutritional security, vegetable productivity

1. Background

Malnutrition and inadequate dietary diversity remain major public health concerns in rural India, particularly among women and children. According to the Global Nutrition Report (2024), Southern Asia continues to experience high levels of anemia and child under nutrition, with a significant proportion of women of reproductive age affected by anemia. In Jammu & Kashmir, the National Family Health Survey (NFHS-5) reports 26.9% stunting and 21% underweight among children under five (MoHFW, 2020). Studies indicate that the average Indian diet is predominantly cereal-based and deficient in fruits and vegetables, leading to micronutrient imbalance and poor nutritional outcomes (Sharma *et al.*, 2020). In rural areas of Samba districts, consumption of vegetables are often seasonal and poorly managed. The benchmark data indicates that the average per day vegetable consumption was 74.78 gm which is far less than requirement. Therefore, under the Farmer FIRST Programme of SKUAST-Jammu, cultivation of different vegetables round the year was introduced in Purmandal block of Samba district to improve vegetable productivity, dietary intake and nutritional status of farm women. The present study was undertaken to assess the impact of nutrigardens on vegetable consumption and hemoglobin status of beneficiaries.

2. Materials and Methods

The study was conducted during 2024-25 in Anandpur, Sadral and Sarmal villages of Purmandal block, Samba district (Jammu & Kashmir). Twenty two farm women were selected purposively with support from National Rural Livelihood Mission (NRLM). Capacity building programmes regarding cultivation of vegetables were organized and quality seeds and planting material of different vegetables were provided. Vegetables included tomato, knol-khol, cauliflower, brinjal, methi, spinach, coriander, broccoli, radish in winter and okra, brinjal, cucumber, bottle gourd, bitter gourd, sponge gourd, pumpkin, round gourd and chilli in summer.

3. Results and Conclusion

The interventions under the Farmer FIRST Programme resulted in significant improvements in vegetable production and consumption. There was 170.01 percent increase in vegetable consumption after the intervention. Before intervention, per capita vegetable consumption was 74.78 g/day that increased to 201.96 g/day with a mean increase of 127.18 g/day ($t=51.30$, $p < 0.001$).

Table 1: Effect of Intervention on Dietary Intake and Hemoglobin Status (n=22)

Parameter	Before Intervention	After Intervention	Mean Difference	t-value	p-value
Vegetable consumption (g/day)	74.78	201.96	127.18	51.30	0.0000
Hemoglobin level (g/dL)	8.35	10.51	2.16	6.34	0.0000

This indicates substantial progress toward the ICMR recommended intake of 300 g/day. The increase in production and consumption of different vegetables has significant effect on mean

hemoglobin levels. Before intervention, the mean hemoglobin level was 8.35 g/dL that increased to 10.51 g/dL after one year of intervention showing a significant improvement of 2.16 g/dL ($t=6.34$, $p < 0.001$). Thus, the interventions resulted in significant improvements in vegetable production, household dietary intake and hemoglobin levels of beneficiary farm women, indicating enhanced nutritional status and health outcomes. Scaling up of interventions along with assured irrigation facilities, timely access to quality seeds and planting materials, has the potential to facilitate achievement of the WHO-recommended vegetable intake (400 g/capita/day) and contribute substantially to strengthening household nutritional security in rural areas.

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4.36 Evaluation of Lemongrass Cultivar (*Cymbopogon flexuosus* cv. Krishna) in a *Terminalia chebula*-based Agroforestry System

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Keywords: Agroforestry, *Cymbopogon flexuosus*, *Terminalia chebula*, Essential Oil.

1. Background

Agroforestry systems have gained considerable importance as sustainable land-use practices that enhance resource utilization, improve microclimatic conditions, and support diversified agricultural production. The integration of medicinal and aromatic plants within tree-based systems has attracted increasing attention due to their high economic value and increasing demand from pharmaceutical, cosmetic and herbal industries. Lemongrass (*Cymbopogon flexuosus*) is an important aromatic grass cultivated for its citral-rich essential oil which is widely used in perfumery, cosmetics, pharmaceuticals and aromatherapy industries (Rajeswara Rao *et al.* 2015). Among the improved cultivars, the cultivar Krishna is well known for its high biomass production, superior oil yield and wide adaptability under different agro-climatic conditions (Tamang *et al.* 2025). Harad (*Terminalia chebula*) is an important multipurpose medicinal tree species widely used in traditional medicine systems such as Ayurveda, Unani and Siddha. The dried fruits of *Terminalia chebula* are an important component of the well-known Ayurvedic formulation Triphala, which is widely used for digestive health and as a rejuvenating tonic (Kim *et al.* 2006). The species is also valued for its antimicrobial, antioxidant and laxative properties, making it an economically important medicinal plant. In agroforestry systems, Harad can influence the microclimate by altering light intensity, temperature and soil moisture conditions, which may affect the growth and productivity of understory crops. Understanding the compatibility of aromatic crops with such tree species is therefore essential for developing efficient agroforestry models. The present study was conducted to evaluate the growth performance, biomass production and essential oil yield of lemongrass (*Cymbopogon flexuosus* cv. Krishna) grown under the canopy of Harad and to assess the influence of tree-induced shade on crop productivity.

2. Materials and Methods

The experiment was conducted for two consecutive growing seasons during 2022–2024 at the experimental farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), Chatha, Jammu, to evaluate the performance of lemongrass (*Cymbopogon flexuosus* cv. Krishna) in a Harad-based agroforestry system. The study was laid out in a randomized block design with two treatments: (i) lemongrass grown under Harad canopy representing partial shade conditions and (ii) lemongrass grown under open-field conditions serving as control. The Krishna slips were planted at a spacing of 40 cm × 40 cm, while the Harad (*Terminalia chebula*) trees in the agroforestry system were maintained at a spacing of 6 m × 4 m. Observations were recorded on growth and yield parameters including plant height, number of tillers per plant, fresh biomass yield, and essential oil content across successive harvests during the two years of experimentation. The recorded data were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for randomized block design, and the analysis was carried out using OPSTAT statistical software.

3. Results and Conclusion

The results indicated that partial shade under Harad canopy had non-significant influence on the plant height of Krishna cultivar. The plants grown under the Harad canopy attained a mean height of 162.89 cm, which was statistically comparable to those grown under open conditions (171.89 cm) with a p-value of 0.551, indicating that shade from Harad trees did not adversely affect plant growth. The number of tillers per plant was slightly higher under open condition (33.22) compared to the tillers grown under the shade of Harad tree (30.45) although the difference was statistically non-significant with a p-value of 0.111. The leaf area also show higher under open condition with a value of 15984.81cm² compared to the leaf area 13805.00 cm² under canopy showing a significant difference with a p-value of 0.00. These observations indicate that moderate shade created by Harad trees does not negatively influence the vegetative growth of *Cymbopogon flexuosus* cv. Krishna. The fresh biomass yield recorded under open-field conditions was 60.05 t ha⁻¹, which was significantly higher than the yield obtained under the Harad canopy (41.20 t ha⁻¹) with a p-value of 0.017. This indicates that although lemongrass (*Cymbopogon flexuosus* cv. Krishna) is capable of growing under partial shade, higher light availability in open conditions promotes greater biomass accumulation, resulting in significantly higher fresh biomass yield compared to the agroforestry condition. The essential oil content showed a slight reduction under shaded conditions (0.85%) compared to open-field cultivation (0.89%), but the difference was not statistically significant (p=0.803). It may therefore be concluded that lemongrass (*Cymbopogon flexuosus* cv. Krishna) can be successfully integrated with Harad (*Terminalia chebula*) without significant reduction in growth or productivity. This tree–crop combination represents a promising agroforestry model for diversified, resilient and economically sustainable production of medicinal and aromatic plants.

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4.37 Evaluation of Early Seedling Growth Traits in *Sophora mollis* Royle- an Endangered Multi-Purpose Legume Plant of Temperate Himalaya

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Keywords: *Sophoramollis*, Endangered Plant, Seed Collection, Propagation, *Ex-Situ* Conservation.

1. Background

Sophoramollis (Royle) Baker is a multipurpose leguminous shrub belonging to the family Fabaceae (subfamily Papilionaceae). It is a small deciduous perennial plant characterized by dense hairy twigs and yellow flowers, typically flowering from March to May (Manzoor *et al.*, 2013). The species is widely distributed across the plains and foothills of the North-Western Himalaya, extending to regions of Nepal, Pakistan, Afghanistan, Iran, and China, generally occurring at altitudes ranging from 700 to 1500 m in India (Jammu and Kashmir, Himachal Pradesh, and Uttarakhand), Pakistan, Afghanistan, and China (Srivastava *et al.*, 2016). It commonly grows on semi-exposed to shaded slopes and forest edges under temperate climatic conditions. It serves as an important source of traditional fodder, while its woody stems are widely used as fuel by local communities. However, overexploitation and habitat degradation have resulted in a substantial decline in its natural populations, placing it in the endangered category according to its conservation status (Mamgain, 1999), thereby highlighting the urgent need for effective conservation and propagation strategies.

2. Materials and Methods

The present study was conducted to promote conservation through seed-based propagation of this species. Mature seeds were collected from Budgam Karewas, where the species was explored growing under the canopy of almond trees. Pre-sowing treatment involved soaking the seeds overnight in water to enhance germination. Germination trials were carried out under nursery conditions, and seedling growth performance was evaluated using parameters such as germination percentage, seedling height, collar diameter, number of branches, and number of leaves per plant.

3. Results and Conclusion

The seeds exhibited high viability with a germination percentage of 85%. Seedlings showed vigorous growth, with a mean height of 22.4 cm and an average collar diameter of 3.8 mm. The plants developed an average of 3.6 branches and 21.3 leaves per plant, indicating strong early establishment potential. Comparable observations have been reported in ecological studies of Rawat *et al.*, 2024 suggesting seedling quality and survival under field conditions as a critical indicator for restoration programmes. The results demonstrate that seed propagation is an effective method for large-scale multiplication of *S. mollis*. Additionally, the observed variability in seedling traits suggests scope for selection of superior planting material. These findings underscore the importance of *ex situ* conservation approaches in preserving genetic diversity and supporting the restoration of this threatened species.

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4.38 Genetic Variation in Growth, Yield, and Fodder Potential of *Terminalia chebula* Selections in Subtropical Jammu

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Keyword: *Terminalia chebula*; genetic variation; fruit yield; green fodder; subtropical Jammu

1. Background

Terminalia chebula Retz., commonly known as Harar and belonging to the family Combretaceae, is a multipurpose medicinal tree widely distributed in tropical and subtropical regions. It holds a prominent place in traditional Ayurvedic medicine due to its rich phytochemical composition, particularly hydrolysable tannins, gallic acid, and chebulagic acid, which impart antioxidant, antimicrobial, and therapeutic properties. In addition to its medicinal value, the species plays an important role in agroforestry systems by providing fruit, fodder, timber, and fuelwood. In subtropical Jammu, *T. chebula* is increasingly recognized for its economic potential; however, limited information exists regarding the performance of different genetic selections under local conditions. Understanding variability in growth, yield, and fruit quality is essential for identifying superior selections suitable for cultivation and sustainable utilization.

2. Materials & Methods

The present study was conducted at the Experimental Farm of the Division of Silviculture and Agroforestry, SKUAST-Jammu, during 2023–2024 under subtropical conditions. Four *T. chebula* selections—Jammu (S_1), Kallar (S_2), Pragpur (S_3), and Palodi (S_4)—were evaluated in a seven-year-old plantation established at 4 m $\times$ 6 m spacing using a completely randomized design with six replications. Observations were recorded on tree growth parameters including tree height, collar diameter, crown spread, and number of branches. Fresh fruit yield and green fodder yield per tree were measured annually. Fruit physical parameters such as fruit length, diameter, fresh and dry weight, and pulp content were assessed at different maturity stages (September to November). Stepwise regression analysis was performed to develop predictive models for fruit yield based on tree growth variables.

3. Results and Conclusion

Significant variation was observed among the selections for growth and yield attributes. Kallar (S_2) recorded the highest tree height (5.93 m) and maximum fresh fruit yield (21.82 kg tree⁻¹), followed by Jammu (S_1), which showed statistically comparable yield (19.19 kg tree⁻¹) along with high green fodder production. Pragpur (S_3) exhibited the greatest collar diameter (16.08 cm) and crown spread (4.96 m). Fruit physical characteristics were superior in the Jammu selection, which recorded the highest fruit length, weight, and pulp content. All fruit parameters increased progressively from September to November, indicating that November is the optimal harvesting period. Regression analysis revealed that collar diameter and number of branches were the major contributors to yield in Jammu selection ($R^2=0.835$), while tree height was the key predictor in Kallar. In Palodi, crown spread, tree height, and collar diameter collectively explained a large proportion of yield variation ($R^2=0.850$). The findings demonstrate considerable genetic variability among selections and highlight the importance of selection-based improvement. Although Kallar showed the highest yield, the Jammu selection offers advantages such as superior fruit quality and shorter tree height, which facilitates harvesting and makes it more suitable for agroforestry systems. These results emphasize the potential of *T. chebula* as a valuable multipurpose species for

subtropical regions and support its promotion for sustainable cultivation and resource management.

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4.39 Ecological Distribution of Morels (*Morchella* spp.) in Jammu & Kashmir

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Keywords: Biodiversity, Ecological distribution, Habitat variability, Himalaya, *Morchella*

1. Background

Morels (*Morchella* spp.) are highly valued wild edible fungi of the Himalayan region, contributing significantly to the livelihoods of nearby populations. A variety of ecological parameters, such as soil properties, moisture availability, vegetation type, topography and microclimatic conditions, have a significant impact on the presence and fruiting of morels (Masaphy, 2011). Morels are frequently found in forest habitats in the Himalayan ecosystems, especially beneath coniferous and mixed vegetation, where their development is supported by organic matter and ideal moisture regimes. They do, however, also appear in disturbed habitats, agricultural fields, and orchards, suggesting some ecological adaptation. The variety and ecological heterogeneity of *Morchella* spp. have been emphasized in earlier research, underscoring the necessity of region-specific studies (Kerry O'Donnell *et al.*, 2011). Despite their importance, systematic studies on their ecological distribution across different habitats and locations remain limited, especially in Jammu and Kashmir. Understanding the habitat preferences and distribution patterns of morels is essential for their sustainable utilization, conservation and potential domestication. In this context, the present study was undertaken to evaluate the ecological distribution of *Morchella* spp. across diverse habitats and locations of Jammu and Kashmir during the 2025 fruiting season.

2. Materials and Methods

Field surveys were conducted during the year 2025 across multiple locations of Jammu and Kashmir, including Baramulla, Ganderbal, Bandipora, Poonch, Pulwama, Shopian, Anantnag and Kupwara. A total of 31 sampling sites were selected, representing diverse ecological conditions, with 3–5 sites within each location. Sampling sites were coded using district initials followed by site numbers (e.g., PO1–PO5 for Poonch, BA1–BA4 for Baramulla, GA1–GA4 for Ganderbal, BD1–BD4 for Bandipora, PU1–PU4 for Pulwama, SH1–SH4 for Shopian, AN1–AN3 for Anantnag, and KU1–KU3 for Kupwara). Surveys were carried out during the active fruiting period and all visible fruiting bodies of *Morchella* spp. were recorded and counted at each site. Sampling covered a wide range of habitat types, including pine forests, oak-dominated forests, orchards, agricultural fields, wheat crop bunds, stream banks and roadside areas, ensuring representation of both natural and disturbed ecosystems. At each site, detailed observations were recorded on habitat type, associated vegetation, soil characteristics (texture and color), moisture status, topography (slope/flat) and microhabitat conditions. Soil type was broadly categorized as loamy, clayey, or sandy based on field characteristics. Seasonal observations were also noted, including time of fruiting initiation and its association with rainfall and prevailing temperature conditions. Special observations such as recurring fruiting sites and occurrence in multiple seasons (spring and autumn) were also documented.

3. Results and Conclusion

A total of 462 fruiting bodies of *Morchella* spp. were recorded during the 2025 season from

31 sampling sites across eight locations of Jammu and Kashmir. Fruiting initiated in late February and was observed throughout the spring season under favorable moisture conditions. A strong association with rainfall events was evident, with emergence typically occurring shortly after precipitation. Larger fruiting bodies were recorded at sites where rainfall was followed by sunny days and cold nights. Morels were recorded from all surveyed locations, indicating a wide ecological distribution. Across regions, occurrence was observed in similar habitat types, including pine forests, oak-dominated forests, orchards, wheat crop bunds, stream banks and roadside areas. However, forest habitats consistently supported higher and more stable fruiting, while agricultural and disturbed habitats showed scattered and less frequent occurrence. Within forest ecosystems, fruiting bodies were predominantly found in moist soils beneath leaf litter, particularly along sloped terrains and natural water runoff channels. Sites with dark, organic-rich soils under pine vegetation showed favorable conditions for occurrence, while higher elevation sites under oak vegetation with relatively clayey soils also supported fruiting. Site wise variation was observed, with certain sites across different districts showing relatively higher occurrence compared to others, reflecting the influence of local microhabitat conditions rather than regional dominance. Lower fruiting intensity was consistently observed in low-altitude areas, whereas higher elevations supported comparatively better occurrence. In addition to spring fruiting, autumn fruiting was observed in selected sites of Poonch, indicating localized seasonal variability and ecological adaptation. The present study demonstrates that the distribution of *Morchella* spp. in Jammu and Kashmir during the 2025 season is governed by a combination of habitat characteristics, soil properties, moisture availability and microclimatic conditions rather than regional dominance. Forest ecosystems, particularly those with moist, organic-rich soils and well-developed leaf litter on sloped terrains, provide optimal conditions for morel occurrence. The consistent association with rainfall and specific microclimatic conditions highlights the sensitivity of morels to environmental variability. The observation of autumn fruiting in Poonch further indicates site-specific ecological adaptation, suggesting the potential for extended fruiting periods under suitable conditions. These findings provide baseline ecological insights essential for the sustainable management, conservation and future domestication of morels in Himalayan agroecosystems.

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4.40 Xenic Influence of Pollen Genotype on the Morpho-Physiological Attributes and Reproductive Efficiency of Kiwifruit (*Actinidia deliciosa* cv. Hayward)

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Keywords: *Actinidia deliciosa*, Xenia, Pollen Parent, Tomuri, Fruit Quality

1. Background

Kiwifruit (*Actinidia deliciosa*), cultivar ‘Hayward’, is a dioecious species that requires effective cross-pollination to ensure commercial fruit size and quality. In the temperate conditions of Kashmir, inadequate natural pollination often leads to undersized and unmarketable fruit. While the importance of pollination is well known, the Xenia effect—the direct influence of the pollen genotype on the development of the maternal fruit tissues—can significantly alter the physico-chemical character of the fruit. The present study was carried out to determine the influence of different pollen parents (‘Tomuri’ and ‘Matau’) on the fruit set, yield, and quality characteristics of ‘Hayward’ kiwifruit.

2. Material and Methods

The study was conducted on 11-year-old ‘Hayward’ vines. Pollen was harvested from two male genotypes: ‘Tomuri’ (M1) and ‘Matau’ (M2). Flowers were collected at the balloon stage, and anthers were extracted for pollen processing. To isolate the xenic effect, female flowers were bagged at the balloon stage and hand-pollinated during peak receptivity. Supplemental treatments involved the application of Boron (0.1% Borax) and Zinc (0.4% ZnSO₄) at the 90% bloom stage, a period identified for peak hormonal sensitivity. Fruit set, physical parameters (weight, length, diameter), and volume were recorded. Biochemical analysis estimated total soluble sugars, Vitamin C, and total phenols. Statistical analysis followed a Completely Randomized Block Design, with significance assessed at $p < 0.05$.

3. Results and Conclusion

The impact of the male genotype was evaluated in terms of the xenic response during the period of study. ‘Tomuri’ (M1) exerted a significantly higher xenic influence on physical traits, resulting in superior fruit set (88.60%), fruit length, and volume compared to ‘Matau’ (M2) and untreated controls. However, ‘Matau’ (M2) influenced a superior chemical profile, producing significantly higher TSS, total sugars, and Vitamin C content.

Biochemical studies revealed that ‘Tomuri’ pollination, synergized with micronutrients, led to increased calcium-mediated firmness. Consistent with Anwar *et al.* (2023), the use of ‘Tomuri’ pollen at the 90% bloom stage enhanced nutritional regulation, likely through increased endogenous IAA levels that prevented fruit abscission.

It may be concluded that the pollen source serves as a biological regulator of fruit development. For maximum yield and storage robustness, ‘Tomuri’ is the recommended donor, whereas ‘Matau’ optimizes the bioactive sugar components. This xenic differentiation provides a strategic tool for customizing fruit quality based on market demand.

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4.41 Adaptation of agroforestry in District Reasi of J&K

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1. Background

Agro-forestry is an excellent medium of land utilization for obtaining the maximum output. In both irrigated and rain-fed environments, agroforestry is practised to produce food, fuel, fodder, timber, fertiliser, and fibre. It also contributes to nutritional and ecological security, supports livelihoods, reduces poverty, and encourages resilient and productive cropping and farming environments. Adoption of different practices of agroforestry systems is very much crucial for sustaining the livelihood of resource poor farmers particularly in rainfed area. The present study was carried out in 2 blocks of Reasi district of Jammu and Kashmir in 2025-26 to identify different agroforestry models and bottlenecks encountered by farmers in adoption of different agro-forestry practices. Multistage random sampling method was used by selecting 120 respondents from study area. The results show lack of awareness, and lack of interactions with respective governmental organizations were the major bottlenecks in adoption of different agroforestry practices.

2. Material and Methods

The study was carried out in Reasi district of Jammu and Kashmir UT during 2025-26. Multistage random sampling technique was adopted for selection of blocks, villages and respondents. Reasi district has 12 blocks; out of these 2 blocks namely Katra and Panthal were selected for study purpose. This stage was also purposive as these 2 blocks have majority of rainfed area. Two villages were taken from each block consisting 4 villages from 2 blocks for the present study. 30 farmers/ households were selected randomly as respondents from each selected village, thus making an aggregate sample of 120 respondents for reporting the constraints encountered by farmers in adoption of different agro-forestry practices.

3. Results & Conclusion

The results on major agricultural crops and the associated woody perennials indicates that Maize (*Zea mays*), Bajra (*Pennisetum glaucum*), Rice (*Oryza sativa*) Wheat (*Triticum aestivum*) Mustard (*Brassica nigra*) were major agricultural crops in Kharif and Rabi and major woody perennials Galgal (*Citrus pseudolimon*), Ber (*Ziziphus mauritiana*), Mango (*Mangifera indica*), Bans (*Dendrocalamus strictus*), Talli (*Dalbergia sissoo*), Tunu (*Toona ciliata*), Simbal (*Bombax ceiba*), Siris (*Albizia lebbeck*), Lacenia (*Lucenea lucocephala*), Dhaman (*Grevia optiva*), Draink (*Melia azadirach*) were identified in the study area. These species significantly contribute in different components of existing agro-forestry systems in study area.

Data on the bottlenecks as reported while interviewing the respondents in different blocks shows that the reasons of low adoption of agroforestry were Lack of awareness, Hilly region and rigid terrain, Damage by wild animals and Non availability of good quality planting material.

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4.42 Decomposer Insect Diversity Across Elevational Gradients: Impacts on Nutrient Cycling in North-Western Himalayas

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Keywords: Decomposer diversity, Altitudinal gradient, Nutrient cycling, Himalayan forests; Ecosystem services

1. Background

Decomposer insects play an essential role in the functioning of forests ecosystems by controlling the decomposition of organic matter, the cycling of nutrients and soil fertility. These mechanisms are essential for sustaining ecosystem production and stability in the delicate Himalayan terrain. According to the biodiversity- ecosystem functioning (BEF) theory, interactions between insects and microbial communities enhance nutrient turnover, while increased species richness and functional diversity promote decomposition through complementarity and selection effects. Decomposer communities in Himalayan forests are still not well understood across altitudinal gradients, despite their ecological significance. Therefore, the present study was undertaken to evaluate the diversity, abundance, and functional role of decomposer insect communities across different forest zones.

2. Materials and Methods

The study was conducted across three altitudinal zones: Lower Shiwaliks (≤ 1100 m), Shiwaliks (1100–1800 m) and Middle Himalayas (> 2800 m). Standardised methods were used to collect samples between April and July. Surface-active decomposers were collected using pitfall traps, while leaf litter arthropods were extracted from 1 m² quadrats using Winkler extractors. Colony density and activity were measured using 100-meter belt transects to evaluate termite populations. Fresh cattle dung was used as bait in dung-baited traps to collect samples of dung beetles. The data were recorded as mean $\pm$ standard error based on five replicates per site. One-way ANOVA and Tukey's HSD test ($p < 0.05$) were used for statistical analysis. The Shannon-Wiener diversity index (H') and evenness (J') were used to assess community diversity.

3. Results and Conclusion

The study revealed clear altitudinal variation in decomposer communities. The Shiwalik forests recorded the highest diversity ($H'=2.58$; $S=17$), followed by Lower Shiwaliks ($H'=2.36$) while the Middle Himalayas showed reduced diversity ($H'=2.07$) (Figure 1). Ants (18.9 ± 1.8 ind./trap) were the most common surface-active decomposers, followed by ground beetles (8.5 ± 0.9) and dung beetles (11.3 ± 1.2). Litter-dwelling communities were primarily composed of springtails (79.3 ± 6.1 ind./m²), detritivorous mites (40.2 ± 4.1), and litter ants (36.7 ± 3.8), indicating active litter decomposition. Termite surveys showed the highest colony density in Shiwaliks, particularly for *Odontotermes obesus* (7.4 ± 0.8 colonies/100 m), highlighting their role in lignocellulosic decomposition. Similarly, dung beetles such as *Onthophagus taurus* (13.7 ± 1.4 ind./trap) contributed significantly to dung breakdown and nutrient recycling. In contrast, the Middle Himalayan zone exhibited lower abundance and diversity, likely due to lower temperatures and slower decomposition rates. Overall, the study demonstrates that mid-altitudinal Shiwalik forests provide optimal environmental conditions for decomposer activity, thereby enhancing nutrient cycling, soil fertility and ecosystem resilience. The findings emphasize the importance of conserving decomposer biodiversity and integrating it into forest management strategies to sustain ecosystem services in Himalayan ecosystems.

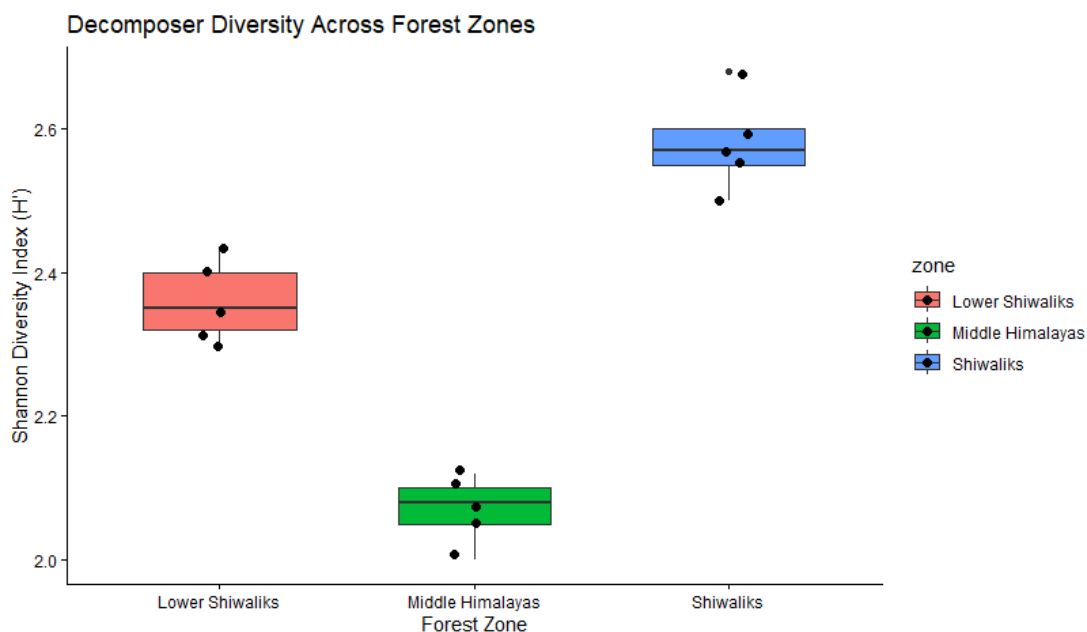


Figure 1. Altitudinal variation in decomposer diversity (Shannon–Wiener index, H') across forest zones, showing highest diversity in Shiwalik forests and lowest in Middle Himalayas.

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4.43 Marker-Assisted Selection and Genome Editing for Targeted Introgression of Precocity, Fruit Quality, and Disease Resistance in Apple (*Malus × domestica* Borkh.)”

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Keywords: Apple, scab resistance, genome editing, precocity, speed breeding, hybridization

1. Background

Apple (*Malus × domestica* Borkh.) is one of the most economically important temperate fruit crop, valued for its high market demand, nutritional benefits, and wide consumer acceptance. Apple consumption has been associated with reduced risk of several chronic diseases, enhancing its importance in human diets. From a breeding perspective, both fruit quality traits (appearance, flavour, texture, biochemical composition, and storage life) and agronomic traits (disease resistance, tree architecture, and vigour) are critical targets. Apple is highly susceptible to more than 70 diseases, among which apple scab caused by *Venturia inaequalis* is the most destructive. Disease management typically requires 20–30 fungicide sprays per season, increasing production costs and posing environmental and health concerns. Development of scab-resistant cultivars offers a sustainable alternative, particularly for low-input and organic production systems. The *Vf* resistance gene derived from *Malus floribunda* 821 has been widely utilized in breeding programs. Cultivars such as ‘Prima’ have successfully incorporated this resistance through interspecific hybridization. However, the durability of resistance and the need to combine it with superior fruit quality necessitate advanced breeding strategies integrating molecular tools, mutation breeding, and genome editing. Apple improvement is constrained by a prolonged juvenile phase, which delays flowering and breeding cycles. The *TERMINAL FLOWER LOCUS 1* (*MdTFL1*) gene has been identified as a key floral repressor regulating flowering time and tree architecture in apple, thereby maintaining juvenility, and inhibiting the transition to reproductive development (Flachowsky *et al.*, 2009). Targeting this gene has therefore emerged as a promising strategy for inducing precocity and accelerating breeding programs

2. Materials and Methods

Breeding strategies combined conventional hybridization, marker-assisted selection (MAS), mutation breeding, transcriptomics, and genome editing. Hybridization programs involved crossing ‘Prima’ (donor of *Vf* resistance) with commercial cultivars ‘Red Delicious’ and indigenous Ambri selection CITH-Ambri-1. Segregating populations were screened using molecular markers linked to scab resistance genes, along with phenotypic evaluation under field conditions. Selected hybrids were advanced based on resistance and fruit quality traits.

Comparative transcriptome analysis was conducted using parental genotypes (‘CITH-Ambri-1’ and ‘Prima’) and their hybrid (‘CITH-Prima’) to identify candidate genes associated with scab resistance and fruit quality. Principal component analysis (PCA) and differential gene expression analysis were employed.

For the enhancement of fruit quality traits, the indigenous cultivar ‘CITH-Ambri-1’ was hybridized with elite donor cultivars ‘Mollies Delicious’ and ‘Top Red’ to develop superior genotypes, ‘CITH-AMMOL’ and ‘CITH-AMRIT’. The hybridity and parentage of the progenies were validated through S-allele-based genotyping, while comprehensive phenotypic and

biochemical profiling was undertaken to assess key fruit quality attributes, including physicochemical parameters and the accumulation of secondary metabolites.”

Mutation breeding was implemented through induced mutagenesis using gamma irradiation (30–40 Gy) and chemical mutagen ethyl methane sulfonate (EMS) applied to scion wood, resulting in the development of a large mutant population (10,000 grafted plants). The resultant population is being systematically screened through integrated phenotypic and molecular approaches for variability in fruit colour, quality attributes, and disease resistance.

CRISPR/Cas9-mediated targeted mutagenesis of the *MdTFL1* gene, a central floral repressor regulating juvenility and vegetative phase maintenance in apple, was undertaken to induce precocious flowering in the cultivar ‘Gala Redlum’.

3. Results and Conclusion

Marker-assisted selection enabled efficient identification of scab-resistant hybrids. Two promising hybrids, ‘CITH-Pride’ (Red Delicious × Prima) and ‘CITH-Priame’ (CITH-Ambri-1 × Prima), were developed, combining disease resistance with desirable fruit traits. These hybrids demonstrated the effectiveness of integrating molecular markers with conventional breeding. Transcriptome analysis revealed that ‘CITH-Priame’ clustered between its parents, confirming its hybrid nature at the gene expression level. Differential expression studies identified key genes and pathways associated with *Vf*-mediated resistance and fruit quality traits such as colour, crispness, and shelf life. Hybridization for fruit quality improvement resulted in superior genotypes ‘CITH-AMMOL’ and ‘CITH-AMRIT’, exhibiting enhanced sweetness with higher TSS values and other desirable quality traits. These hybrids retained the desirable attributes of ‘Ambri’ (CITH-Ambri-1) while incorporating improved size, colour, and market appeal. The germplasm has been registered with ICAR–NBPGR, highlighting its breeding value and released through CVRC.

Mutation breeding generated substantial variability, particularly in fruit colour and quality traits. Several promising mutants are under evaluation (M2 & M3 generations), providing a valuable resource for future breeding programs.

Genome editing of *MdTFL1* represents a significant advancement toward reducing the juvenile phase in apple. Edited lines are being evaluated for early flowering and growth characteristics, offering potential for rapid varietal development. Additionally, genome editing strategies targeting disease resistance genes are being explored to complement conventional breeding approaches.

The integration of MAS, mutation breeding, transcriptomics, and genome editing provides a comprehensive framework for accelerating apple improvement. These approaches enable precise, efficient, and sustainable development of cultivars combining precocity, superior fruit quality, and durable disease resistance.

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4.44 From Degradation to Regeneration: Soil Improvement through Fruit Tree Systems in Semi-Arid Zones

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Keywords: Carbon sequestration, Land degradation, Orchard systems, Semi-arid regions, Soil quality

1. Background

Land degradation is a critical constraint in semi-arid regions (Kumar et al 2022) and is characterized by soil compaction, low organic matter, nutrient depletion and increased salinity (Alnaimy and Elrys 2026). Barren lands, in particular, often exhibit elevated soil pH and electrical conductivity, which further limit crop productivity and biological activity. Tree-based systems have gained attention as sustainable interventions due to their ability to improve soil structure, enhance organic inputs and regulate soil chemical properties. Fruit trees such as bael, guava, jamun and mango can play a vital role in reversing degradation processes through litter deposition, root interactions and improved soil microenvironment. However, their comparative effectiveness in restoring degraded soils under semi-arid conditions remains insufficiently explored. Therefore, the present study aimed to evaluate the role of different fruit-based systems in mitigating soil degradation and improving soil health in semiarid region.

2. Material and Methods

The study was conducted at the experimental farm of the Department of Horticulture, CCS Haryana Agricultural University (CCSHAU), Hisar, during 2022–2023 to evaluate the effect of fruit tree species on soil physical, chemical and biological properties. Four orchard systems (bael, guava, jamun and mango) along with a barren as control were studied using a two-factor Randomized Block Design (RBD), with orchard system and soil depth as factors. Soil samples were collected in December 2022 prior to fertilizer application. From each orchard, samples were taken under the tree canopy from four points at depths of 0–15, 15–30, 30–60, and 60–90 cm. Samples from each depth were composited and reduced to approximately 1 kg after quartering. Sampling was carried out from four trees per orchard. Surface soil (0–15 cm) was used for analysis of physical and biological properties, while samples from all depths were used for chemical analysis. Fresh surface samples were stored at 4°C for biological analysis. Soil physical properties, including bulk density (BD), water holding capacity (WHC), and penetration resistance (PR), were determined using standard methods. Soil chemical properties were analyzed following standard procedures. Statistical analysis was performed using a two-factor RBD, and treatment means were compared at the 5% level of significance.

3. Results and Conclusion

The results demonstrated that orchard-based systems significantly improved soil properties and mitigated degradation compared to the barren control. Bulk density and penetration resistance were highest in the control (1.66 g cm⁻³ and 2.58 MPa), indicating severe compaction, whereas all orchard systems showed lower values, reflecting improved soil structure. Water holding capacity was significantly higher under tree systems, with maximum value in jamun (40.68%), while the control recorded the lowest (27.15%), indicating poor moisture retention in degraded soils. The control exhibited the highest soil pH (8.68) and EC (2.77 dS m⁻¹), indicating increased alkalinity and salinity, which are key indicators of degradation in semi-arid regions. In contrast, orchard

systems effectively reduced pH and EC, thereby improving the soil chemical environment. Biological properties, including microbial biomass carbon and enzymatic activities (DHA, AP, URA), were significantly enhanced under orchard systems, with jamun showing the highest values, indicating improved microbial activity and nutrient cycling. Nutrient availability (N, P, K) and micronutrients, along with soil organic carbon and its fractions, were also markedly higher in orchard systems, particularly in surface soils. Depth-wise analysis revealed a decline in soil quality with increasing depth. Overall, fruit-based tree systems proved effective in preventing and reversing soil degradation in semi-arid regions. Among them, jamun-based orchards were most effective in improving soil structure, enhancing biological activity, reducing alkalinity and salinity and promoting carbon sequestration. Therefore, integration of tree-based systems can serve as a sustainable strategy for land restoration and long-term productivity in semi-arid agroecosystems.

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4.45 Nano-Calcium Borate: Enhancing Calcium and Boron Partitioning in Apple through Improved Bioavailability

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Keywords: Nano-calcium borate, nutrient bioavailability, calcium and boron partitioning, nano-fertilizer technology, sustainable apple nutrition

1. Background

Calcium (Ca) and boron (B) are vital for fruit quality, structural integrity, and reproductive development in apple, primarily through their roles in cell wall stabilization and borate cross-linking (Shetty *et al.*, 2024; Nayana *et al.*, 2026). However, their deficiencies are widespread in temperate regions due to limited mobility within plants. Calcium is largely immobile in the phloem and transported via the xylem, while boron mobility is restricted and depends on complexation with sugar alcohols like sorbitol. Although apple synthesizes sorbitol, its efficiency in enhancing boron transport during critical stages such as fruit development remains inadequate.

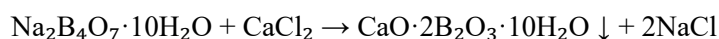
Conventional management through repeated foliar sprays of calcium chloride and boric acid is often ineffective due to poor absorption, cuticular barriers, wash-off losses, and limited nutrient re-translocation. Consequently, deficiency symptoms persist despite multiple applications.

Nanotechnology presents a promising solution by improving nutrient delivery efficiency. Nano-fertilizers, with their high surface area and small size, enhance foliar penetration, bioavailability, and controlled release of nutrients (Babu *et al.*, 2024). Calcium borate nanoparticles (Ca-B NPs) are hypothesized to improve Ca and B uptake and their internal partitioning in apple, potentially enhancing sugar alcohol-mediated boron mobility. Therefore, this study aims to (i) synthesize and characterize calcium borate nanoparticles and (ii) evaluate their effect on Ca and B partitioning in apple.

2. Materials and Methods

Calcium borate nanoparticles were synthesized using a co-precipitation method followed by heat treatment. Calcium chloride (CaCl₂) and borax (Na₂B₄O₇·10H₂O) served as precursor sources of calcium and boron, respectively, while polyvinylpyrrolidone (PVP) was used as a capping agent to prevent agglomeration.

PVP (1 g) was dissolved in 100 mL deionized water, followed by the addition of CaCl₂ at three molar concentrations (0.05, 0.10, and 0.15 M). Borax solutions of corresponding concentrations were prepared separately. Both solutions were heated to 48°C and stirred for one hour to ensure homogeneity. The calcium solution was then added dropwise to the borax solution under continuous stirring, resulting in the formation of a fine white precipitate of calcium borate nanoparticles:



The synthesized nanoparticles were characterized using FTIR, XRD, Dynamic Light Scattering (DLS), UV-Visible Spectrophotometry, and SEM-EDS to assess their structural,

crystallographic, and morphological properties.

Based on characterization results, the optimal nanoparticle formulation was selected for field application in apple orchards. Foliar sprays were applied at the peanut stage of fruit development, followed by a second spray after 21 days. The treatments included: T1 (control), T2 (water spray), T3 (NP @ 50 ppm), T4 (NP @ 100 ppm), T5 (NP @ 150 ppm), T6 (NP @ 200 ppm), and T7 (CaCl_2 + boric acid @ 50 ppm each). Leaf and fruit samples were analyzed to determine calcium and boron content.

3. Results & Conclusion

Characterization results indicated that precursor concentration significantly influenced nanoparticle properties. FTIR analysis revealed that nanoparticles synthesized at 0.05 M exhibited a well-defined borate framework, with clear vibrational bands corresponding to BO_3 , BO_4 , B–O–B linkages, and Ca–O bonds, indicating superior structural organization and surface reactivity. In contrast, higher concentrations (0.10 and 0.15 M) showed broader peaks, suggesting increased lattice disorder.

However, XRD analysis identified 0.10 M as the optimal concentration for achieving high crystallinity, single-phase formation, and minimal lattice strain. SEM–EDS results further demonstrated that intermediate concentration (0.10 M) produced morphologically stable and compositionally uniform nanoparticles, whereas higher concentrations led to agglomeration. DLS analysis showed larger hydrodynamic sizes due to aggregation effects in suspension.

Overall, a critical synthesis window (0.05–0.10 M) was identified, where 0.05 M favoured surface chemistry and borate network development, while 0.10 M ensured crystallographic stability. Based on these findings, nanoparticles synthesized at 0.05 M were selected for field application due to their superior surface properties.

Foliar application of calcium borate nanoparticles significantly enhanced calcium and boron partitioning in apple compared to control and conventional treatments. Among all treatments, NP @ 100 ppm (T4) recorded the highest total calcium uptake (20.54 ppm), with increased calcium accumulation in both leaves and fruits. This improvement is attributed to enhanced foliar absorption, better cuticular penetration, and sustained nutrient release under nano-formulation.

At higher concentrations (150 and 200 ppm), a decline in calcium uptake was observed, indicating an optimal threshold beyond which mobility may be restricted due to the inherent immobility of calcium in the phloem.

Similarly, boron partitioning was significantly improved under nano-fertilizer application. The NP @ 100 ppm treatment recorded the highest boron content in leaves (0.052 ppm) and fruits (7.36 ppm), indicating efficient uptake and translocation. The coordinated increase in both vegetative and reproductive tissues suggests improved phloem mobility, possibly mediated by enhanced interaction with sugar alcohols.

At higher concentrations, boron content declined slightly, indicating concentration-dependent antagonism or reduced mobility. Compared to conventional CaCl_2 and boric acid sprays, nano-calcium borate treatments consistently performed better, demonstrating enhanced bioavailability, improved nutrient use efficiency, and reduced losses.

In conclusion, calcium borate nanoparticles synthesized within an optimal precursor range offer a viable and efficient strategy for correcting calcium and boron deficiencies in apple. The study highlights that nano-formulations enhance nutrient uptake, internal partitioning, and

utilization while reducing the need for repeated applications. The 100 ppm dose emerged as the most effective treatment. These findings underscore the potential of nanotechnology in developing sustainable and efficient nutrient management strategies for horticultural crops.

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4.46 A Study on the Accuracy of Medium Range Weather Forecasts for Rajouri district of J&K

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Keywords: Medium Range Weather Forecast, Forecast accuracy, Usability, Ratio Score.

1. Background

Weather forecast information's play a vital role in making short-term adjustments in daily agricultural operations. A more accurate prediction would enable farmers to plan and make the required decisions, lowering the risks associated with weather-related events (Kumar and Khan, 2018). Improving forecast accuracy for agriculture is crucial due to its reliance on timely and reliable weather information for optimizing farming practices. Timely weather forecasts help farmers optimize resource use by enabling them to make informed decisions regarding irrigation, sowing, harvesting, and pest management, reducing the risks associated with unexpected weather changes. Institutions like the National Centre for Medium-Range Weather Forecasting (NCMRWF), India Meteorological Department (IMD), Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) work together to deliver Agrometeorological Advisory Services (AAS), which offer region-specific guidance on agricultural activities like crop selection, sowing, irrigation, and pest management based on medium range weather forecast. These advisories are tailored to the specific needs of local farming communities and help mitigate the impacts of weather variability. A major constraint in farm planning and operations is the lack of reliable and timely agrometeorological advice (Chaubey *et al.*, 2018). Weather-based AAS are essential for weather adapted farm activities, and making farmers aware of the value of these advisories can enhance day-to-day farm management, reduce losses and increase production.

2. Materials and Methods

The study was conducted in the intermediate mid hills of Pir Panchal range of district Rajouri in the Union Territory Jammu and Kashmir, located at 33° 42' N latitude and 74° 13' E longitude at an elevation of 950 meters above mean sea level. The dataset is stored in .csv format and includes weather data from 01-01-2024 to 31-12-2025. Medium Range Weather Forecasts (MRWF) are issued regularly by the India Meteorological Department (IMD), New Delhi through Meteorological Center, Srinagar. These forecasts provide predictions for various meteorological parameters such as rainfall, cloud cover, maximum and minimum temperatures, relative humidity, wind speed, and wind direction. The forecast verification is performed using statistical tool like Ratio Score. This metric is used to quantify forecast accuracy, ranging from 0% (no accuracy) to 100% (perfect accuracy), calculated as the percentage of correct forecasts relative to the total forecasts issued.

Where,

$$\text{Ratio score} = \frac{\text{Correct forecast} \times 100}{\text{Total no. of forecast}}$$

3. Results and Conclusion

Improving forecast accuracy is essential for agriculture, as farming activities depend heavily on timely and reliable weather information. This study assesses the accuracy of Medium-Range Weather Forecasts (MRWF) issued by the India Meteorological Department (IMD) on various weather parameters and actual weather data recorded at Agrometeorological observatory of Regional Agricultural Research Station, Rajouri were compared to check the validity and accuracy of weather forecast during 2024 and 2025, covering all four seasons. An analysis of seasonal ratio scores reveals notable variability in forecast performance (Fig. 1). During the summer/pre-monsoon season, the ratio score slightly increase from 74.2 in 2024 to 76.8 in 2025, indicating improved forecast reliability. In contrast, the southwest monsoon (SWM) exhibited improved forecast accuracy, with the ratio score increasing from 61.2 in 2024 to 64.2 in 2025. Similarly, the post-monsoon experienced a decline in forecast performance, with the ratio score dropping from 52.3 in 2024 to 44.7 in 2025. Winter forecasts, however, demonstrated a remarkable improvement, with the ratio score rising sharply from 84.5 in 2024 to 90.0 in 2025. The higher accuracy observed during winter, followed by pre-monsoon and monsoon seasons, suggests that predicted rainfall during winter was closer to observed values compared to other seasons. It may be concluded that the accurate weather forecasting with respect to various weather parameters is important as this can be used to facilitate the farmers to make broad decision on the crop management operations and this type of analysis will help in generating fairly accurate weather forecast for this area.

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4.47 Exploring combination of dynamic factors on success of walnut (*Juglanus regia* L) grafting in open field conditions.

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Keywords: Walnut (*Juglans regia* L), in-situ & ex-situ grafting methods, graft success

1. Background

Walnut (*Juglans regia* L.) is one of the several fruit species indigenous to Jammu & Kashmir, India and its plants distributed worldwide, ranking third in nut production (Ercisli *et al.*, 2012), and is considered to be quite healthy for human nutrition (Khir *et al.*, 2014). Jammu and Kashmir contribute 91.68 % share of country production. However, the multiple difficulties for vegetative propagation hinder its area extension and quality production. Such problems pressed to devise the current research programme to create a convenient and economical modus operandi that can grant a higher percentage of graft take success and also to particularize the desirable technique for large-scale exploitation under open field conditions. In general, the main objective of our research is to compare and optimize all of the success-related components in one package, which can conform best in combination, when grafting walnuts under In-situ and Ex-situ conditions. Keeping all these important factors into consideration, the present study was carried out to determine the exploring combinations of dynamic factors on success of walnut (*Juglanus regia* L) grafting under open field conditions.

2. Materials and Methods

This experiment was carried out under “In-situ” with exploring combinations of dynamic factors in the open field conditions. The two years old seedling rootstocks of uniformity size were used in the experiment. The rootstocks used were not disturbed from their present (original) location on the ground, while the grafting operation was made. Two grafting methods (Tongue and Wedge) with different timing (1st and 2nd week of February) were selected in the experiment. The scion wood materials were removed at the dormant stage during the grafting time from the basal and median portions of 1-year-old shoots of a native, superior variety of walnut (SJPW-01) growing at the station and scion wood materials instantly used for grafting purpose without stored under protected conditions. The union of the stock and scion was covered around by using the aluminium foil and polythene bag and gently wrapped and fastened around the union. The growth parameters i.e. (shoot length, shoot diameter, number of leaves and leaf area) and graft take and survival percentage were evaluated after grafting, as per the standard procedure.

This experiment was carried out under “Ex-situ” with exploring combinations of dynamic factors in the open field conditions also. The two years old seedling rootstocks of uniformity size were also used in the experiment. The rootstocks were taken out from the nursery, during last week of January. The tap root of all the rootstocks was trimmed and sorted for size and uniformity and stored underground till the grafting operation made. The grafting operation with same methods (wedge and tongue grafting) was carried out after two weeks. After completion of grafting

operation, the grafted plants were planted in separate blocks near the In-situ grafting. The blocks containing grafted plants were irrigated with the interval of alternative days for three weeks.

Statistical analyses between groups were made by One-way ANOVA followed by Least-significant difference (*LSD*) using SPSS version 13.0 program for Windows (*SPSS*, Chicago, IL, USA). The significance of the difference between the means of the examined characteristics was tested using the Duncan test for significance at $P < 0.05$.

3. Result and conclusion

By evaluating the In-situ and ex-situ walnut grafting, the data in Table-3 and Table-4, showed that a statistically significant influence of the applied production technology was seen on graft success and plant survival percentage. Under in-situ grafting, the highest values of graft success (96.33 %) and plant survival of (94.66 %) respectively, were obtained in treatment combination T₃: WG + 2nd week of February + scion thickness (10-15 mm) + In-situ grafting in comparison to ex-situ grafting resulted graft success (46.51%) and plant survival (39.20 %) under the treatment combination T₃: WG + 2nd week of February + scion thickness (10-15 mm) + Ex-situ grafting.

Days taken to bud burst and growth performance

The statistical analysis of data showed a significant variation of various active factors for days taken to sprouting. The minimum number of days (41.33) taken to bud burst were recorded with treatment T₃: WG + 2nd week of February + scion thickness (10-15 mm) + In-situ grafting. Whereas, the maximum number of days (54.00) were recorded under treatment T₆: TG + 1st week of February + scion thickness (<10 mm) + In-situ grafting.

3.1.2 “Ex-situ” grafting

As per the study findings, it can be deduced that various dynamic factors had significantly affected the percentage of graft success and plant survival under “ex-situ” grafting. The highest percentage of graft success (46.51 %) and plant survival (39.20 %), respectively among different treatment combinations were recorded in the treatment combination T₃: WG + 2nd week of February + scion thickness (10-15 mm) + Ex-situ grafting. However, the results recorded under ex-situ grafting were found lesser as comparison to in-situ grafting.

It is concluded on the basis of these experimental observations, the applied walnut grafting production technology of “in-situ” grafting proved significantly better with respect of all the observed traits in comparison to “ex-situ” grafting under open field conditions.

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4.48 Pre-harvest melatonin spray extends harvesting period and improves quality in litchi fruits

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Keywords: Litchi, Melatonin, Pre-harvest spray, Ripening delay, Yield, Fruit quality

1. Background

Litchi (*Litchi chinensis* Sonn.) is an important subtropical fruit crop valued for its attractive red pericarp, juicy aril, and excellent flavour. India is one of the major producers of litchi, with Bihar contributing a significant share of national production. However, the short harvesting window and rapid ripening of fruits often lead to market glut and reduced economic returns to growers. Regulation of fruit ripening through pre-harvest treatments has therefore gained considerable research attention.

In recent years, melatonin has emerged as a promising plant growth regulator capable of influencing fruit development, ripening behaviour, and quality attributes. Considering its regulatory potential, the present study was undertaken to evaluate the effect of pre-harvest foliar application of melatonin on ripening behaviour, yield attributes, and quality parameters of litchi cv. Purbi.

2. Materials and Methods

The experiment was conducted on litchi cv. Purbi under field conditions. Two concentrations of melatonin (0.1 mM and 0.5 mM) were applied as foliar sprays at different stages of fruit development: 10 days after fruit set, 40 days after fruit set, and a combined spray at both 10 and 40 days after fruit set. Untreated trees served as control.

Harvested fruits were analyzed for important yield and quality parameters including total soluble solids (TSS), ascorbic acid, total sugars, total anthocyanin content, total phenolic content, total flavonoids (Zhishen *et al.* 1999) and antioxidant capacity (Apak *et al.* 2008) using standard biochemical methods. The experimental data were analyzed statistically to determine the significance of treatment effects.

3. Results and Conclusion

Pre-harvest application of melatonin significantly influenced ripening behaviour, yield attributes, and fruit quality in litchi cv. Purbi. Among the treatments, foliar spray of 0.1 mM melatonin applied 10 days after fruit set was found to be the most effective. This treatment delayed fruit ripening by approximately 11 days compared with untreated trees, thereby extending the harvesting period. In contrast, fruits treated with 0.5 mM melatonin showed a comparatively smaller delay in ripening. Melatonin treatment also enhanced yield and maintained quality parameters.

The findings demonstrate that pre-harvest foliar application of melatonin, particularly at 0.1 mM concentration applied 10 days after fruit set, effectively delays ripening, improves fruit quality, and enhances yield in litchi cv. Purbi. This approach can be considered a promising and eco-friendly strategy for extending the harvesting window and improving the market value of litchi fruits.

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4.49 Appraisal of Phytochemical Constituents of *Cordia myxa* Fruit Pulp in Kathua District of Jammu

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Keywords: *Cordia myxa*, DBH classes, Harvesting time, Phytochemical constituents, Two-way ANOVA

1. Background

Cordia myxa L., commonly known as Lasora, is an important multipurpose tree species belonging to the Boraginaceae family. It is valued for its nutritional, medicinal and economic importance, particularly due to the presence of various bioactive compounds in its fruits. The fruit pulp is rich in phytochemical constituents such as phenolics, alkaloids, carbohydrates, proteins, and crude fiber, which contribute to its therapeutic potential. Despite its significance, the species remains underutilized and limited scientific information is available regarding the variation in phytochemical constituents with respect to tree size and harvesting stage. Diameter at Breast Height (DBH) is an important indicator of tree growth and physiological efficiency, which may influence fruit quality. Similarly, harvesting time plays a crucial role in determining the biochemical composition of fruits. Therefore, the presented study evaluated the phytochemical constituents of *Cordia myxa* fruit pulp across different DBH classes and harvesting stages in Kathua district of Jammu.

2. Material and Methods

The study was conducted in four villages (Prangoli, Sohal, Saida, and Badholi) of District Kathua (Jammu & Kashmir). A total of 50 trees were surveyed and classified into five DBH classes: D1 (10–20 cm), D2 (20–30 cm), D3 (30–40 cm), D4 (40–50 cm), and D5 (50–60 cm). Fruits were collected at two harvesting stages: H1 (before ripening: 20th May–15th June) and H2 (after ripening: 1st July–15th July). The experiment comprised ten treatment combinations (5 DBH classes $\times$ 2 harvesting stages) with four replications. Various fruit parameters were analyzed, including fruit weight, pulp stone ratio, total soluble solids (TSS), moisture content, ash content, carbohydrate content, crude fat, crude fiber, protein content, calorific value, phenolic content, and total alkaloid content. Data were analyzed using two-way ANOVA to assess the effects of DBH classes and harvesting time, along with their interaction, using SPSS software.

3. Results and Conclusion

The results revealed that DBH classes significantly influenced most phytochemical constituents of *Cordia myxa* fruit pulp. Higher DBH classes exhibited superior performance for key parameters such as fruit weight, pulp stone ratio, total soluble solids, moisture content, crude fat, crude fiber, phenolic content, and total alkaloid content. However, ash content and protein content were found to be comparatively higher in the intermediate DBH class, though statistically at par with the highest class. In contrast, carbohydrate content and calorific value showed a reverse trend, with higher values observed in the lowest DBH class.

Harvesting time also had a significant effect on phytochemical composition. Fruits harvested before ripening showed higher levels of phenolic content, carbohydrate content, ash content, and calorific value, whereas fruits harvested after ripening exhibited higher fruit weight, pulp stone ratio, total soluble solids, moisture content, and crude fat content.

The interaction between DBH classes and harvesting time was significant only for selected parameters, indicating combined effects on fruit quality. Overall, the findings suggest that phytochemical constituents are directly influenced by DBH classes, with larger trees producing better quality fruits. Fruits harvested at the pre-ripening stage were found to be richer in most phytochemical constituents, indicating their suitability for obtaining superior fruit quality.

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4.50 EFFECT OF IRRIGATION REGIMES AND FERTIGATION LEVELS ON GROWTH, YIELD AND FRUIT QUALITY OF SWEET ORANGE CV. MOSAMBI IN JAMMU SUBTROPICS

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Keywords: Irrigation, Fertigation, Leaf nutrients, Drip irrigation, Mosambi

1. Background

The sweet orange (*Citrus sinensis* L. Osbeck) cultivar Mosambi is a significant citrus crop in subtropical areas. In the subtropics of Jammu, the effective utilization of irrigation water and fertilizers is crucial for enhancing fruit productivity while sustainably managing soil and water resources. Drip irrigation combined with fertigation has demonstrated favorable outcomes in citrus cultivation by improving nutrient absorption, fruit yield, and overall quality.

2. Material and Methods

This experiment will take place at ACHR, Udheywala, SKUAST-Jammu, utilizing six-year-old Mosambi trees that are spaced at 5×5 m, arranged in a Factorial Randomized Block Design with ten treatments replicated four times. The treatments include three irrigation volumes: 1.0 volume (I_1), 0.8 volume (I_2), and 0.6 volume (I_3), alongside three levels of fertigation: 100% RDF (F_1), 80% RDF (F_2), and 60% RDF (F_3), in addition to a control group (surface irrigation + RDF). Data will be collected on flowering characteristics, leaf nutrient levels, yield, and biochemical traits.

3. Results and Conclusion

The results indicated that treatment T_4 (I_2F_1 : 0.8 volume irrigation + 100% RDF fertigation) demonstrated the most effective performance in terms of flowering, nutrient uptake, and biochemical quality. The earliest flowering occurred in T_4 when compared to the control (T_{10}). The highest fruit set percentage (41.7%) and fruit retention rate (30.4%) were also noted in T_4 , while the control recorded 30.9% and 22.4%, respectively. Leaf nutrient analysis during the flowering stage showed significantly elevated levels of N (2.51%), P (0.17%), and K (1.61%) in T_4 , in contrast to the control's 2.11%, 0.11%, and 1.12%. During the fruit development stage, T_4 sustained higher nutrient concentrations with 2.32% N, 0.16% P, and 1.51% K, whereas the control plants exhibited 1.97% N, 0.10% P, and 1.09% K. The enhancement in nutrient status under fertigation was attributed to improved nutrient solubility and effective root zone delivery. Among the biochemical characteristics, fruits from T_4 displayed the highest total soluble solids (TSS) at 9.6 °Brix, ascorbic acid content of 52.9 mg per 100 ml of juice, total sugars at 8.13%, and the lowest acidity at 0.56%. In contrast, the control fruits had 8.1 °Brix, 44.2 mg per 100 ml, 6.25% total sugars, and 0.69% acidity, respectively. The study concluded that drip irrigation at 0.8 volume water combined with 100% RDF (T_4) was superior in enhancing leaf nutrient status and the

biochemical quality of sweet orange cv. Mosambi in the Jammu subtropics. This treatment provides improved nutrient use efficiency and promotes sustainable management of soil and water resources.

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4.51 Evaluation of indigenous entomopathogenic fungi as mycoinsecticides against walnut weevil (*Alcidodes porrectirostris* Marshall) adults.

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Keywords: *Beauveria bassiana*, *Metarhizium anisopliae*, Mortality, Walnut weevil

1. Background

Walnut weevil, *Alcidodes porrectirostris* Marshall (Coleoptera: Curculionidae) is a key pest within the arthropod complex of walnut, *Juglans regia* L. in Jammu and Kashmir, causing substantial economic loss to it (Mir and Wani 2005). Contemporary pest management strategies are primarily dependent on synthetic chemical insecticides, however, their excessive and non-judicious application has resulted in deleterious impacts on human health, environment, development of resistance, negative effects on pollinators (Rundlof et al 2015) and birds and so on. Entomopathogenic fungi such as *Beauveria bassiana* (Bals.) and *Metarhizium anisopliae* (Metschnikoff) have emerged as viable biocontrol agents against various curculionid species and have been extensively investigated and commercially exploited for weevil management globally. Given the absence of systematic studies on the management of *A. porrectirostris* using entomopathogenic fungi in Jammu and Kashmir, the present investigation was designed to develop a baseline data on the virulence and efficacy of indigenous isolates of *B. bassiana* and *M. anisopliae* against this pest.

2. Materials and Methods

Bioassays were conducted using conidial suspensions of two *B. bassiana* (Bb-BH1 and Bb-BH2) and two *M. anisopliae* (Ma-PO1 and Ma-PO2) isolates. The bioassay treatments with five different spore concentrations (1×10^4 , 1×10^5 , 1×10^6 , 1×10^7 and 1×10^8 spores/ml) were serially diluted from the primary suspension of 1×10^8 spores/ml. For control treatment the individuals were sprayed with distilled water containing 0.3% Tween 80 solution. Each individual adult placed in petri dish on filter paper was sprayed directly with 1ml of the appropriate concentration. After 10 minutes, the treated adults were transferred to their cages. Each replicate consisted of 10 adults placed in one cage. The adults were held for 20 days at $25 \pm 1^\circ\text{C}$, 85–90% R.H. under a 16L: 8D photoperiod. Three days after treatment until 20th day, the number of dead adults were counted and Probit analysis was performed for the calculation of median lethal concentration (LC_{50} and $\text{LC}_{90} \pm 95\%$ C.L.). Median Survival times (ST_{50}) and corresponding confidence interval was calculated using log rank test under Kaplan-Meier analysis.

3. Results and conclusion

Exposure of *A. porrectirostris* adults to indigenous fungal isolates at concentrations of 1.0×10^4 , 1.0×10^5 , 1.0×10^6 , 1.0×10^7 , and 1.0×10^8 conidia/ml resulted in cumulative mortality ranging from 7.50% to 62.50%, with significant dose dependent variation. Among the isolates tested, *B. bassiana* isolate Bb-BH2 from Bhaderwah exhibited the highest virulence, causing

62.50% adult mortality at 1.0×10^8 conidia/ml. Probit analysis revealed significant differences in susceptibility to *B. bassiana* isolates Bb-BH1 and Bb-BH2 and *M. anisopliae* isolates Ma-PO1 and Ma-PO2, as evidenced by non-overlapping 95% confidential limits of LC_{50} and LC_{90} values. Bb-BH2 showed the lowest LC_{50} (9.72×10^6) and LC_{90} (1.30×10^{11}) values, indicating superior infectivity against adult weevils relative to other isolates. Time mortality assays showed that initial mortality commenced on day 6 post-inoculation and progressed until day 17, beyond which no further mortality was recorded. The results indicated that indigenous isolates of *B. bassiana* and *M. anisopliae*, particularly Bb-BH2, possess substantial biocontrol potential and represent a viable, ecologically rational alternative to conventional chemical insecticides for *A. porrectirostris* management.

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4.52 Assessment of Cotton Growers' Knowledge of Integrated Pest Management Practices for Controlling Pink Bollworm in Nagpur District, Maharashtra

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Keywords: Cotton growers, Descriptive research design, Integrated Pest Management (IPM), Knowledge level, Pink bollworm.

1. Background

Cotton (*Gossypium* spp.) is the most widely cultivated natural fibre and an integral part of the agricultural and industrial economy of India. India is distinguished for cultivation of all four commercially viable types of cotton - *G. hirsutum*, *G. barbadense*, *G. arboreum* and *G. herbaceum*. Apart from fibre, cotton has many uses, which include extraction of edible oil, animal feed and industrial products. India holds the top position in cotton production and supports more than 6 million families depending on cotton cultivation, with its predominant cultivation occurring in Maharashtra and Gujarat. The most destructive insect pest in cotton is the bollworm complex, with special emphasis on pink bollworm (*Pectinophora gossypiella*). Pink bollworm causes damage to the internal structures of the boll and seeds; thus, poor boll opening and low lint quality result. Resurgence of resistance in pink bollworm to Bollgard-II (cry1Ac + cry2Ab) has been observed in many cotton-growing states with infestation rates reaching 80-92% and yield losses ranging between 10 and 30%. Resurgence of pink bollworm poses serious problems to the sustainability of Bt cotton, especially in rain-fed zones due to restricted possibilities of rotation. Thus, identification of pests incidence and implementation of efficient and environmentally safe management methods should be considered as priority goals. IPM involves multiple strategies to reduce the population of pests below economic levels by using cultural, mechanical, biological and botanical approaches. With special attention paid to the use of biopesticides and herbal pesticides, such as neem formulations, IPM aims at ensuring sustainability.

2. Material and Methods

The descriptive research approach was applied because the phenomena that required study had taken place. The area that was purposively selected for this research is Nagpur district in the region of Vidarbha in Maharashtra. This is because this district has large-scale cultivation of cotton crops and has a high prevalence of pink bollworms. Two talukas with the largest cotton crop areas from the 14 talukas found in the district were selected, and out of the two, 12 villages having the most IPM cotton growers were selected. Out of the 12 villages, 120 cotton farmers were randomly selected from the list provided by the taluka agriculture officers.

3. Results and Conclusion

It is elucidated in Table 1 that the majority (55.00%) of the respondents had a medium level of knowledge about IPM technologies for controlling pink bollworm, followed by 27.50 per cent and 17.50 per cent of the respondents having low and high level of knowledge, respectively. Similar findings were reported by Khodake et al., The medium knowledge level of majority of the cotton growers might be since the farmers have good extension contacts and information sources.

Table 1: Distribution of cotton growers according to their overall knowledge level

Sr. No.	Category	Frequency	Percentage
1.	Low	33	27.50
2.	Medium	66	55.00
3.	High	21	17.50
	Total	120	100.00

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4.53 Identification and Weather Driven Epidemiology of Chilli Leaf Curl Disease in Jammu Region

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Keywords: Chilli, epidemiology, identification, leaf curl

1. Background

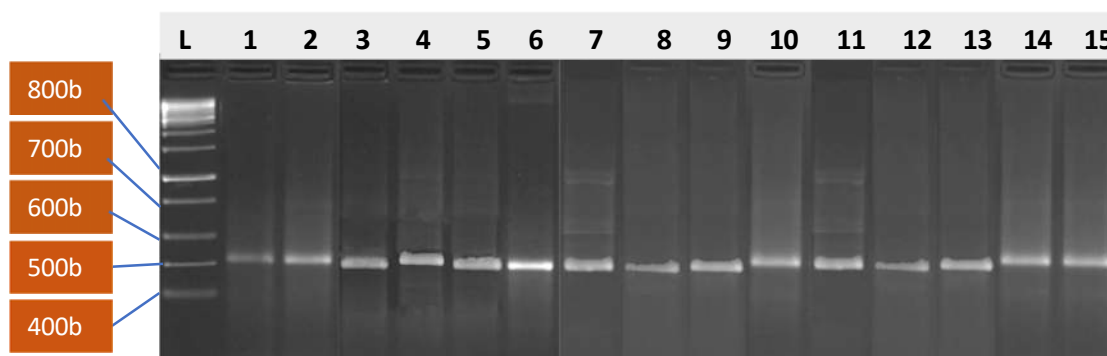
Chilli (*Capsicum annum* L.), a vital spice and vegetable crop in India, faces significant threats from viral diseases that drastically reduce yield and quality. Among these, chilli leaf curl disease (CLCD) stands out as a major constraint, causing symptoms like upward curling of leaves, stunting and fruit deformation, often leading to 40-100% yield losses in affected fields. This disease, prevalent in major chilli cultivation regions of Jammu and Kashmir and other chilli growing belts, is primarily incited by begomoviruses transmitted by whiteflies (*Bemisia tabaci*), though mixed infections involving satellites and other viruses complicate its etiology. Accurate identification of the causal virus through molecular tools like PCR and sequencing is crucial. Weather parameters further modulate disease epidemics, with high temperatures, low humidity and erratic rainfall favoring vector proliferation and disease spread. Assessing these interactions via correlation studies (e.g., temperature-humidity indices) enables predictive modeling and timely interventions.

2. Materials and Methods

The isolated genomic DNA samples were subjected to Polymerase chain reaction (PCR) amplification to confirm the virus presence. Each PCR amplification reaction was prepared with optimized concentrations of DNA template, primers, dNTPs, buffer, $MgCl_2$ and *Taq* DNA polymerase. The impact of weather factors, including average air temperature, relative humidity and rainfall, on the development of the disease and the population dynamics of whitefly (*Bemisia tabaci*) was assessed under field conditions at the University farm. Five plants were selected randomly to monitor whitefly populations from each replicated plot and three leaves one each from the upper, middle and lower canopy were chosen from each plant for counting. Observations were taken on a weekly basis. For epidemiological study, the G-4 variety was used. Weather data, including temperature, relative humidity and rainfall, was obtained from the Division of Agro-Meteorology, SKUAST-Jammu.

3. Results and Conclusion

The PCR amplification yielded distinct DNA bands of approximately 500 base pairs, as expected, confirming the presence of the viral coat protein gene. The amplified products were resolved on a 0.8% agarose gel. The data indicated that the disease first appeared during the 38th standard week (SW), when the crop was 60 days old. A sharp rise in disease incidence was recorded at the 44th SW with 21.99% when temperature minimum and maximum, relative humidity in morning and evening and rainfall were 14.6°C, 31.7°C, 94%, 54% and below 10 mm respectively. After this the disease incidence increased gradually.



Gel electrophoresis showing amplifications of coat protein gene (AVR) of ChiLCV

L- Ladder, 1- Makhyal, 2- Laswara, 3- Badyal brahmna, 4- Ferna, 5- Tikri, 6- Chenani, 7- Bashat, 8- Ramnagar, 9- Raghu chak, 10- Gho brahmna, 11- Rajpura, 12- Purmandal, 13- Nagrota, 14- Sanoora, 15- Mawa

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4.54 Impact of mutagenesis on bioactive compounds in *Cordyceps militaris*

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Keywords: *C. militaris*, Mutagenesis, UV irradiation, Cordycepin, Biometabolite content

1. Background

Cordyceps militaris, is rich in bioactive compounds such as carotenoids, polysaccharides, ergosterol, and especially cordycepin, a potent secondary metabolite known for its therapeutic properties. Due to its medicinal importance, enhancing cordycepin production in *C. militaris* has become a major research focus. Several strategies, including mutagenesis, optimisation of growth conditions, have been explored to improve its yield. Among these, mutagenesis is considered effective for increasing metabolite production, as it induces changes in DNA that can lead to enhanced gene expression and metabolite biosynthesis (Oh *et al.*, 2019). The present study investigates the influence of mutagens on the production of secondary metabolites in *C. militaris*.

2. Material and Methods

The study was carried out in the Laboratory of Molecular Biology in the Division of Biochemistry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K, India. The fungus was grown on Potato Dextrose Agar (PDA) medium and mycelium was subjected to UV irradiation for different time intervals inside the Laminar air flow and placed them in different distances from the UV lamp (Bangyeekhun *et al.*, 2019). Biochemical investigation was done by estimating Total phenolic content (Chen *et al.*, 2001) and total carotenoid content (Yang *et al.*, 2014).

3. Results and conclusion

Biochemical analyses were carried out to assess total phenolic content and total carotenoid content. Total phenol values 17.4, 19.8, 21.5 µg/g and 3.2, 4.6, 2.8 µg/g for total carotenoid content at 60, 120 and 180 minutes of UV radiation, was obtained. These results help determine the effectiveness of mutagenesis in enhancing the biosynthesis of key medicinal compounds in *Cordyceps militaris*.

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Theme 5:

Digital Agriculture, Artificial Intelligence, and Emerging Technologies for Climate Resilience



5.1 YouTube as an Extension Tool: Lesson Learned from viewer reaction

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Keywords: Content Analysis, Digital Agricultural Extension, Social Media, Viewer Reaction, YouTube

1. Background

Information plays a vital role in influencing human behaviour through its effect on thinking and decision-making (Chauhan, 1980). Among these platforms, YouTube has emerged as an important tool for education, communication and entertainment. In agriculture, YouTube serves as an effective e-extension medium by providing farmers with visual and practical knowledge on crop production, pest and disease management, mechanization and new technologies (Gharis *et al.*, 2014; Doyle and Briggeman, 2014). The visual format helps farmers to better understand and adopt improved practices. Viewer responses such as likes, comments and shares indicate the usefulness, credibility and relevance of the videos (Ma *et al.*, 2016). These responses help in assessing farmers' engagement, learning and decision-making. Punjab Agricultural University (PAU) uses YouTube as a digital extension platform to support the farming community of Punjab.

2. Material and Methods

The study was conducted in five agro-climatic zones of Punjab by selecting one district from each zone, namely Sangrur, Mansa, Ferozepur, Nawanshahr and Hoshiarpur. The respondents were grouped into farmers and extension experts. From each selected district, one village was chosen randomly and thirty farmers were selected from each village through simple random sampling, making a total sample of 150 farmers. All the 64 Agriculture Development Officers (ADOs) posted in these five districts were included in the study. The PAU Ludhiana YouTube channel had 731 videos available up to 1 March 2023, out of which 501 were scripted videos. All the scripted videos were considered for analysis. These videos were classified into four categories, namely crop management, water management, pest management and weed management. From each category, two videos were selected randomly, resulting in a total of eight videos for content analysis. The selected videos were shown personally to all respondents and their responses were recorded. Data were collected through personal interviews using a structured interview schedule. Viewer response was defined as the feedback regarding coverage, usefulness and suggestions for improvement, and was assessed in terms of title suitability, clarity, utility and completeness etc.

3. Result and Conclusion

The study revealed that the PAU Ludhiana YouTube channel plays a significant role in disseminating agricultural information to farmers and extension personnel. Among the selected videos, "Prevention of *Phalaris minor* in wheat" recorded the highest views and likes, indicating high relevance and usefulness, whereas "Information regarding drip irrigation" received the lowest views, suggesting the need for improvement. The video "How to prevent weeds in wheat – Dr. Makhan Singh Bhullar" achieved the highest overall reaction score, reflecting strong viewer engagement. Most respondents were middle-aged and graduates, indicating their ability to understand scientific information. The majority of ADOs and farmers found the language simple and the duration adequate. Most respondents expressed satisfaction with the videos, although the drip irrigation video showed lower satisfaction. Overall, 86 per cent of respondents considered the information factual, confirming the credibility of PAU's YouTube content.

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5.2 Rice Yield Prediction in Kashmir Using Weather Variables: A Comparison of ANN and Penalized Regression Model

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Keywords: Rice yield, weather variables, Prediction, ANN and Penalized Regression, Comparison

1. Background

Jammu and Kashmir (J&K) is an agrarian state, occupies 15th rank in term of agriculture production. Rice is the major food crop for more than 90% of the Kashmir population. Rice is farmed on an area of 133.28 thousand hectares respectively, with production of 3410 thousand quintals and at a productivity of 25.59 quintal/ha respectively in the Kashmir division (Anonymous 2021). The effect of weather parameters plays an important role in agricultural production such as on plant growth, development, and harvesting. Climate change has affected the production of major crops in Kashmir region such as rice, maize, wheat, barley, pulses, and oilseeds, along with various fruits (Tabasum et al 2018). As weather variables are interrelated, an issue of multicollinearity arises. To avoid this, penalized regression and machine learning approach was used to develop the forecasting model in addition to routine regression models. The models were validated for two years and comparison was made for efficient performance.

2. Material and Methods

The long term secondary (27 years form 1995-2021) data on area, production and productivity of Rice for the UT of Kashmir was collected from Directorate of Economics and Statistics, Kashmir and data on weather variables viz. including maximum, minimum temperature and rainfall was collected from IMD. Correlation analysis and multicollinearity among the independent variables were tested using standard approach. The forecasting models were developed using linear regression, ANN and penalized regression i.e. ridge and lasso regression using yield as dependent variable and weather variable as independent variables. The developed models were validated for 2 years and compared using higher R^2 and lower error matrix criterias viz. Root Mean Square Error (RMSE), Mean Square Error (MSE), AIC (Akaike Information Criteria) and BIC (Bayesian Information Criteria).

3. Results and Conclusion

Rice production in Kashmir was significantly correlated with maximum temperature ($r=0.54$) at 5% level of significance. Estimation of VIFs for independent variables in revealed that moderate Multicollinearity was caused by total area, technological parameter; maximum temperature, minimum temperature and Rainfall, each of which had a VIF value between 1 to 5, indicating moderate multicollinearity exist among the independent variables. Linear and Penalized regression (Ridge and Lasso) of explanatory variables (area, technology and weather) on Rice production has been fitted. In case of linear regression, only technology parameters were significantly influencing the model and explaining 67% of variation in the rice production and low prediction error. Using cross validation technique Ridge Regression model has been fitted with minimum lambda value 774.38 with lambda 1se is 1520.14. In case of Lasso regression all the three variables are

significantly affecting the model with R^2 of 0.78. Minimum lambda value 521.57 with lambda 1se is 1747.78 has been obtained from cross validation of Lasso regression. ANN model explained the total variation of 84% in dependent variable. In case of Rice Production, among all four models Artificial Neural Network has shown the highest R^2 (0.84) value in training and the lowest errors criteria in both training (model fitting) and testing set (model validation). Forecasting was done for the next six years using the best fitted model, Artificial Neural Network model for Rice Production. From the forecasting, it is observed that the rice production was increasing in coming years. For the rice production it was observed that Artificial Neural network (ANN) fits produced satisfactory results than penalized regression. It can be concluded that Artificial Neural (ANN) models and Ridge regression model outperformed the linear regression and can be used for forecasting of Rice crop in Kashmir.

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5.3 Predicting Apple Yield Using Time Series and Machine Learning Models

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Keywords: Apple Production, Climate change, Forecasting, and Machine Learning Models

1. Background

Agriculture plays a vital role in India's economy, with horticulture emerging as a key sub-sector, particularly in Jammu & Kashmir (J&K). Apples, a high-value horticultural crop, contribute significantly to the region's economy, accounting for over 70% of India's total apple production. However, recent climate variability has adversely impacted apple yield and quality in Kashmir. This study aims to forecast the area, production, and productivity of apples in Kashmir using statistical and machine learning models in changing climate.

2. Materials and Methods

Secondary data on apple area and production (1991–2023), alongside weather parameters (Tmax, Tmin, RF, RH1, and RH2), was collected for the entire Kashmir region. Initially, the data series were tested for normality, the presence of outliers, and randomness. Following this, univariate time series forecasting models using ARIMA were developed for area, production, and productivity of apples. Significant weather parameters affecting apple production and productivity were identified using regression analysis. Subsequently, ARIMAX models were developed by incorporating these identified weather variables to improve forecasting accuracy. The fitted models were evaluated using residual diagnostics and selected based on RMSE, MAE, MAPE, MaxAE, MaxAPE, and BIC criteria. Additionally, XGBoost, a machine learning algorithm, was employed to enhance prediction accuracy.

3. Results and Conclusion

In case of ARIMA, the best-fit models were ARIMA (1,1,2) for area, ARIMA (1,1,1) for production, and ARIMA (3,1,0) for productivity, all demonstrating good diagnostic performance with R^2 values of 0.98, 0.89 and 0.26 respectively. ARIMAX models are also developed by incorporating weather variables to improved forecasting accuracy. For production, April minimum temperature and rainfall were significant and included in the ARIMAX (4,1,0) model, achieving a high R^2 of 0.917. For productivity, rainfall in December and March were used in the ARIMAX (3,1,1) model, with an R^2 of 0.743. Both models passed residual diagnostics and showed low validation errors (e.g., 4.82% for production in 2023 and 3.88% for productivity), confirming their effectiveness in capturing climate-driven yield variations. XGBoost was applied to forecast apple production and productivity using historical weather and cultivation data, achieving outstanding predictive accuracy. The model showed an R^2 of 0.99 for both parameters, with extremely low RMSE and MAPE values (e.g., 0.05% for production). Compared to ARIMA and ARIMAX, XGBoost outperformed traditional models by capturing nonlinear and complex agro-climatic relationships more effectively. Overall, the study confirms that while ARIMA models remain effective for short-term forecasting of stable parameters, integrating exogenous variables and advanced machine learning approaches can significantly enhance yield prediction under changing agro-climatic conditions. These insights can support policymakers, planners, and farmers in mitigating risks and ensuring sustainable apple production in Kashmir.

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5.4 Factors Influencing Farmers' Utilization of ICT Tools for Accessing Information on Maize Production Practices in Rajouri District of Jammu Division

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Keywords: e-Agriculture Strategies, Extension Services, ICT tools, Utilization

1. Background

India's agriculture faces maize yield challenges as farmers rely on local shopkeepers for inputs due to limited expert access. Traditional extension services struggle with accessibility, funding shortages and outdated methods, especially in remote Rajouri district of Jammu division where maize cultivation dominates agricultural practices (Jadhav *et al.*, 2024). ICT tools like mobiles, internet and social media offer timely solutions for cultivation information, market trends, and weather forecasts, yet adoption remains low despite national production of 31.65 MMT (IIMR, 2024). This study explores key factors influencing farmers' utilization of ICT tools for maize production practices in Rajouri, aiming to enhance e-Agriculture strategies and sustainable livelihoods.

2. Material and methods

The study was conducted in the Rajouri district of Jammu and Kashmir, which was purposively selected due to its prominence in maize cultivation. The data were collected from 120 maize growers which were randomly selected using multistage random sampling technique. Farmers' utilization of ICT tools for accessing information on maize production practices was considered as the dependent variable, while selected socio-economic and psychological factors were treated as independent variables.

3. Result and Conclusion

To identify the factors affecting utilization of ICT tools for seeking information about maize practices, linear regression analysis (Table 1) was employed and the findings indicated that possession of Kisan Credit Card ($p=0.00$), perception ($p=0.01$), education level ($p=0.01$) and family type ($p=0.04$) significantly and positively influenced farmers' utilization of ICT tools for maize production. Possession of KCC had the strongest effect, highlighting that financial access enables farmers to adopt digital technologies more effectively. Positive perception and higher education further supported ICT adoption by enhancing awareness, understanding and confidence in using technology. Family type also played a role, as farmers from joint or extended families were better able to share resources and make collective decisions regarding ICT use. The significant constant ($p=0.03$) suggests a baseline level of ICT adoption even in the absence of these predictors. Overall, the findings emphasize that financial resources, knowledge, education and social support are crucial determinants of digital extension adoption in maize farming.

Table 1: Factors affecting utilization of ICT tools for seeking information about maize practices

Model	Unstandardized Coefficients		t	p-value
	B	Std. Error		
(Constant)	10.823	4.929	2.196	0.030
Possession of KCC	3.938	0.853	4.617	0.000
Perception	0.307	0.121	2.527	0.013
Education	0.251	0.096	2.621	0.010
Family type	1.726	0.861	2.006	0.047
R ² =0.32; Adjusted R ² =0.29				

Significant at 5% level of significance

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5.5 Attitude Towards Online Agricultural Education: A Study of Formal and Non-Formal Stakeholders

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Keywords: Agricultural education, E-learning, Formal education, Non-formal education, Stakeholder attitude

1. Background

The rapid digital transformation of education, accelerated by the COVID-19 pandemic, has significantly reshaped agricultural education systems worldwide. Traditionally dependent on field-based and experiential learning, agricultural education faced unique challenges in adapting to online formats. However, the expansion of Information and Communication Technologies (ICTs), Massive Open Online Courses (MOOCs), and digital platforms has created new opportunities for flexible and accessible learning. Attitude plays a critical role in determining the effectiveness of online education, as learners' perceptions directly influence engagement, comprehension, and learning outcomes. In agricultural universities, both formal (degree-based) and non-formal (extension and training-based) education systems coexist, involving multiple stakeholders including students, teachers, participants, and organizers. Understanding their attitudes toward online education is essential for designing effective digital and hybrid learning models. The present study aimed to assess and compare the attitudes of formal and non-formal stakeholders toward online agricultural education at Punjab Agricultural University (PAU), Ludhiana.

2. Material and Methods

The study followed a descriptive research design and was conducted at Punjab Agricultural University, Ludhiana. A total of 400 respondents were selected, comprising: Students (n=150) enrolled in formal agricultural programs; Teachers (n=50) engaged in online formal teaching; Participants (n=150) involved in non-formal agricultural programs; Organizers (n=50) responsible for conducting non-formal programs; Two separate Likert-type attitude scales were developed- one for online formal agricultural education and another for online non-formal agricultural education. The scales were validated through item analysis, and reliability was assessed using Cronbach's alpha. Positive statements were scored on a five-point continuum (5 to 1), and reverse scoring was applied for negative statements. Data were collected through both online and offline questionnaires. Descriptive statistics, including frequency and percentage, were used to analyze overall attitude levels.

3. Results and Conclusion

The findings revealed a generally favorable attitude toward online agricultural education across all stakeholder groups. Among students, 53.33 per cent expressed a favorable attitude toward online formal agricultural education, while 46.66 per cent reported unfavorable perceptions. The average attitude score was 3.51, indicating a moderately positive orientation. Students appreciated flexibility, recorded lectures, and access to digital resources. However, concerns were raised regarding limited practical exposure, reduced peer interaction, unstable internet connectivity, and difficulty concentrating in home environments. Teachers demonstrated a slightly higher favorable attitude (54%), with an average attitude score of 3.235. They valued the flexibility of remote teaching and integration of multimedia tools. Nevertheless, they reported challenges such as reduced student participation, limitations in assessment methods, and the need for enhanced digital

pedagogical training. In the non-formal education category, 52 per cent of participants expressed favorable attitudes toward online learning, with an average score of 3.439. Convenience and reduced travel requirements were major advantages. However, digital literacy gaps, device limitations, and internet affordability emerged as significant constraints. Organizers showed the highest favorable attitude (60%), with an average score of 3.626. They highlighted scalability, cost-effectiveness, and broader outreach as major strengths of online non-formal programs. Despite this optimism, they acknowledged reduced real-time interaction and feedback as limitations. Comparatively, the ranking of favorable attitudes was: Organizers > Teachers > Students > Participants. The results indicate that administrative and delivery stakeholders are more optimistic about online education than learners themselves. While flexibility, accessibility, and digital resource availability contribute to positive attitudes, infrastructural limitations, lack of practical exposure, and digital competency gaps remain critical challenges. The study concludes that online agricultural education holds substantial potential, particularly when integrated into a blended or hybrid framework. For effective implementation, institutions must invest in digital infrastructure, strengthen ICT capacity, train faculty in online pedagogy, and redesign curricula to incorporate experiential learning components. A balanced integration of digital tools with field-based training is essential to sustain quality agricultural education in the evolving digital era.

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5.6 Cultivating Connections: Social Media and the Future of Farmer Communication in Hamirpur District

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Keywords: Agricultural communication, Agricultural information, Digital extension, Farmers, ICT, Social media.

1. Background

Agriculture plays a vital role in India's economy by ensuring food security generating rural employment and contributing to national income. In Himachal Pradesh agriculture is marked by small landholdings diverse cropping patterns and heavy dependence on climate. Despite potential in horticulture and cash crops the state faces challenges such as hilly terrain remote villages scattered settlements and limited infrastructure. These factors restrict farmers' access to markets extension services and timely information. Conventional extension methods are often constrained by manpower and logistical limitations leaving many farmers without updated knowledge and technologies. The spread of smartphones and internet connectivity has created new opportunities for agricultural communication. Social media platforms provide real time access to weather updates market prices government schemes and improved farming practices while encouraging peer learning. The present study in Hamirpur district examines how farmers use social media and its role in strengthening digital agricultural communication.

2. Materials and Methods

The study adopted a descriptive research design to examine patterns of social media utilization among farmers without altering the natural setting. A stratified random sampling technique was used to ensure representation from all six development blocks of Hamirpur district. Each block was treated as a separate stratum and 257 respondents were selected proportionally using Cochran's formula at a 95 percent confidence level. Primary data were collected through structured personal interviews using a pre tested schedule covering demographic profile awareness usage of social media platforms extent of agricultural use and time spent accessing farm information.

3. Results and Conclusion

The findings of the study reveal a high level of social media penetration among farmers in Hamirpur district. Among the various platforms, Facebook emerged as the most widely used platform, with 96.50 per cent of respondents reporting its usage. This high adoption rate may be attributed to its user-friendly interface, availability of regional language content, group formation features and ability to share multimedia information. Facebook groups dedicated to farming activities enable collective discussions, exchange of experiences and access to expert advice, thereby strengthening its role in agricultural communication. WhatsApp was the second most popular platform, used by 87.55 per cent of respondents. Its instant messaging features, low data consumption and ability to share images, videos and voice messages make it particularly suitable for rural users. Farmers frequently use WhatsApp groups to circulate timely information on crop diseases, weather conditions, input availability and government schemes. The platform's immediacy and accessibility contribute significantly to real-time agricultural decision-making. Similarly, YouTube was used by 85.99 per cent of respondents, highlighting the growing importance of video-based learning in agriculture. YouTube serves as a valuable source of demonstrations, tutorials and expert lectures on modern farming techniques, pest management,

livestock care and post-harvest practices. Visual learning through videos is particularly beneficial for farmers with limited formal education, as it enhances understanding and practical application of scientific practices. Moderate adoption was observed for Instagram, indicating a growing but still limited role in agricultural communication. Although Instagram supports visual content sharing, its use for farming-related purposes appears to be evolving. On the other hand, Twitter (X) and LinkedIn recorded minimal usage among farmers. The low adoption of these platforms may be due to limited awareness, perceived irrelevance to practical farming needs, language barriers or unfamiliarity with their professional networking features.

The analysis of the extent of use further indicated that a majority of respondents frequently used Facebook, WhatsApp and YouTube for agricultural purposes. These platforms were accessed regularly for information exchange, advisory services and peer interaction. The mean score analysis of time spent on social media platforms also ranked Facebook highest, followed by YouTube and WhatsApp, confirming their central role in digital agricultural engagement. The overall trend suggests a clear preference for platforms that provide simple interfaces, real-time communication, and multimedia content. Farmers are more inclined toward applications that directly address their immediate informational needs and enable community-based interactions. The relatively lower engagement with professional networking and microblogging platforms highlights a digital divide in terms of advanced or specialized platform usage.

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5.7 A modified performance-based ensemble framework for improved climate projections

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Keywords: Climate impact assessment, CMIP6, Ensemble methodology, Probability of Detection

1. Background

Accurate climate projections are fundamental for impact assessments in agriculture, hydrology, and climate risk management. Although General Circulation Models (GCMs) provide future climate information, individual models exhibit considerable uncertainty due to differences in structure, parameterization, and initialization. Multi-model ensembles are therefore widely used to reduce uncertainty. However, traditional approaches such as simple averaging ignore differences in model skill, while existing performance-based methods rely mainly on statistical indicators like bias, RMSE, and correlation, which do not adequately capture event-level accuracy. To overcome these limitations, this study proposes a modified performance-based ensemble framework that integrates Mean Absolute Error (MAE), Probability of Detection (POD), and Probability of False Detection (POFD) to generate dynamically weighted projections for precipitation, maximum temperature, and minimum temperature.

2. Materials and Methods

Daily gridded observational rainfall ($0.25^\circ \times 0.25^\circ$) and temperature ($1^\circ \times 1^\circ$) data from India Meteorological Department for 1981–2010 were used as reference. CMIP6 downscaled climate projections from CanESM5, MIROC6, and MPI-ESM1-2-HR were obtained from NASA NEX-GDDP for the same baseline period over a selected grid in northwest Delhi (28.75° – 29.0° N; 77.0° – 77.25° E). Systematic biases in GCM outputs were corrected using the quantile mapping technique. Subsequently, three ensemble approaches were evaluated: Equal-weighted ensemble (Ensemble-EqW); Legacy performance-based ensemble using bias, RMSE, and correlation (Ensemble-WO); Proposed modified ensemble (Ensemble-WN) using MAE, POD, and POFD. The modified ensemble assigns higher weights to models with lower MAE and POFD and higher POD, thereby emphasizing both statistical accuracy and event detection capability. Model performance was assessed using RMSE, MAE, POD, and POFD for precipitation, T_{max}, and T_{min}.

3. Results and Conclusion

Quantile mapping substantially improved agreement between modelled and observed climate variables, reducing RMSE across all GCMs. For precipitation, raw RMSE values decreased from 12.62 mm (CanESM5) to approximately 8.3–8.4 mm after bias correction. Similar improvements were observed for T_{max} and T_{min}. All ensemble approaches outperformed individual GCMs. However, the proposed Ensemble-WN consistently showed superior performance. For daily precipitation, RMSE reduced further to 6.88 mm under Ensemble-WN, compared to 6.88 mm and 6.88 mm for Ensemble-EqW and Ensemble-WO, respectively. For T_{max} and T_{min}, Ensemble-WN achieved the lowest RMSE values of 2.871 °C and 2.223 °C. High POD (up to 0.957) and low POFD (as low as 0.057) demonstrated enhanced event detection with minimal false alarms. Bi-metric evaluation revealed that replacing RMSE and correlation with MAE, POD, and POFD improved ensemble responsiveness to climatic events while maintaining statistical robustness. Cumulative error analysis over 30 years showed substantial long-term reductions in daily error magnitude for all variables under Ensemble-WN. It is concluded that the modified ensemble

framework provides statistically reliable and application-relevant climate projections. By integrating error magnitude and event-based indicators, the proposed approach enhances the suitability of ensemble climate data for agricultural modeling, water resource planning, and climate risk assessment.

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5.8 In vitro comparative analysis of growth kinetics of ovine Wharton's jelly and cord blood derived stem cells supplemented with IGF-1

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Keywords: Growth curve, Insulin-like Growth Factor (IGF-1), Mesenchymal stem cells (MSCs), Population Doubling Time (PDT), Wharton's Jelly

1. Background

Stem cells are generally defined as immature cells with self-renewal competencies and the capability of differentiating into other cell types. Stem cells may be differentiated into a wide range of mature cell types. Mesenchymal stem cells (MSCs) are generally considered the main toolbox for cell-based therapies. The umbilical cord has been divided into six regions. We refer to the intervacular stroma as Wharton's jelly. Cell isolation is a painless, non-invasive procedure. Additionally, it has been demonstrated that the cells suppress the immune system and are non-immunogenic. Umbilical Cord Blood (UCB)-MSCs expanded in vitro also retain low immunogenicity and an immunomodulatory effect. Moreover, cells derived from the UCB elicit a lower incidence of graft rejection and post-transplant infections compared with other source. Insulin-like growth factor- I (IGF- I) plays a vital role in various cellular processes, Insulin-like growth factor- I is produced by the liver and other tissues, including the intestine, where it plays an important role in regulating cell growth and nitrogen balance. This study tests IGF-1's role in enhancing ovine fetal WJ- and UCB-MSC proliferation, advancing stem cell tech for climate-resilient agriculture (e.g., veterinary regenerative medicine in harsh environments).

2. Materials and Methods

Ovine gravid uteri (N=3) from slaughterhouses, transported in PBS + antibiotics. Allantoic fluid drained; cord blood isolated via Ficoll centrifugation (LSM-1077). Umbilical cords processed per Babaei *et al.* (2008): vessels stripped, WJ scraped/minced into 1-2 mm³ explants. Passage 3 cells underwent RNA extraction via TRIzol (wash DPBS, add TRIzol/chloroform, centrifuge, isopropanol/ethanol precipitate), quantified by NanoDrop (A260/280 1.9-2.0). cDNA synthesized using RevertAid kit. P3 cells (1×10⁴/well) in 12-well plates, DMEM + 15% FBS±5 ng/ml IGF-1. Viable counts biweekly (12 days). Growth curves plotted; PDT calculated: $PDT = t \log_2 / \log(N_t/N_0)$

3. Results and Conclusion

The present study was conducted in the Division of Veterinary Physiology, FVSc&AH, Shuhama with the objective that Ovine WJ- and UCB-MSCs were successfully isolated, cultured to P3, and characterized per ISCT criteria. IGF-1 (5 ng/ml) enhanced proliferation: UCB-MSCs showed superior growth (higher counts, shorter PDT: 46.34h vs. WJ

Table 1: Growth kinetics of oWJ and cord blood derived MSCs at p3& 5ng/ml IGF-I.

Source	IGF-I (ng/ml)	Time period (days)						
		0	2	4	6	8	10	12
Whar ton's jelly	Control (0)	10000	12017 ^E ±329.00	36217 ^D ±375.00	61150 ^C ±623.00	78600 ^B ±814.00	102967 ^A ±590.00	106667 ^A ±560.00
	5	10000	14233 ^F ±473.00	50167 ^E ±579.00	88208 ^D ±984.00	136750 ^C ±1024.00	145867 ^B ±1026.00	150633 ^A ±460.00
Cord Blood	Control (0)	10000	14083 ^E ±403.00	64050 ^D ±712.00	117417 ^C ±1012.00	213667 ^B ±2108.00	251667 ^A ±3456.00	233417 ^A ±1981
	5	10000	19618 ^F ±750.00	77850 ^E ±832.00	135733 ^D ±960.00	216130 ^C ±1887.00	282167 ^B ±684.00	279983 ^A ±1626.00

Values (Mean±SE) with superscripts (ABCDEFG) in the same row differ significantly (p<0.05)

Table 2: Population Doubling Time (in hours) of oWJ and cord blood derived MSCs after exposure to IGF-I

IGF-I ng/ml	Source	
	Wharton's Jelly	Cord Blood
0	96.22 ^A ±14.02	58.17 ^A ±4.88
5	82.69 ^B ±6.05	46.34 ^B ±4.49

Values with different superscripts (AB) differ significantly at p<0.05

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5.9 Forecasts and Insecticide Calculator for Management of Cotton Sap Feeders

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Keywords: Cotton, Sap feeders, Forecasting model, Weather-based prediction

1. Background

Cotton is one of the most important commercial crops, and effective pest management is essential for sustaining productivity. In the era of Bt cotton, sap-feeding pests such as jassids (*Amrasca biguttula biguttula* Ishida), thrips (*Thrips tabaci* Lindeman), and whiteflies (*Bemisia tabaci* Gennadius) have emerged as major pests causing significant yield losses. Forecasting pest outbreaks and adopting precise insecticide recommendations can help farmers take timely management decisions. Digital tools and decision-support systems play a critical role in strengthening integrated pest management and improving advisory services to farmers.

2. Materials and Methods

Weather-based forecasting models were developed using multiple linear regression analysis for cotton-growing regions of North India, particularly Maharashtra and Gujarat. Historical weather parameters including temperature and rainfall were used as predictors to estimate pest population levels expressed as number per five leaves per plant. An application named Forecasts and Insecticide Calculator was developed using R software. The forecasting module enables users to input weather parameters to generate pest predictions for selected locations and sap feeders for three forecast periods. The insecticide calculator module integrates insecticides with approved label claims and recommended dosages, allowing users to select suitable insecticides for managing one or multiple sap-feeding pests.

3. Results and Conclusion

The developed application provides location-specific forecasts of major cotton sap feeders and assists in selecting appropriate insecticides based on recommended dosages and application technology. The tool supports researchers, extension personnel, and farmers by providing instant predictions and management options. This digital decision-support system facilitates timely and informed pest management strategies, thereby enhancing crop protection practices and promoting sustainable cotton production. The application also contributes to the dissemination of crop protection technologies in line with the objectives of the Digital India initiative.

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5.10 Utilization pattern of Information and Communication Technologies (ICTs) by the farmers in Punjab

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Keywords: Agricultural Information, Communication Technologies, Farmers, Utilization pattern

1. Background

Information and Communication Technology (ICT) includes digital tools such as mobile phones, computers, internet services, GIS, and remote sensing used for collecting, processing, and sharing information efficiently (Shrestha *et al.* 2021). In agriculture, ICT helps bridge the information gap between farmers, researchers, extension workers, and policymakers. It enables farmers to access real-time information on weather, crop management, pests, market prices and government schemes. This improves decision-making, enhances productivity, and promotes better resource utilization and market linkages. Thus, ICT plays a vital role in modernizing agriculture and supporting sustainable agricultural development (Patil *et al.* 2021).

2. Material and Methods

The present study was conducted during the year 2024-2026 in two purposively selected districts of Punjab, namely, Jalandhar (having highest literacy rate) and Tarn Taran (having lowest literacy rate). Further, two blocks were selected randomly from each of the selected districts. From Jalandhar district, Bhogpur and Jalandhar-west were selected. Similarly, from Tarn Taran district, Tarn Taran and Gandiwind blocks were selected. From each of the selected block, 30 farmers were selected randomly. Thus making a total sample size of 120 farmers for the present study. Primary data was collected through personal interview method using well-structured and pre-tested interview schedule.

3. Results and Conclusion

The results indicated that mobile phones/smartphones were the most frequently utilized ICT tools by farmers in both districts for obtaining information on agriculture, with 66.67 per cent respondents in Jalandhar and 63.34 per cent in Tarn Taran using them on daily basis. Television was the second most commonly used ICT tool, where 31.67 per cent farmers in Jalandhar and 30.00 per cent in Tarn Taran used it daily. The findings further revealed that farmers primarily utilized ICTs for obtaining latest agricultural information (75.00% in Jalandhar and 71.67% in Tarn Taran), weather information (66.67% and 61.67%), and market information (63.33% and 66.67%), mainly through smartphones. In contrast, ICT platforms such as e-NAM portal, mKisan SMS portal, PAU website, KVK portal, kiosks, and e-newspapers showed comparatively lower utilization among farmers. The comparative analysis indicated that farmers in Jalandhar district exhibited slightly higher utilization of ICT tools than farmers in Tarn Taran, possibly due to better literacy, awareness, and accessibility of ICT services. Overall, the study concludes that the significant role of smartphones in disseminating agricultural information among farmers.

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5.11 Effect of KGR Tab on Growth, Growth Indices and Yield of Papaya cv. Taiwan

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Keywords: KGR Tab, Potassium nutrition, Growth parameters, Yield attributes

1. Background

Papaya (*Carica papaya* L.) is an important tropical fruit crop known for its high nutritional value and quick economic returns, often producing fruits within 6–12 months after planting. India is the leading producer of papaya with major cultivation in states such as Andhra Pradesh, Gujarat, and Karnataka. Proper nutrient management, particularly potassium fertilization, plays a crucial role in enhancing plant growth, fruit yield, and quality. Potassium is involved in several physiological and biochemical processes including photosynthesis, translocation of assimilates, stress tolerance, and improvement of fruit quality parameters such as total soluble solids and sugar content. Therefore, evaluating potassium-based formulations like KGR Tab for improving papaya growth and productivity is of significant importance.

2. Materials and Methods

A field experiment was conducted during the 2025–26 season at a farmer's field in Simli, Vadodara, on clay loam soil to evaluate the effect of KGR Tab on growth, flowering, yield, and fruit quality of papaya cv. Taiwan. Six-month-old plants were planted at a spacing of 3 × 3 m under drip irrigation. The experiment was laid out in a randomized block design with five treatments and three replications. The treatments included: T1 – Untreated control, T2 – KGR @ 1 tablet/15 L water, T3 – KGR + Pluton @ 1 tablet/15 L water + 750 g/ha, T4 – Legend (FMC) @ 120 g/ha, and T5 – Pluton @ 750 g/ha. Foliar applications were carried out twice at the flowering and fruit-set stages with a 20-day interval. Data on crop vigor, number of flowers, fruits per plant, fruit length, fruit diameter, and yield were recorded and subjected to analysis of variance (ANOVA), and treatment means were compared using LSD at 5% significance.

3. Results and Conclusion

The results indicated that all potassium-based treatments significantly improved crop vigor, number of flowers, fruits per plant, and fruit size compared to the untreated control. The treatment KGR @ 1 tablet/15 L water showed notable improvement in growth and yield parameters, recording higher numbers of fruits per plant (23.33), fruit length (22.33 cm), fruit diameter (45.33 cm), and yield (85.33 kg/plant or 94.81 t/ha) compared with control. The combined treatment of KGR + Pluton showed slightly higher values but the performance of KGR alone was also significantly superior to other treatments. The positive effects may be attributed to the role of potassium in enhancing photosynthesis, assimilate transport, and nutrient balance, leading to better fruit retention and yield. The study demonstrates that foliar application of KGR Tab can effectively enhance growth, yield attributes, and fruit quality of papaya cv. Taiwan, making it a promising nutrient management option for papaya cultivation.

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5.12 Advancing Climate-Resilient Agriculture in Bihar: Addressing Field-Level Gaps and Scaling Policy Innovations

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Keywords: Capacity, Climate-Resilience, Extension, Gaps, Scaling

1. Background

Agriculture in India is profoundly affected by the changing climate, confronting severe challenges such as shifting rainfall patterns, prolonged droughts, and extreme hydro-meteorological events. The state of Bihar is uniquely vulnerable within this context; its primarily agrarian economy is under immense stress due to frequent floods, heatwaves, and declining soil fertility. A district-level climate vulnerability assessment reveals that 21 out of Bihar's 37 districts are categorized as having 'Very High' or 'High' vulnerability to climate change (Mohanty and Wadhawan 2021). Historical data indicates that 81 percent of Bihar's districts are affected by floods and 70 percent are affected by droughts (Mohanty and Wadhawan 2021). To combat these threats, the state prioritized a Climate-Resilient Agriculture (CRA) programme, which was launched in 2019 and scaled to all 38 districts by 2020 (Department of Agriculture, Government of Bihar 2023). However, the adoption of innovative practices, such as zero-tillage farming and direct-seeded rice, remains largely pilot-driven and fragmented. Scaling these grassroots innovations demands a critical assessment of the on-the-ground challenges faced by farmers and the subsequent enactment of targeted policy reforms. This paper assesses the institutional capacity gaps in Bihar's CRA implementation and outlines the pivotal policy and partnership recommendations required to sustainably scale up these agricultural practices.

2. Material and Methods

This study adopts a qualitative research methodology to assess institutional capacities, blending action research with a case study method to provide a bottom-up analysis of CRA adoption. To measure the state's capability to deliver on climate goals, a Capacity Assessment Framework (CAF) was utilized, evaluating eight primary indicators: vision mandates and priorities, planning and implementation, monitoring and evaluation, collaboration and coordination, information dissemination, financing, human resource capacity, and research and development.

Primary data was collected to capture field-level realities, in-depth interviews and focus-group discussions were conducted with 81 farmers and local officials. The field sites were purposively selected from three major agro climatic zones in Bihar, specifically the districts of Darbhanga, Madhubani, Bhagalpur, and Banka, to encompass diverse topographic vulnerabilities, including both flood-prone northern plains and drought-prone southern plains.

3. Results and Conclusion

The capacity assessment revealed critical bottlenecks and field-level gaps that hinder the scaling of innovative CRA practices.

Human Resource and Extension Gaps: State-level survey respondents and field observations identified a severe deficit of skilled human resources at the local level (Mohanty and Wadhawan 2021). The local extension ecosystem is heavily overburdened. For instance, a single Krishi Vigyan Kendra (KVK) is often responsible for an entire district with a staff of just four scientists, limiting

their ability to perform field trials, demonstrations, and capacity building at scale.

Market and Financial Disconnects: Farmers in the field highlighted significant challenges regarding post-harvest value chains. Inefficiencies within the Progressive Agriculture Cooperative Society (PACS) system, such as delayed payments and poor bargaining power, prevent farmers from discovering fair prices for their climate-resilient produce.

Policy Exclusion and Gender Gaps: A major policy limitation identified is the CRA program's narrow focus on targeting "CRA-adopting farmers," who are typically male landowners. This approach inadvertently ignores the broader household dynamic and marginalizes women, who largely manage allied agricultural activities like livestock rearing. By excluding these allied activities from CRA support networks, the policy fails to protect the household's supplementary buffer income, which ultimately reduces the farming family's risk appetite to sustain technological transitions.

To overcome these barriers and scale up innovations, this paper proposes the following targeted policy reforms:

1. **Redefining Policy Beneficiaries:** Policies must transition from targeting individual farmers to targeting 'CRA-adopting families'.
2. **Deploying Thematic Human Resources:** Scaling innovations requires specialized local support. Policy reforms must mandate the deployment of block-level thematic human resources, specifically climate data analysts, agribusiness development officers, and dedicated MRO staff for CRA-related machinery.
3. **Formalizing Non-State Partnerships:** The state cannot scale CRA in isolation. Policies must formalize consortiums of non-state actors (CSOs, the private sector, and research bodies) to fill capacity gaps in agricultural extension.

Scaling climate-resilient agriculture in Bihar demands a departure from pilot-centric models that suffer from severe local capacity constraints. True scalability relies on enacting inclusive policies that empower the entire farming household, overhauling the local human resource and extension architectures, and forging strategic partnerships with non-state innovators to bridge persistent technical and financial gaps.

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5.13 Effect of foliar application of nitrogenous fertilizers using drone and knapsack in wheat crop

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Keywords: Drone, precision, sprayers, smart agriculture, wheat.

1. Background

Wheat (*Triticum aestivum* L.) is a major cereal crop essential for global food security, with increasing demand projected to reach 140 million tonnes in India by 2050. Nitrogen (N) is a critical nutrient influencing plant growth, chlorophyll formation, and yield, but conventional fertilizers suffer from low nutrient use efficiency (30–40%) and significant losses through leaching and volatilization (Upadhyay *et al.*, 2023). Recent advancements in precision agriculture, especially drone (UAV) technology, enable efficient, uniform, and targeted fertilizer application while reducing labour and water use. Studies show drone spraying can achieve similar yield and crop response compared to conventional methods while saving up to 95% water. Foliar spray plays a pivotal role in modern agriculture by offering an efficient method to supplement soil-applied fertilizers. This technique facilitates quick nutrient uptake through leaves, enabling timely correction of deficiencies and boosting overall plant vigour.

2. Material and Methods

A field study was undertaken at ICAR-Indian Agricultural Research Institute, New Delhi to see the effect of spraying using drone and knapsack sprayer in wheat crop. In addition to the control, the treatments contained two foliar sprays of different nitrogenous fertilizers (nano urea, prilled urea and nano DAP) and 50% & 75% of the recommended dose of nitrogen (RDN, 150 kg/ ha). Two foliar sprays of these fertilizers were applied during crucial growth stages of nitrogen need i.e. the tillering and jointing stages using drone-based sprayer and knapsack sprayer to assess their impact on wheat growth and yield. Multispectral vegetation indices were calculated and their thematic maps were generated from the drone-based multispectral imagery to study the effect of sprayer type and different nitrogenous fertilizer sources.

3. Results and Conclusions

After the first spraying, there was a noticeable increase in NDVI and LCI particularly in treatments with drone spraying, which suggests improved plant vigor and chlorophyll content. The second spraying further enhanced NDVI and LCI values, with the highest readings observed in treatments combining 75% RDN+ 2 foliar sprays of nano-urea, prilled urea and nano-DAP. This progression underscores the effectiveness of foliar sprays using drones in enhancing vegetation density and health over time. The yield was found higher in treatment sprayed with drone 75% RDN +2 foliar spray of Nano-DAP.

Nano fertilizers (Nano Urea and Nano DAP) significantly enhance growth, yield, and nitrogen use efficiency in wheat. Drone spraying is an effective alternative to knapsack spraying in terms of uniformity. Integration of nano fertilizers with drone technology can reduce nitrogen input without

compromising yield, supporting sustainable agriculture. The use of drones also leads to a substantial reduction in labour, outperforming both knapsack and boom sprayers. Drone technology can decrease labour requirements by as much as 85% compared to traditional hand methods. (Hiremath *et al.*, 2024).

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5.14 Spatial estimation of Banana crop evapotranspiration using the EEFlux energy balance model

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Keywords: Banana, Evapotranspiration, EEFlux, Remote sensing, Soil moisture probe.

1. Background

Evapotranspiration (ET) is a crucial component of the hydrological cycle and significantly influences crop water requirements and irrigation scheduling. Accurate estimation of ET is essential for optimizing water use efficiency, particularly in water-intensive crops like bananas (*Musa spp.*). Banana cultivation necessitates a consistent water supply throughout its growth cycle, and improper irrigation management can result in reduced productivity and inefficient water resource utilization. Conventional methods for estimating crop evapotranspiration, such as lysimeter measurements and the FAO Penman–Monteith method, necessitate extensive meteorological data and field measurements. However, these methods may not adequately capture spatial variability in crop water use across agricultural fields. Remote sensing techniques have emerged as effective tools for estimating evapotranspiration at field and regional scales. The EEFlux (Earth Engine Evapotranspiration Flux) model, based on the METRIC algorithm and implemented on the Google Earth Engine platform, utilizes Landsat satellite imagery to estimate actual evapotranspiration (ET_a) through surface energy balance calculations. This approach enables spatial mapping of evapotranspiration and provides valuable information for irrigation management. Consequently, the present study aimed to estimate the evapotranspiration of bananas using the EEFlux model in the Tiruchirappalli district of Tamil Nadu and validate the estimates using ground-based soil moisture probe observations.

2. Materials and Methods

The study was conducted in a banana cultivation area located in Tiruchirappalli district, Tamil Nadu, India. Satellite imagery from Landsat was processed using the EEFlux platform available through Google Earth Engine to estimate actual evapotranspiration. The EEFlux model employs the METRIC (Mapping Evapotranspiration at High Resolution with Internalized Calibration) algorithm, which calculates evapotranspiration based on the surface energy balance approach. The model estimates evapotranspiration using satellite-derived parameters, including land surface temperature, vegetation indices, albedo, and net radiation. These parameters are integrated with meteorological data such as air temperature, solar radiation, humidity, and wind speed to compute energy balance components, including soil heat flux, sensible heat flux, and latent heat flux. The latent heat flux is subsequently converted to actual evapotranspiration values. To validate the satellite-based estimates, ground truth observations were collected using a soil moisture probe installed in the banana field. Soil moisture data were recorded periodically to assess soil water dynamics and compare them with evapotranspiration patterns estimated from EEFlux. The spatial distribution of evapotranspiration across the study area was analyzed to identify variations related to crop growth conditions and soil moisture availability.

3. Results and Conclusion

The EEFlux model successfully generated spatial maps of evapotranspiration for banana fields

in the Tiruchirappalli district. The estimated evapotranspiration values varied across the study area based on crop growth stage, canopy density and soil moisture conditions. Higher evapotranspiration rates were observed in well-irrigated areas with dense banana canopy, while relatively lower values were recorded in areas with lower vegetation cover or reduced soil moisture. The comparison between EEFlux-derived evapotranspiration and soil moisture probe observations indicated a consistent relationship between soil water availability and evapotranspiration patterns. The ground truth measurements helped validate the reliability of remote sensing-based ET estimation. The results demonstrate that the EEFlux model is an effective tool for estimating evapotranspiration in banana cultivation and can support improved irrigation management and water use efficiency. The study highlights the potential of integrating satellite-based evapotranspiration estimation with ground-based soil moisture monitoring to enhance irrigation scheduling and sustainable water management in banana-growing regions.

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5.15 Impact of Climate Variability on Apple Scab Infection Dynamics in Temperate Himalayan Regions

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Keywords: Apple scab; *Venturia inaequalis*; climate variability; infection dynamics; Ascospore release; disease forecasting

1. Background

Apple (*Malus domestica*) is one of the most important fruit crops grown in the Himalayan region of India, especially in Jammu and Kashmir, where Horticulture economy of whole state is dependent on Apple. However, apple production in this region is heavily affected by apple scab, a disease caused by *Venturia inaequalis*, which is widely recognized as one of the most damaging diseases of apple worldwide. The development of this disease is closely linked to environmental conditions such as temperature, rainfall, humidity, and the duration of leaf wetness. With changing climate patterns, these factors are becoming more variable, making it increasingly important to understand how climate influences disease outbreaks. With this, this study aims to investigate how climate variability affects apple scab infection dynamics in Kashmir Region

2. Material and Methods

This study was carried out in apple orchards located at experimental sites of SKUAST Shalimar. The hourly weather data was collected on temperature, rainfall, relative humidity, leaf wetness, and wind parameters, allowing us to capture the microclimatic conditions within apple orchards. Additionally data on ascospore activity was also recorded from 2024 to 2025. The data is further statistically analyzed to identify periods when environmental conditions were favourable for infection and examined how different climatic factors influenced disease development. Statistical methods were used to explore relationships between weather variables and ascospore activity, which is a key indicator of infection risk.

3. Results and Conclusion

From the results it is revealed that the Infection risk generally began in late February to early March, as temperatures gradually increased and moisture became available after winter. The risk rose quickly during March and reached its peak between late March and mid-April. This critical period was characterized by moderate temperatures (around 10–15°C), frequent rainfall events, and prolonged leaf wetness, creating highly favourable conditions for disease development. The highest ascospore activity was observed during mid-April (Weeks 15–16), with peak counts of 28 spores in 2024 and 30 spores in 2025. Among all climatic factors, rainfall emerged as the most important driver of infection, showing a strong positive relationship with ascospore activity. Rainfall events not only triggered spore release but also resulted in extended leaf wetness periods, sometimes lasting from 10 to 100 hours, which significantly increased the likelihood of infection. Although temperature was not the primary trigger, it played an important role in determining how efficiently infections occurred, with the most favourable range being 10–18°C, where shorter wetness durations were sufficient for infection. Relative humidity also contributed by maintaining moist conditions, although its effect was less pronounced compared to rainfall. The study further highlighted noticeable year-to-year variations, reflecting the influence of climate variability. For instance, in 2025, infection began slightly earlier and persisted longer than in 2024 due to more favourable spring weather conditions.

These findings underline the importance of identifying critical infection periods, particularly between late March and mid-April, which consistently showed the highest risk. Focusing disease management efforts during this window can greatly improve control efficiency. Overall, the study demonstrates that apple scab dynamics in the Himalayan region are strongly influenced by climatic factors, especially rainfall and temperature, and emphasizes the value of weather-based forecasting systems for timely, efficient, and sustainable disease management.

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5.16 Estimating the Energy Rebound Effect in Indian Industries

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Keywords: Energy Efficiency, Rebound Effect, Sustainable Development

1. Background

Improving energy efficiency in the context of sustainable economic growth is essential in the current global energy scenario, but its efficacy is limited by growing energy demand and a heavy reliance on fossil fuels, which account for about 84.65% of energy supply in India (International Energy Agency, 2025). Improvements in energy efficiency do not always translate into proportionate decreases in energy consumption due to a phenomenon called the rebound effect, which is explained by the Jevons Paradox (Alcott, B. 2005). This is because improvements in efficiency can lower the effective costs of energy services, which raises demand and partially or completely offsets anticipated energy savings. This problem is especially pertinent to developing countries like India, where energy consumption is rising due to factors like infrastructure development, industrial growth and cooling needs. There is currently a dearth of research on rebound effects in India, which frequently relies on crude price elasticity methods that overlook sectoral diversity and actual engineering efficiency. Also, decoupling economic growth from energy consumption is a critical step towards achieving Sustainable Development Goal (SDG) 7.3. Therefore, two major research questions were addressed in this study, first, how to accurately estimate the true energy efficiency of Indian industries and second, which industries show notable rebound effects.

2. Material and Methods

The study uses panel data from the Annual Survey of Industries (ASI) for the period 2008–09 to 2023–24, incorporating variables such as capital, labour, output, and detailed energy consumption across multiple fuels. Industries are grouped into homogeneous cohorts based on 3-digit NIC classification, state and year of initial production to control for technological and regional heterogeneity. The analysis employs Panel Data Stochastic Frontier Analysis (SFA) with a time-varying decay specification to estimate technical efficiency, followed by a Two-Way Fixed Effects (TWFE) model to estimate rebound effects through the elasticity of energy demand with respect to effective energy prices, controlling for output, capital-labour ratio and fixed effects.

3. Results and Conclusion

The results show strong sectoral variation in rebound effects. Industries such as auto trade and repair (200.21%), pharmaceuticals (110.17%), and furniture manufacturing (83.13%) exhibit backfire, where efficiency improvements increase energy consumption. In contrast, sectors such as waste management, water supply, and petroleum products demonstrate negative rebound effects, implying net energy savings. The findings indicate that low-efficiency, low-rebound sectors need technology subsidies; high-efficiency, low-rebound sectors need expansion incentives; low-efficiency, high-rebound sectors require conditional technology updates with strict policy terms; and high-efficiency, high-rebound sectors demand firm policy restrictions. These results indicate that effective energy policy must move beyond technological efficiency and incorporate mechanisms to control total energy use. Policy recommendations include setting absolute energy caps, implementing rebound-sensitive taxation, reallocating subsidies toward net-saving industries, linking financial incentives to actual energy reduction and meeting new energy demands with

renewable sources. A coordinated approach involving government, industry and financial systems is essential to align energy efficiency with sustainable development goals.

Table 1: Estimated Energy Rebound Effects across Industrial Sectors in India

S.No.	Industry Name (NIC 2008)	Sector Type	Rebound Percentage	S.No.	Industry Name (NIC 2008)	Sector Type	Rebound Percentage
1	Auto Trade & Repair	Commercial / Services	200.21*	18	Electronics & Optics	Manufacturing	38.23***
2	Pharmaceuticals	Manufacturing	110.17**	19	Fabricated Metals	Manufacturing	35.5***
3	Furniture Manufacturing	Manufacturing	83.13***	20	Food Manufacturing	Manufacturing	31.74***
4	Chemicals	Manufacturing	69.44***	21	Publishing	Services	28.44***
5	Other Manufacturing	Manufacturing	63.69***	22	Agriculture & Hunting	Agriculture / Allied	25.54***
6	Equipment Repair	Manufacturing	60.66***	23	Wood Products	Manufacturing	24.59***
7	Textile Manufacturing	Manufacturing	60.24***	24	Warehousing & Logistics	Logistics / Services	24.07***
8	Machinery & Equipment	Manufacturing	59.72***	25	Leather Products	Manufacturing	19.78***
9	Rubber & Plastics	Manufacturing	58.29***	26	Professional & Tech Services	Services	10.79***
10	Paper Products	Manufacturing	55.33***	27	Tobacco Manufacturing	Manufacturing	5.54***
11	Printing & Media	Manufacturing	53.7***	28	Mining & Quarrying	Mining	0.68***
12	Basic Metals	Manufacturing	52.21***	29	Power & Utilities	Utilities / Energy	-2.34***
13	Beverage Manufacturing	Manufacturing	51.54***	30	Office & Business Support	Services	-2.36***
14	Non-Metallic Minerals	Manufacturing	49.83***	31	Water Supply	Utilities	-10.35***
15	Motor Vehicles	Manufacturing	46.73***	32	Petroleum Products	Manufacturing	-10.95***
16	Other Transport	Manufacturing	45.46***	33	Waste Management	Utilities / Waste	-24.09***
17	Electrical Equipment	Manufacturing	45.32***				

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5.17 Promoting Digitization for Sustainable Agriculture

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Keywords: Digitization, Sustainable, Relevant, Timely

1. Background

Digitization in the present era holds the key to bring in sustainability, profitability and empowerment of the farming community. The shortage of extension functionaries has also forced the policy makers and planners to focus more on digitization. Digitalization of Agriculture and the use of ICTs hold great potential in dissemination of relevant and timely information to the farming community as well as providing feedback of the farmers to the extension system.

2. Material & Methods

The government has also launched various apps and different programmes aimed at increasing the efficacy of extension delivery mechanism through digital means. Various mobile apps catering to the diverse needs of farming community have been developed by different ministries of Government of India, Indian Council of Agricultural Research (ICAR), Agricultural Universities, various individuals and entrepreneurs. Some of them include Kisan Suvidha, Pusa Krishi, Plantix, IFFCO Kisan, PMKISAN, Poultry Manager, Crop Insurance, Agri-Media Video, Feed calculator, Farm Bee and various other related apps. Similarly, the use of robotics and precision farming with the help of sensors have also enhanced the productivity by ensuring timely farming operations and precise supply of inputs to crops. The provision of weather related advisories help in providing real time information about different weather parameters which help the farmers to plan their farming operations accordingly well in advance of time. In the present era of climate change when Studies on Information and Communication Technology (ICT) in agriculture demonstrate that digital tools- IoT, AI, and mobile apps- significantly increase crop yields, enhance sustainability, and improve income by connecting farmers to markets. Key benefits include real-time weather data, improved financial services, and reduced reliance on middlemen. Mobile phones serve as a two-way communication mode and provide access to the information service even in the fields (Mittal and Tripathi, 2009). Casaburi *et al.* (2014) reported that sending SMS messages with agricultural advice to smallholder farmers increased yields by 11.5 per cent relative to a control group with no messages. The use of ICT tools in farming have revealed that IoT, sensors, and farm management software improve resource efficiency (water and fertilizers), boosting profitability. Research also shows that ICT adoption, such as mobile phone use, can lead to a 21% increase in income for rural farmers by providing better market access.

3. Result and Conclusion

The use of Digital tools has so many benefits in agriculture but its full scale adoption also has many challenges. Lack of reliable internet and electricity in rural areas remains a significant challenge in timely dissemination of information to farming community. The extension functionaries also do not have updated their knowledge about different digital tools and technologies. Their capacity building represents another challenge. Another challenge is the relevant content. In this era of information overload, seeking information from a reliable and credible source is also another big issue. It can be concluded that Digital technologies provide critical access to the knowledge, information and technology that farmers require to improve the

productivity and thus improve the quality of their lives and livelihoods. (Nandeesh, 2016).

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Theme 6:

Integrating Indigenous Knowledge and Innovative Extension Services for Climate Resilience



6.1 Knowledge and Adoption of Indigenous Fodder and Grain Storage Structures in the Hilly Regions of Doda

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Keywords: Indigenous knowledge, Adoption behaviour, Mountain agriculture

1. Background

Indigenous knowledge systems play a crucial role in sustaining agriculture and natural resource management in rural communities. Developed through long-term interaction with local environments, these practices provide location-specific solutions for food, fodder and resource conservation. Traditional agricultural technologies based on indigenous knowledge contribute to food security, biodiversity conservation and climate resilience, particularly in ecologically fragile regions (Suri, S. 2025).

In mountain farming systems, indigenous storage structures have historically been used to preserve fodder and grains under harsh climatic conditions (Lamichaney, A., *et al.* 2019). However, modernization, changing livelihoods and declining livestock rearing have resulted in a gradual decline in the use of such traditional practices. Despite this decline, some farmers still retain knowledge and continue to practice these indigenous technologies. Understanding the knowledge and adoption status of traditional storage structures such as *Taye*, *Kundu* and *Kothar* is therefore essential for promoting climate-resilient agricultural practices in hilly regions.

2. Materials and Methods

The study was conducted during 2025–26 in selected villages of Bhalla block of Doda district, Jammu and Kashmir, where indigenous storage structures such as *Taye*, *Kundu* and *Kothar* are traditionally practiced. A total of 60 farmers were selected using simple random sampling from three villages. Primary data were collected through semi-structured interviews, field observations and participatory discussions with farmers possessing knowledge of these storage structures.

Respondents were categorized into three groups based on their knowledge and adoption status: (i) farmers having knowledge and currently practicing indigenous storage structures, (ii) farmers having knowledge but not practicing them at present and (iii) farmers having no knowledge about these traditional technologies. Information related to socio-economic characteristics such as age, education, farming experience and livestock holding was also collected.

The collected data were analysed using descriptive statistics and multinomial logistic regression analysis to identify the factors influencing farmers' knowledge and adoption behaviour regarding indigenous storage structures.

3. Results and Conclusion

The study revealed varying levels of knowledge and adoption of indigenous storage structures among farmers in the study area. Out of the total respondents, 38.3% possessed knowledge and were actively using indigenous structures such as *Taye*, *Kundu* and *Kothar* for storing fodder and grains. About 40.0% of farmers had knowledge but had discontinued their use, mainly due to declining livestock numbers, labour constraints and increasing preference for modern storage alternatives. Meanwhile, 21.7% of respondents reported having no knowledge of these traditional storage technologies, particularly among younger farmers.

Multinomial logistic regression analysis indicated that age and livestock holding significantly influenced the likelihood of adoption of indigenous storage structures ($p < 0.05$). Older farmers and those with larger livestock holdings were more likely to retain and practice these traditional techniques, whereas younger and more educated farmers tended to shift toward modern methods.

The findings highlighted that although indigenous storage practices remain cost-effective, climate-resilient and locally adapted, their continued use is gradually declining due to generational shifts and socio-economic changes. Strengthening extension efforts, awareness programmes and documentation of indigenous knowledge can play a crucial role in preserving these traditional technologies and integrating them with modern agricultural systems for sustainable mountain farming.

Table 1: Multinomial logistic regression analysis of factors influencing knowledge and adoption of indigenous storage structures

Variable	Coefficient (β)	Standard Error	Wald value	p-value
Age	0.42	0.18	5.41	0.020*
Education	-0.31	0.14	4.67	0.031*
Livestock holding	0.37	0.16	5.02	0.025*
Farming experience	0.29	0.17	2.91	0.088

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6.2 Validation of Indigenous and Eco-Friendly Management Practices for Red Pumpkin Beetle, *Aulacophora foveicollis* L. on Bottle Gourd

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Keywords: *Beauveria bassiana*, Bottle gourd, Dung ash, Integrated pest management, Red pumpkin beetle

1. Background

Red pumpkin beetle (*Aulacophora foveicollis*) is one of the most destructive pests of bottle gourd, causing severe damage at early and later crop stages (Khan *et al.*, 2012). Excessive reliance on chemical insecticides has resulted in environmental concerns, resistance development, and health hazards. Indigenous and eco-friendly pest management practices such as ash application and biological control have long been used by farmers but lack scientific validation. Integrating traditional knowledge with modern pest management approaches is essential for developing climate-resilient and sustainable crop protection strategies (Chandi *et al.*, 2022). Therefore, the present study aimed to evaluate indigenous, biological, and need-based chemical practices for managing red pumpkin beetle under field conditions was planned.

2. Materials and Methods

A field experiment was conducted during *kharif* 2024 at CCS Haryana Agricultural University, Hisar, using bottle gourd variety GH-22. Eight treatments comprising indigenous practices (dung ash, rice husk ash), biological agents (*Beauveria bassiana* and *Metarhizium anisopliae*), botanical insecticide (azadirachtin), chemical insecticides (Cyantraniliprole 10.26 OD, Cypermethrin 10 EC), and an untreated control were evaluated in a randomized block design with three replications. Two applications were given at a 15-day interval. Beetle population was recorded before treatment and at 1, 3, 7, and 10 days after application. Fruit yield and benefit-cost ratio (B:C) were computed.

3. Results and Conclusion

All treatments resulted in significant reduction of red pumpkin beetle population compared to the untreated control. Among indigenous practices, dung ash recorded a mean reduction of 64.05%, followed by rice husk ash with 58.73% reduction in beetle population. The biological agent *Beauveria bassiana* showed a gradual but sustained effect with 46.41% mean reduction, indicating its suitability for long-term pest suppression. Chemical treatments showed higher immediate efficacy; however, indigenous and biological treatments significantly improved fruit yield over control. Economic analysis revealed that eco-friendly treatments provided favourable benefit–cost ratios compared to the untreated control, demonstrating their economic feasibility along with environmental safety. Indigenous practices, due to low input cost and local availability, proved particularly suitable for small and marginal farmers. The study scientifically validates indigenous practices such as dung ash and rice husk ash as effective, economical, and environmentally safe options for managing red pumpkin beetle in bottle gourd. Although chemical insecticides recorded higher immediate pest suppression, indigenous and biological treatments offered sustainable control with favourable B:C ratios and minimal ecological risk. Integration of these eco-friendly practices into extension programmes can promote climate-resilient, low-cost, and farmer-friendly pest management strategies in vegetable production systems.

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6.3 Awareness and Content Preference of Farmers about Weather Based Agromet-Advisory Services in Jammu District of J&K, India

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Keywords: Agromet-advisory services, Awareness, Content preference

1. Background

The study was designed to investigate the awareness and content preference of farmers towards weather based agromet advisory services (AAS) in Jammu district of Union Territory of J&K. AAS disseminated by Agro-meteorological Field Unit (AMFU) Centre of SKUAST-Jammu in collaboration with IMD, New Delhi has started issuing quantitative district level medium range weather forecast up to 5 days from 1st June, 2008. The products comprise quantitative forecasts for 7 weather parameters *viz.*, rainfall, maximum and minimum temperatures, wind speed and direction, relative humidity and cloudiness, besides weekly cumulative rainfall forecast that help farmers in reaping the benevolent effects and has a profound influence on the growth, development and yield, incidence of pests and diseases, water needs, fertilizer requirements and cultural operations in crops (Ray *et al.*, 2017). The agromet-advisory bulletins (AAB) are issued biweekly on every Tuesday and Friday at block level for major crops grown in the area. The bulletin is provided in English and regional language and disseminated through Meghdoot app, WhatsApp, newspapers, short message services (SMS) through state agricultural department, research stations, GKMS and web portals.

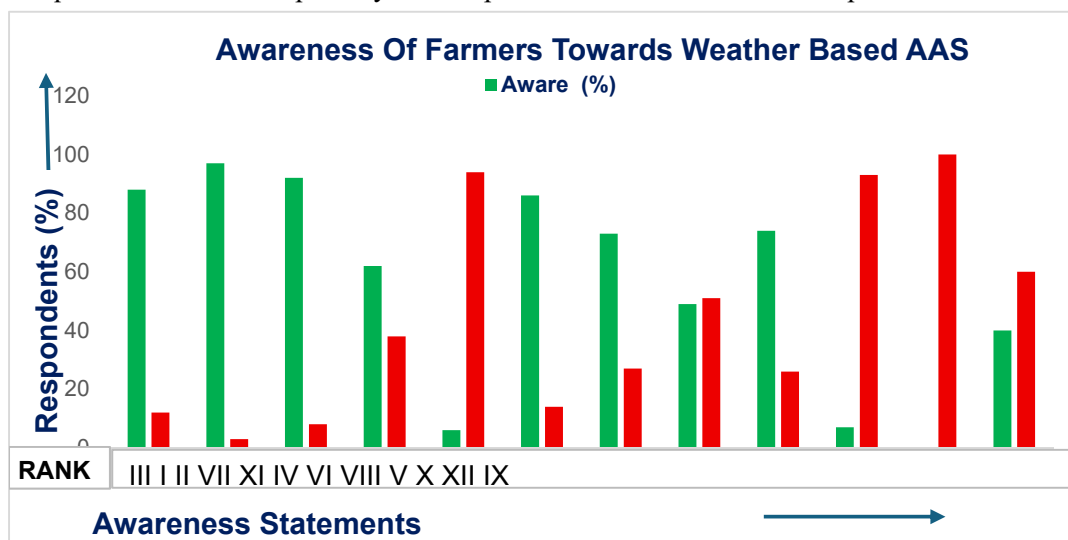
2. Material and Methods

The study was conducted purposively in Jammu district of Union Territory (UT) of J&K in year 2022 because maximum numbers of farmers were registered under the weather based AAS in the district. A list of 576 registered AAS farmers were procured from the Agro-meteorological Field Unit (AMFU) Centre, SKUAST-Jammu, Chatha. From the available list, 100 number of AAS farmers were selected by using simple random sampling technique. Post-test only control group design was employed for the study. The awareness of beneficiary farmers towards AAS was assessed via 12 dichotomous statements measured by Aware and Not Aware and content preference was assessed in the same schedule through a set of nominal-scale items and the distribution of responses was summarized in terms of frequencies and percentages.

3. Results and Conclusion

In agricultural extension research, farmer awareness serves as the initial stage in the Diffusion of Innovations (Rogers, 1962) pivotal for agromet-advisory service (AAS). Extension outreach proved robust in core deliverables and the results reveal that 97 % of the respondents were aware of communication channels (Rank I) followed by 92 % of biweekly dissemination (Rank II), 88 % confirming local provisioning (Rank III) and 86 % recognizing utility in crop/allied enterprises (Rank IV). Moderate awareness spanned multi-channel strategies *viz.* 74 % identified newspapers, AIR and Doordarshan (Rank V). 73 % noted multilingual AABs in Urdu, Hindi and English (Rank VI), 69 % acknowledged SKUAST-Jammu SMS services, 62 % grasped biotic/abiotic stress

indicators and 40 % knew of departmental dissemination. However, laggards in technical/digital tools persisted, only seven per cent were aware of skuast.org /imdagrmet.gov.in website uploads signifying digital literacy gap. Six per cent were aware of AAS generation protocols due to infrequent AMFU visits paid by the respondents and none of the respondents were alert of



Meghdoot app (Rank XII), henceforth, underscoring the needs for targeted extension interventions like farmer field schools, ICT training and reinforced demonstrations to accelerate knowledge transfer and foster climate-smart practices in Jammu's agrarian landscape (Fig. 1).

Furthermore, in the Diffusion of Innovations (DOI) framework (Rogers, 1962), farmers' content preferences for weather-based AAS critically shape the persuasion and decision stages by enhancing perceived relative advantage and compatibility among surveyed farmers. Language preference favoured Hindi (58 %) for cultural compatibility over English (30%), Dogri (7%) and Urdu (5%). Message modes stressed multi-sensory delivery *i.e.*, text with audio (61%) for better observability ahead of text-only (32%), audio-video (7%) and none for voice-only. Brevity boosted trialability with 89% preferring ≤ 150 words of text followed by lesser percentages of 9% (151-300) and 2% (301-450) thereby rejecting longer formats. Channels emphasized WhatsApp (92%) for low complexity and rapid diffusion over SMS (8%), shunning Meghdoot, email and other Apps for the dissemination. Frequency retained biweekly (84%) for reduced complexity, with 10% weekly, 3% fortnightly, 2% daily, 1% occasional and none monthly. Flexible timing (83% anytime) further eased adoption. These DOI- aligned preferences advocate concise, Hindi-WhatsApp multi-media AAS to accelerate technology dissemination in climate-vulnerable extension systems.

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6.4 Indigenous Agricultural Practices in Finger Millet (*Eleusine coracana* (L.) Gaertn.) Cultivation: Rationality and Adoption among Tribal Farmers of Tamil Nadu

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Keywords: Finger millet, Indigenous agricultural practices, Rationality, Adoption, Tribal farmers

1. Background

Finger millet (*Eleusine coracana* (L.) Gaertn.) is an important traditional millet crop cultivated in rainfed and hill ecosystems of India. The crop is highly valued for its nutritional quality, adaptability to marginal environments and resilience to climatic stress. Tribal communities inhabiting the Kolli Hills of Namakkal district in Tamil Nadu possess rich indigenous knowledge related to finger millet cultivation developed through generations of experience. Indigenous Tribal Agricultural Practices (ITAPs) play an important role in sustaining agricultural productivity in fragile hill ecosystems. However, many of these practices remain undocumented and their scientific rationality is seldom assessed. Therefore, the present study was undertaken to examine the rationality and adoption of indigenous agricultural practices followed by tribal farmers in finger millet cultivation.

2. Materials and Methods

The study was conducted in Kolli Hills of Namakkal district, Tamil Nadu. Seven clusters of villages namely Ariyur Nadu, Bail Nadu, Gudini Nadu, Gundur Nadu, Selur Nadu, Thinnanur Nadu and Valappur Nadu were selected for the study. In the first phase, 140 experienced farmers were contacted through informal interviews to document indigenous practices associated with finger millet cultivation. Information was also obtained from secondary sources such as the M. S. Swaminathan Research Foundation and the State Department of Agriculture. A total of 32 indigenous practices were documented. After eliminating cluster-specific practices, 16 ITAPs were selected for further analysis. The rationality of these practices was assessed by 50 scientists using a four-point continuum scale. Practices with a mean score of 2.5 and above were considered rational. In the next phase, 210 finger millet farmers were selected through proportionate random sampling to determine the extent of adoption of the selected practices using a structured interview schedule.

3. Results and conclusion

Out of the 16 identified Indigenous Tribal Agricultural Practices, 15 practices (93.75%) were found to be rational, while one practice (6.25%) was categorized as irrational. Adoption analysis revealed that 11 practices were adopted by more than 75 per cent of the respondents, while five practices were adopted by 50-75 per cent of the farmers. Higher adoption was observed for practices related to traditional finger millet varieties, mixed farming systems, crop rotation and use of locally available inputs such as cow urine and neem-based products for crop protection. Although one practice related to assessing seed dryness through chewing was considered irrational by scientists, it was widely adopted by farmers based on their experience. Overall adoption of indigenous practices in finger millet cultivation was high, as all practices were adopted by more than 50 per cent of the respondents. The study highlights the importance of indigenous knowledge

in sustaining agricultural production in hill ecosystems and suggests that scientifically validated practices can be integrated with modern technologies to promote sustainable and ecologically resilient farming systems.

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6.5 Role of Indigenous Knowledge in Promoting Climate Resilient Farming in Rural Maharashtra

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Keywords: Climate resilience, Indigenous knowledge, Rural livelihoods, Sustainable agriculture, Traditional farming practices

1. Background

Climate change has emerged as a major challenge affecting agricultural sustainability worldwide. Increasing temperature variability, irregular rainfall patterns, and frequent droughts are significantly affecting agricultural productivity and rural livelihoods, particularly in developing countries where farming systems remain highly climate-dependent. In India, the impacts of climate variability are more pronounced in semi-arid regions that depend heavily on monsoon rainfall and have limited irrigation infrastructure. Agriculture across several parts of Maharashtra frequently faces climatic uncertainties, including erratic rainfall, prolonged dry spells, and recurrent droughts. These conditions pose serious challenges for small and marginal farmers who depend on agriculture for their livelihoods. In response to these challenges, farming communities often rely on locally evolved knowledge systems that have developed over generations of interaction with the natural environment. Indigenous knowledge refers to traditional skills, practices, and experiences developed by local communities through long-term engagement with their ecological surroundings. In agriculture, such knowledge includes practices such as crop diversification, mixed cropping systems, the use of local seed varieties, organic soil fertility management, and traditional water conservation techniques. These practices are generally low-cost, environmentally sustainable, and well-suited to local agro-climatic conditions. Understanding the role of these practices in strengthening farmers' adaptive capacity is therefore important for promoting climate-resilient agriculture.

2. Materials and Methods

The present study adopts an empirical approach to examine indigenous agricultural practices and their contribution to climate resilience in rural farming systems. The study is based primarily on qualitative primary data collected from farmers in selected drought-prone rural areas of Maharashtra. Data were gathered through field observations, semi-structured interviews, and discussions with farming households. A purposive sampling method was used to identify farmers who continue to practice traditional agricultural methods. Information was collected on indigenous farming practices used by farmers to cope with climatic variability, including crop diversification, mixed cropping, the use of traditional seed varieties, organic soil management, and water conservation techniques. In addition to primary data, relevant secondary sources, including research articles, reports, and policy documents on climate-resilient agriculture and indigenous knowledge, were also reviewed. The collected information was analysed using qualitative descriptive methods to understand the role of indigenous knowledge in strengthening climate adaptation strategies among rural farmers.

3. Results and Conclusion

The findings indicate that indigenous knowledge plays an important role in enhancing farmers' capacity to adapt to climatic variability. Farmers adopt several traditional practices to reduce the risks associated with unpredictable rainfall and drought. Crop diversification and mixed

cropping systems are widely practised, enabling farmers to reduce crop failure risks and ensure more stable agricultural production. The use of traditional seed varieties adapted to local climatic conditions also contributes to improved resilience. Farmers rely on organic soil fertility management practices, such as farmyard manure and compost, to maintain soil health and reduce dependence on chemical inputs. Traditional water conservation methods, including farm bunding and small-scale rainwater harvesting, further support sustainable farming in water-scarce environments. The study highlights that indigenous agricultural knowledge provides cost-effective and environmentally sustainable solutions for coping with climate variability. Integrating these traditional practices with modern agricultural extension services and scientific innovations can strengthen climate resilience in rural farming systems. Recognising and promoting indigenous knowledge in agricultural development strategies can contribute to sustainable, climate-resilient farming in vulnerable regions.

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6.6 Maize Growers Adoption of Recommended Cultivation Practices in Kashmir Region of Jammu and & Kashmir

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Keywords: Adoption, Maize growers, Land Preparation and Sowing, Weed and Fertilizer Management, Post-Harvest Management and Value addition

1. Background

Maize (*Zea mays*) is one of the most important food grain crops in world agricultural economy. It is utilized as human food, livestock and poultry feed, raw material for a large number of industrial products and as fodder. It is a staple food in 22 countries, two thirds of the produce is consumed as feed, and a very large number (>3500) products/bye-products can be derived from it. As maize has yield potential far higher than any other cereal, it is referred to as the miracle crop or the 'Queen of Cereals'. The India's maize production for the year 2022-2023 stands at 35.67 million tonnes on the area of 9.9 million hectares. In Kashmir valley, maize cultivation is significant, particularly among tribal communities like the Gujjar and Bakarwal, who rely on it as a staple food. It's grown in various regions, with Anantnag, Baramulla, Budgam and Kupwara, and having the largest areas under maize cultivation. The crop is crucial for their livelihoods and is often grown in hilly terrains and karewas under rain-fed conditions. (ICAR-IMR, 2023)

2. Materials and Methods

The study was conducted in three purposively selected districts namely Budgam, Anantnag, and Baramulla (having maximum area under maize crop) of Kashmir Valley. Further these districts represent all the three regions namely central, south and north of Kashmir valley. From each selected district two subdivisions were selected and from each selected subdivision three zones were selected. The selection followed the non-random sampling method i.e. purposive sampling method having more number of registered growers. From the selected districts, a list of registered maize growers having more than two kanals of land under maize cultivation was prepared in consultation with the respective Chief Agriculture Officers. From that list of maize growers, a proportionate random sample of 298 maize growers (determined by Slovin's formula) in proportion to the total population of maize growers was selected and from each selected district a proportionate random sample through proportionate allocation method was selected covering the total sample size of 298 maize growers. Final selection of the maize growers was done randomly falling under villages of selected zones.

3. Results and Conclusion

The study revealed that nearly half of the maize growers i.e., 46.98 per cent belonged to medium category (9.45 to 19.48) of adoption, 27.52 per cent belonged to low category (< 9.45) of adoption and 25.50 per cent belonged to high category (19.48 & above) of adoption. District wise comparison revealed that from district Budgam majority of the maize growers 41.00 per cent

belonged to medium category (9.45 to 19.48) of adoption, 32.00 per cent belonged to low category (< 9.45) of adoption and 27.00 per cent belonged to high category (19.48 & above) of knowledge. From district Anantnag majority of the maize growers 43.83 per cent belonged to medium category (9.45 to 19.48) of adoption, 30.33 per cent belonged to low category (< 9.45) of adoption and 25.84 per cent belonged to high category (19.48 & above) of adoption. From district Baramulla majority of the maize growers 52.29 per cent belonged to medium category (9.45 to 19.48) of adoption, 25.69 per cent belonged to low category (< 9.45) of adoption and 22.02 per cent belonged to low category (19.48 & above) of adoption.

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6.7 Farmers' Preferences to Varietal Attributes in the Adoption of maize Varieties by Maize Growers in Kashmir Valley of Jammu and Kashmir

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Keywords: Adoption, Maize growers, scientific orientation, varietal attributes, varietal preference

1. Background

Maize (*Zea mays*) is one of the most important food grain crops in world agricultural economy. It is utilized as human food, livestock and poultry feed, raw material for a large number of industrial products and as fodder. It is a staple food in 22 countries, two thirds of the produce is consumed as feed, and a very large number (>3500) products/bye-products can be derived from it. As maize has yield potential far higher than any other cereal, it is referred to as the miracle crop or the 'Queen of Cereals'. The India's maize production for the year 2022-2023 stands at 35.67 million tonnes on the area of 9.9 million hectares. In Kashmir valley, maize cultivation is significant, particularly among tribal communities like the Gujjar and Bakarwal, who rely on it as a staple food. It's grown in various regions, with Anantnag, Baramulla, Budgam and Kupwara, and having the largest areas under maize cultivation. The crop is crucial for their livelihoods and is often grown in hilly terrains and karewas under rain-fed conditions. (ICAR-IMR, 2023).

2. Materials and Methods

The study was conducted in three purposively selected districts namely Budgam, Anantnag, and Baramulla (having maximum area under maize crop) of Kashmir Valley. Further these districts represent all the three regions namely central, south and north of Kashmir valley. From each selected district two subdivisions were selected and from each selected subdivision three zones were selected. The selection followed the non-random sampling method i.e. purposive sampling method having more number of registered growers. From the selected districts, a list of registered maize growers having more than two kanals of land under maize cultivation was prepared in consultation with the respective Chief Agriculture Officers. From that list of maize growers, a proportionate random sample of 298 maize growers (determined by Slovin's formula) in proportion to the total population of maize growers was selected and from each selected district a proportionate random sample through proportionate allocation method was selected covering the total sample size of 298 maize growers. Final selection of the maize growers was done randomly falling under villages of selected zones.

3. Results and Conclusion

Regarding varietal preference by the maize growers, that "cost of variety" was ranked first by the maize growers for selecting any particular variety for cultivation, "grain yield" was ranked second, "taste of the grain" was ranked third, "disease resistance" was ranked fourth, "colour of the grain" was ranked fifth, "drought resistance" was ranked sixth, "short duration maize" was ranked seventh, "trialability" was ranked eighth, "adoption by others" was ranked ninth,

“awareness” was ranked tenth, “fodder yield” was ranked eleventh, and “long duration maize” was ranked twelfth. Further, the attribute having highest weighted mean square was ranked one and so on. The study concluded that “cost of variety” was ranked first by the maize growers for selecting any particular variety for cultivation, which could be because of the fact, that maize growers must be doing market oriented farming, using their farm as a business of buying and selling inputs and outputs. They may be doing maize farming for marketing and selling its products for cash and their goal may be increasing their profits. Market oriented varieties are strongly liked by farmers and are more influenced by markets, prices of produce and the cost of farm inputs. The findings slightly differ from that of Adu *et al* (2021) who concluded that the most preferred trait by farmers was the grain yield of maize variety.

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6.8 Traditional Ghrat (Water Mill) as a Climate-Resilient Indigenous Technology in the Hilly Regions of Jammu and Kashmir

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Keywords: Indigenous knowledge, Adoption behaviour, Mountain agriculture

1. Background

Indigenous knowledge systems play a crucial role in sustaining agriculture and rural livelihoods in mountainous regions (Paing, J., *et al.* 2025). Among these, the traditional water-powered flour mill, locally known as *Ghrat* (Gharat), represents an important indigenous technology widely used in the hilly districts of Doda, Poonch and Kishtwar of Jammu and Kashmir. Developed through long-term interaction with local natural resources, ghrats utilize flowing water to grind cereals such as maize wheat and paddy.

Traditionally, entire villages depended on ghrats for processing grains. However, with modernization, improved market access and livelihood diversification, the use of these systems has declined significantly (Bey, S., Thabab, *et al.* 2025). Many traditional ghrats have either been abandoned or transformed into electricity-powered mills, while households increasingly rely on ready-processed grains available in markets. Understanding this transition is essential for promoting climate-resilient and sustainable agricultural practices.

2. Materials and Methods

The study was conducted during 2025–26 in selected villages of Doda, Poonch and Kishtwar districts of Jammu and Kashmir. A total of 90 respondents (30 from each district) were selected using purposive sampling. Primary data were collected through semi-structured interviews, field observations and participatory discussions. Recall-based questions were used to capture earlier dependence on ghrats and present usage patterns. Respondents were categorized into binary groups for impact analysis: (i) earlier use of ghrat (yes/no) and (ii) present use of ghrat (yes/no). The collected data were analysed using descriptive statistics and McNemar's test to assess the significance of change in ghrat usage over time. Additionally, Garrett ranking technique was used to identify major reasons for decline in usage.

3. Results and Conclusion

The study revealed a substantial decline in the use of traditional ghrats across the study area. Earlier, about 88.9% of households depended on ghrats, whereas currently only 57.8% continue to use them. The McNemar's test results showed that out of 90 respondents, 30 farmers had discontinued the use of ghrats, while only 2 farmers adopted or re-adopted them. The test indicated a highly significant change in usage pattern ($\chi^2=24.5$, $p < 0.001$), confirming a strong shift away from traditional water-powered milling systems. The decline in ghrat usage was mainly attributed to increased availability of processed grains in markets, shift from agriculture to non-farm occupations, improved access to electricity and transformation of traditional ghrats into electric-powered units. Despite this transition, ghrats remain environmentally sustainable, cost-effective and nutritionally beneficial due to slow grinding processes that preserve grain quality. They also hold social and cultural importance in rural communities. The study concluded that although ghrats are climate-resilient and eco-friendly indigenous technologies, their usage is gradually diminishing

due to socio-economic transformation. Strengthening extension services, promoting awareness and integrating traditional ghrats with modern micro-hydropower innovations can help revive and sustain these systems in mountain agriculture

Table 1: McNemar's test results for change in ghrat usage

Parameter	Value
b (Yes → No)	30
c (No → Yes)	2
Chi-square (χ^2)	24.5
p-value	< 0.001

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6.9 Risk Management Strategies Among PMFBY Farmers and non-PMFBY farmers against crop failure due to natural calamities in Samba District, Jammu and Kashmir

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Keywords: Agricultural risk management, PMFBY, Crop diversification, Climate resilience, Natural calamities

1. Background

Agriculture remains one of the most risk-prone sectors due to its direct dependence on climatic conditions and exposure to natural calamities. In regions like Jammu and Kashmir, recurrent weather uncertainties severely threaten crop productivity, farm income and livelihood security. Agricultural insurance has emerged as a critical instrument for risk financing and climate resilience. The introduction of the Pradhan Mantri Fasal Bima Yojana (PMFBY) in 2016 marked a significant policy intervention aimed at providing comprehensive and affordable insurance coverage against non-preventable natural risks from pre-sowing to post-harvest stages. However, farmers' responses to risk are largely shaped by their perceptions, access to resources and institutional support. Against this backdrop, the present study critically examined the spectrum of risk management strategies adopted by PMFBY beneficiary and non-beneficiary farmers in Samba district of Jammu and Kashmir.

2. Material and Methods

The study was conducted across all nine blocks of Samba district. A total sample of 225 farmers was selected, comprising 150 PMFBY beneficiaries through proportionate random sampling and 75 non-beneficiaries through convenient sampling for comparative analysis. Primary data were collected using a semi-structured interview schedule through personal interviews. Risk management strategies were assessed in terms of adoption of crop diversification, mixed farming, income diversification, risk-avoidance measures and risk-sharing practices. The data were systematically analyzed using frequency, percentages and z-test of proportion to identify significant differences between the two groups.

3. Results and Conclusion

The findings demonstrate that farmers employ a combination of formal and informal strategies to mitigate the adverse impacts of natural calamities. Crop diversification was adopted by 17 per cent of PMFBY farmers and 23 per cent of non-PMFBY farmers, indicating a stronger reliance on diversification among uninsured farmers. Mixed farming and income diversification were widely practiced across both groups; however, non-PMFBY farmers depended more heavily on informal mechanisms such as low-input use and diversification to buffer risks. In contrast, PMFBY farmers exhibited greater engagement in non-farm activities and more efficient resource utilization, supported by the financial security of crop insurance. Statistically significant differences were observed in income stability, year-round income generation and adoption of selected risk-avoidance practices. Participation in these welfare schemes likely provides farmers a supplementary income or a buffer against shocks, diminishing the perceived need for additional, formalised insurance like PMFBY, possibly due to greater security. The result supports the findings of (Shahin & Pradhan, 2014). Another perspective of adoption of practices for sharing risk with

others may be to enhance community-to-community and farmer-to-farmer interactions to enhance local adaptive capacity and service provision. The study identified the potential role of such cooperation in enhancing local adaptation and decision-making processes (Abid *et al*, 2016).

The study underscores that while informal coping mechanisms remain predominant, crop insurance under PMFBY strengthens farmers' adaptive capacity, enhances financial confidence and promotes more strategic resource allocation. Strengthened extension outreach, improved market infrastructure and intensified awareness campaigns are imperative to maximize the effectiveness of integrated risk management approaches.

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6.10 Integrating Indigenous Knowledge and Innovative Extension Services for Climate-Smart Post-Harvest Management of Cereals

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Keywords: Indigenous knowledge, Climate-smart agriculture, Extension services, Post-harvest management, Cereal storage, Weevils.

1. Background

Meeting the food demand of India's rapidly growing population remains a major challenge, particularly under increasing pressures of climate change and urbanization. Although India is one of the leading producers of food grains, significant post-harvest losses continue to affect food availability and security. A substantial portion of these losses occurs during storage due to improper handling, pest infestation, moisture, and inadequate storage facilities. Insects, rodents, and microbial contamination further deteriorate grain quality, resulting in both quantitative and qualitative losses. Traditional grain storage practices, developed through indigenous knowledge, have long supported farmers in preserving cereals for consumption, seed, and future sale. However, these methods often require improvement to cope with emerging climate-related risks and storage challenges. Integrating indigenous knowledge with innovative extension services and improved storage technologies can enhance climate-smart post-harvest management. Such integration can significantly reduce storage losses, improve grain quality, and strengthen food security and sustainable agricultural systems.

2. Material and Methods

The study was conducted in Jammu district of the Union Territory of Jammu and Kashmir, which has the highest area under cereal cultivation in the Jammu division. An exploratory research design was adopted and a multistage random sampling technique was employed for the selection of respondents. A total sample of 160 farmers, comprising 80 farmers each from irrigated and unirrigated areas, was selected randomly for the study.

3. Results and Conclusion

The study revealed that farmers adopted both indigenous and chemical practices for cereal storage. Among indigenous methods, neem leaves were the most commonly used practice, particularly in wheat and maize, while a small proportion of farmers used matchboxes, cloves, curry leaves, and eucalyptus leaves for protecting stored grains. Occasionally, farmers placed leaves from plants believed to have insecticidal properties, results are consistent with the results of Mobolade *et al.* (2019). Chemical practices were more prominent, with the majority of rice growers using boric acid, while aluminium phosphide was widely used in wheat and maize storage. The predominant reason for these is that they effectively control over a wide variety of pests. They can quickly eliminate existing infestations and prevent further damage to stored crops. Due to their long-lasting effects, they continue to control pests for an extended period after application. This aligns with the findings of Abamecha *et al.* (2020). A small percentage of farmers did not adopt any storage protection measures. The perceived storage losses were highest in maize, followed by wheat and rice. These findings indicate the coexistence of indigenous and modern storage practices among farmers and highlight the need for effective extension interventions that integrate traditional knowledge with improved climate-smart technologies to minimize post-harvest losses and enhance

sustainable cereal storage management.

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6.11 Adoption Status of Insecticides in Litchi Crop: A study of Indian Punjab

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Keywords: Adoption, insecticides, non-recommended

1. Background

Insecticides have been used worldwide for centuries to control insects, especially in agriculture, horticulture, and forestry. As a result, farmers, farmhands, and their families face the highest levels of exposure to these compounds. These chemicals come from many different classes and harm not just insects but also mammals through various action mechanisms (Gupta *et al.*, 2019). Litchi (*Litchi chinensis* Sonn.) is a fruit belonging to the Sapindaceae family and is commonly referred to as the "Queen of fruits." India is the second-largest litchi producer globally, exhibiting substantial growth in both cultivation area and output over time (Nath *et al.*, 2022). Insects-pests are one of the major constraints affecting production and productivity of litchi. Litchi trees are reported to be attacked by about 40-50 insect and mite species in nature. This study examines farmers' adoption of non-recommended insecticides in litchi crop highlighting persistent reliance on harmful practices despite known ecological and health drawbacks.

2. Material and Methods

The present study was conducted in three districts of Punjab namely Pathankot, Hoshiarpur, and Gurdaspur which were purposively selected due to their highest area under litchi cultivation. Eight blocks were purposively chosen across these districts. A multistage sampling technique was employed, with a total sample size of 220 litchi farmers.

3. Results and Conclusion

Table 1 shows the distribution of respondents based on their utilization of insecticides, and findings indicate a tendency among litchi growers to rely predominantly on chemical insecticides with a smaller group using organic options for pest management. Notably, both approaches are non-recommended as according to package of practices of Punjab Agriculture University, Ludhiana. These findings provide valuable insights into current pest management trends and highlight areas for potential improvement in package of practice.

Table 1 Distribution of the respondents according to their utilization of insecticides (n=220)

S.No	Insecticides	f	%
	Inorganic		
1.	Quinalphos (3-5ml)/l	42	19.09
2.	Deltamethrin (2-5ml)/l	36	16.36
3.	Monocrotophos (5ml)/l	70	31.82
4.	Quinalphos (3-5ml)/l + Deltamethrin (2-5ml)/l + Monocrotophos (5ml/l)	4	1.82
5.	Quinalphos (3-5ml)/l + Monocrotophos (5ml/l)	18	8.18
6.	Quinalphos (3-5ml)/l + Monocrotophos (5ml/l) + Neem oil (1- 5ml)/l	10	4.55
7.	Deltamethrin (2-5ml)/l + Monocrotophos (5ml/l)	11	5.00
	Organic		
1.	Natural remedies i.e (1ml)/l	3	1.36
2.	Neem oil (1- 5ml)/l	26	11.82

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6.12 Constraints faced by Beekeepers of Rajouri District of Jammu & Kashmir in Rearing and Marketing

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Keywords: Beekeeping, constraints, marketing, Rajouri

1. Background

Honeybees hold a crucial significance for rural hill communities and the ecosystem. Products derived from honeybees, particularly honey and beeswax, serve as vital sources of income, nutrition, and medicinal benefits. Simultaneously, these bees play a pivotal role as pollinators in both agricultural and natural settings. Rajouri district is blessed with diversity of climate viz-a-viz flora and fauna. This diversity supports various crops and enterprises including Beekeeping. About 86 farmers are engaged in beekeeping with 4369 colonies and the production of honey across the district accounts to merely 13 tonnes, which is considerably low. Various programmes and schemes have been launched by central and state government for popularization and promotion of beekeeping, but the progress has not reached the desired level of satisfaction, and its extent varies across regions. The adoption of recommended beekeeping technologies by beekeepers is influenced by multiple factors and the challenges they encounter (Mishra and Rana, 2023). Constraints, in this context, refer to the difficulties faced by beekeepers in actually adopting the recommended technologies, creating a technological gap and also marketing of their produce in Rajouri district..

2. Materials and Methods

The study was carried out in the Rajouri district of the Jammu & Kashmir. The entire district was chosen as study area and the list of registered beekeepers was obtained from the Apiculture Section of Department of Agriculture and Farmer's Welfare, Rajouri. Respondents were chosen based on a census method from the list of beekeepers provided. A comprehensive list of registered beekeepers was acquired and response of 45 farmers was recorded which comprised of small (< 50 hives), medium (50-100 hives) and large farmers (more than 100 hives).

3. Results and Conclusion

Various constraints were disclosed by the responding beekeepers which led to low production of honey and also proved detrimental in further increasing the colonies by these farmers. As per the response received, it was observed that majority of farmers (91.10 %) held the lack of government support for prices responsible for poor benefits of the farmers and major constraint in boosting this industry (Table-1). They suggested for fixation of minimum support price for honey in tune with other agricultural commodities. Other factors which were majorly found as constraint were lack of organized market and ravages of predators and diseases, accounting 88.88 and 84.44 per cent, respectively. 82.20 percent respondents revealed that lack of honey processing facility leads to low quality honey packing which ultimately lowers the selling price of their honey. Other factors causing constraints in honey productivity were lack of formal training (77.88%), lack of skills to adopt scientific recommended practices (71.10%), lack of knowledge about institutional support (68.89%), and weather calamities during floral season i.e. peak activity period (64.40%). Asrani *et al.* (2017), in their investigation into the potential of beekeeping in Haryana, identified technical constraints as the primary challenges faced by respondents. Phadke (2008) identified obstacles in the advancement of beekeeping on agricultural plains in India, listing excessive pesticide use, the absence of forage during certain months, and the intense summer heat as

significant constraints. Bhusal and Thapa (2005) revealed that majority of bee keeping lacked working capital and could not produce quality honey.

Table-1

S. No.	Constraint	Number	Percentage
1	Predators & Diseases	38	84.44
2	Lack of Knowledge about Recommended Practices	32	71.10
3	Lack of Skills to adopt recommended practices	29	64.44
4	Lack of Government Support for Prices	41	91.10
5	No organized market / Mandi	40	88.88
6	Lack of Knowledge about institutional support	31	68.89
7	No formal training by organizations for management of hives	35	77.78
8	Lack of facility for Honey Processing	37	82.20
9	Weather calamities during floral season	29	64.40

The above mentioned observations reveal that honey production in these potential hilly areas can be increased by managing these factors which are causing major concern to the bee keepers of the district, support to the price and organized market for support in marketing of honey being the major ones.

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Theme 7:

Innovations, Policy, and Partnerships for Climate Resilient Agriculture



7.1 TiO₂ Nanoparticles' Contribution to Increasing Crop Productivity and quality characteristics in Changing Climate Conditions.

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Key-words: *Cauliflower, Nanotechnology, Quality parameters, Titanium dioxide, Yield*

1. Background

Titanium dioxide nanoparticles (TiO₂-NPs) are emerging as nano-enabled innovations for improving crop productivity and resilience. A two-year open-field experiment (2022–2023) evaluated the effects of TiO₂-NPs on growth, yield, and quality of cauliflower using seed treatment and foliar application at 500, 1000, and 1500 ppm in a randomized block design. Seed treatment with 1000 ppm TiO₂-NPs significantly enhanced yield and quality attributes, such as chlorophyll contents (chlorophyll a and chlorophyll b). The study demonstrates the potential of optimized TiO₂-NP application as a sustainable nano-fertilizer supporting climate-resilient agriculture

2. Materials and Methods

Two-year open field experiment was conducted during winter seasons (2022&2023) at Crop Research Farm, Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh-211007, India. This region has a sub-tropical climate prevailing in the South-Eastern part of Uttar Pradesh. Cauliflower (*Brassica oleracea* var. botrytis) variety 'Aadhira' was used in the experiment. Titanium dioxide (anatase) powder with particle size <25 nm with 99.7% purity applied as seed treatment and foliar spray at 500, 1000 and 1500 ppm. The experiment comprised of seven treatments viz., T1: control (no application of TiO₂), T2: Foliar spray of 500 ppm TiO₂, T3: Foliar Spray of 1000 ppm TiO₂, T4: Foliar Spray of 1500 ppm TiO₂, T5: Seed Treatment of 500 ppm TiO₂, T6: Seed Treatment of 1000 ppm TiO₂ and T7: Seed Treatment of 1500 ppm TiO₂, replicated thrice and arranged in RBD. Yield was calculated by measuring the weight of curd in all plots and expressed in tonnes per hectare. The chlorophyll contents (chlorophyll a and chlorophyll b) were estimated by Dimethyl sulfoxide (DMSO) method and expressed in µg g⁻¹. The experimental crop management practices were carried out following the recommendations given by ICAR-IIVR guidelines. The data generated from the present investigation were analysed by randomized block design (RBD) and analysis of variance (ANOVA) were used to determine significance at p≤0.05.

3. Result and Conclusion

The results of this study revealed that, maximum yield per plot (18.65 tonnes per ha), chlorophyll-a (430 µg g⁻¹), chlorophyll-b (530 µg g⁻¹) were recorded under treatment T6 that consisted of seed treatment of 1000 ppm TiO₂-NPs. The minimum value yield per plot (7.70 tonnes per ha) was obtained under treatment T1, whereas minimum chlorophyll-a (320 µg g⁻¹), chlorophyll-b (440 µg g⁻¹) was obtained under treatment T4 (foliar application of TiO₂-NPs at the concentration of 1500 ppm).

Table 1: Effect of TiO₂ Nanoparticles on yield and quality parameters of cauliflower.

Treatments	Yield (tonnes per ha)	Chlorophyll-a (µg g ⁻¹)	Chlorophyll-b (µg g ⁻¹)
T1	7.70	340	450
T2	9.28	360	460
T3	13.20	380	470
T4	13.80	320	440
T5	17.25	410	510
T6	18.65	430	530
T7	16.08	390	490
Mean	13.70	380	480

In the present study, yield of cauliflower was significantly ($p \leq 0.05$) influenced by the use of TiO₂-NPs. Our results are aligning with the results of Brar *et al.* (2025), they recorded that applying seed treatment of TiO₂-NPs @1000 ppm significantly improved the growth and yield characteristics of cabbage. This might be because of photo-catalytic ability of titanium dioxide at nano scale. The enhanced activity of the enzymes may potentially be the cause of this beneficial effect on photosynthetic pigments. the seed treatment of 1000 ppm TiO₂-NPs also enhanced quality parameters of cauliflower i.e. chlorophyll-a, chlorophyll-b.

Hence it is concluded that among various concentrations of TiO₂-NPs i.e. 500, 1000 and 1500 ppm, TiO₂-NPs @ 1000 ppm concentration significantly improved yield per plot, chlorophyll-a, chlorophyll-b in cauliflower as compared to control and other treatments. The application of nanoparticles in agricultural may aid in increasing the technological inputs' accuracy. Simultaneously, it may tackle the significant issue of low productivity and inefficient use of resources.

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7.2 Zinc Nano-formulation Based Management of *Trichoderma* sp. Affecting Oyster (*Pleurotus* sp.) Mushroom

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Key-words: Antifungal activity, Green mould, *Pleurotus eryngi*, Zinc nano-formulation

1. Background

Mushrooms are considered to be next generation health food as they are low in fat, no cholesterol, high protein biological value and other bioactive agents and minerals such as selenium which is known to be potent antioxidant (Manzi *et al.*, 2004). Mushroom production is adversely affected by a large number of biotic and abiotic factors. Among the several biotic factors associated with reduction in yield of mushroom, competitor moulds significantly affect the mushroom production and yield (Thakur *et al.*, 2022). Among competitor moulds, green mould, caused predominantly by *Trichoderma* species, poses a major threat to commercial mushroom cultivation by rapidly colonizing substrates, competing for nutrients and secreting toxic metabolites that inhibit mycelial growth of edible fungi leading to severe yield losses. A number of chemical fungicides have been evaluated against green mould of mushrooms, despite their effectiveness against green mould, their application also harms the mycelium, spores, fruiting body of the mushroom fungus thus leads to stunted growth, reduced yields or even complete crop failure. Taking into consideration the limitation of current management strategies the present study was carried out to analyze the capability of Zinc (Zn), nano-formulation in managing *Trichoderma* spp., causing green mold in oyster mushrooms (*Pleurotus* sp.).

2. Material and Methods

The sample of the visible green growth apparently *Trichoderma* sp. on the crop of *Pleurotus eryngi* was collected. The isolation was done using the standard techniques followed by purification through single spore isolation method. Identification was done using the cultural, morphological and molecular studies. Molecular study was carried out by targeting the *tefl-α* locus. The Zn nano-formulation used during present study was obtained from Agri-Nanotechnology Laboratory, Faculty of Horticulture, Shalimar, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir Shalimar-Srinagar. The evaluation of different concentrations of Zn nano-formulation against green mould (*Trichoderma* sp.) and *Pleurotus eryngi* was conducted under *In-vitro* conditions, using the poison food technique (Nene and Thapliyal, 1973). The nano-formulation was also evaluated for the management of *Trichoderma* spp. in spawn and crop of *P. eryngi* by giving nano-formulation treatments to wheat grains and substrate, respectively before autoclaving. This experiment was carried out in three sets; in the first set of experiment only inoculum of *Trichoderma* sp. prepared on wheat grains was inoculated on nano-formulation treated wheat grains contained in glass bottles. In the second set of experiments only master spawn of the *P. eryngi* was inoculated on treated wheat grain bottles and in the third set of experiment both the *P. eryngi* and *Trichoderma* sp. were inoculated on the same treated wheat grain bottles. *P. eryngi* was inoculated after autoclaving while as *Trichoderma* sp. was inoculated at different time intervals i.e., at the time of *P. eryngi* inoculation and after 12, 24 and 36 hrs of inoculation of *P. eryngi*. The same process was repeated while managing the *Trichoderma* spp. crop/ substrate of *P. eryngi*.

3. Result and Conclusion

In-vitro assay through poison food technique revealed that ZnNF @ 200 ppm, effectively inhibited the mycelial growth of *Trichoderma* sp. by 99.13 per cent, with minimal inhibitory effects on *P. eryngi* followed by Carbendazim 50 WP @ 230 ppm inhibiting mycelial growth of *Trichoderma* sp and *P. eryngi* by 97.50 per cent and 59.73 per cent respectively. Evaluation of nano-formulations for the management of *Trichoderma* sp. in spawn and crop of *P. eryngi* showed that ZnNF @ 200 ppm, recorded the complete suppression of *Trichoderma* sp. without adversely affecting *P. eryngi* colonization and growth. ZnNF @ 200 ppm, was significantly at par with Carbendazim 50 WP @ 230 ppm. The possible reason for the inhibition of mycelial growth of *Trichoderma* sp. by the nano-formulations can be attributed to the high surface area to volume ratio of NPs. The high surface area to volume ratio allows NPs to interact more efficiently with fungus, leading to enhanced absorption and cellular penetration, thus causing disruption of integrity of cell membrane, leakage of cellular contents and ultimately cell death. The possible reasons for lower antifungal activity of Zn nano-formulation in *P. eryngi* can be attributed to the cell wall structure of *P. eryngi* which is thicker and rich in chitin and β -glucans providing a dense physical barrier to limit nano particle penetration. Also *P. eryngi* has a good bioaccumulation capability it can absorb and sequester metals into its cellular structure without significant toxicity. Moreover, *Pleurotus* spp. are known to produce extracellular ligninolytic enzymes, including laccases and peroxidases, that can interact with or detoxify nano particles, thereby lowering their bioavailability and antifungal efficiency. The study concludes that Zn nano-formulation exhibit strong antifungal potential against *Trichoderma* sp. with non-significant effect on the mycelial growth of *P. eryngi* and can serve as safer and more sustainable alternatives to conventional fungicides like Carbendazim 50 WP, which is in a process of to be phased out for its agricultural use due to resistance development, health and environmental risks.

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7.3 Integrated Nutrient Management as an innovative Climate-Resilient Soil Management Strategy under acid Alfisols

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Key-words: Biofertilizers, climate, integrated nutrient management, sustainable

1. Background

Climate change is intensifying abiotic stresses such as drought, heat and erratic rainfall, posing serious challenges to crop productivity and nutritional security in agricultural system (IPCC 2022). Under such conditions, the role of micronutrients for sustaining crop growth and enhancing stress tolerance is recognized as a critical component of climate-resilient agroecosystems. Micronutrients play a fundamental role in plant physiological and biochemical processes, thereby increasing plant tolerance to climatic stresses by regulating reactive oxygen species, maintaining membrane stability and improving nutrient use efficiency. Therefore, improving soil micronutrient availability is essential for optimum crop productivity under climate variability and for strengthening crop resilience to abiotic stresses. However, intensive agricultural practices such as monocropping and the widespread cultivation of high-yielding varieties have led to progressive depletion of soil nutrients. Moreover, indiscriminate and imbalanced application of synthetic fertilizers has resulted in deficiencies of essential micronutrients such as zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu), even in acidic soils, leading to reduced crop productivity and impaired nutritional quality of food crops. In this context, a holistic approach, combining organic and inorganic inputs along with biofertilizers, often referred as Integrated nutrient management (INM), has emerged as a sustainable strategy for improving micronutrient dynamics in soils (Meena and Vishnuvardhan 2021). INM enhances micronutrient solubility, reduces fixation and promotes biological mobilization, thereby improving their availability to crops. Hence, the present study was undertaken to evaluate the impact of INM practices on soil micronutrient availability and maize productivity under acid Alfisol of Himachal Pradesh.

2. Materials and Methods

The study was conducted at the Research Farm of Department of Soil Science during *kharif* season, 2022. The experiment was carried out in a randomized block design comprising nine treatments with recommended NPK levels (120:60:40) applied at graded rates of 100, 75 and 50 % integrated with either FYM (10, 7 t ha⁻¹), vermicompost (5, 3.5 t ha⁻¹) and biofertilizers (*Azotobacter* and *Bacillus* sp.). Maize was planted as the test crop and after harvest both grain and stover yield was recorded. Further, post-harvest soil samples were collected, processed and analysed for available micronutrient content. The DTPA extraction method was employed for analysing Fe, Mn, Zn and Cu as given by Lindsay and Norvell (1978) and statistical analysis was performed using ANOVA as given by Gomez and Gomez.

3. Result and Conclusion

The treatment comprising 75% NPK + 5 t vermicompost ha⁻¹ + *Azotobacter* + *Bacillus* sp. (T₇) recorded the highest availability of all micronutrients, which was statistically at par with T₆ (75% NPK + 10 t FYM ha⁻¹ + biofertilizers) (Figure 1). The Fe, Mn, Zn and Cu increased by 31.9%, 70.5%, 16.7%, and 26.3%, respectively under treatment T₇ as compared to the sole application of chemical fertilizers (T₁). Among organic sources, vermicompost integrated treatments showed slightly higher micronutrient content than FYM, indicating the superior role of vermicompost in

micronutrient solubilization and mobilization. However, treatments receiving reduced NPK levels (50%) along with organic and biological inputs also improved micronutrient availability compared to 100% NPK alone, highlighting the synergistic effects of organic and biological amendments on micronutrient dynamics. Thus, the findings underscore that partial substitution of synthetic fertilizers with organic and biological inputs sustain soil fertility and ensures better crop production, crowning INM as a viable strategy for sustainable soil management and climate adaptation.

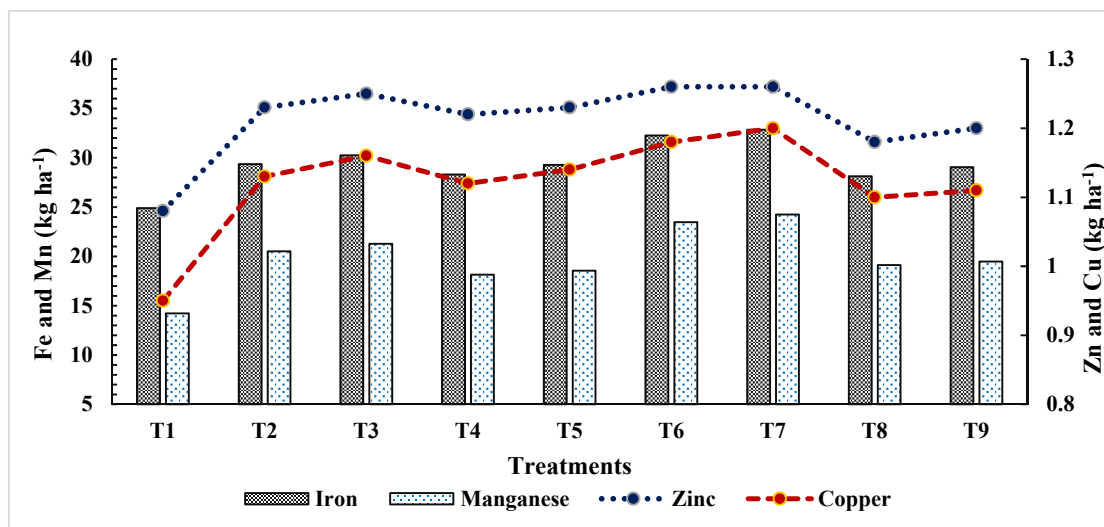


Figure 1 Influence of INM practices on available micronutrient content

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7.4 Nano-bio-sulphur: Fabrication, Characterization and anti-microbial activity against *Colletotrichum capsica* causing fruit rot of Chilli crop

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Key-words: Antifungal, Chili Sulphur nanoparticles, Fruit rot, Nanoparticles

1. Background

Chilli crop suffers heavy losses in yield due to many diseases especially fruit rot in the chilli growing areas of the world with Kashmir valley being no exception. Present study was undertaken with emphasis on development of simple, cost-effective and reliable method for green synthesis of nanoparticles and their application in the management of this disease.

2. Materials and Methods

Present study was undertaken with emphasis on development of simple, cost-effective and reliable method for green synthesis of nanoparticles and their application in the management of this disease. Albizia lebbeck fruits were collected from Karnataka, while fresh mint (*Mentha piperita*) leaves were collected from Kashmir and used for the green synthesis of sulphur nanoparticles. Diseased chilli fruits (cv. KL-1) showing typical fruit rot symptoms were collected from chilli fields of the Faculty of Agriculture, Wadura. All nanoparticle characterization studies, including X-ray diffraction (XRD), particle size analysis (PSA), scanning electron microscopy (SEM) and transmission electron microscopy (TEM), were conducted at the UGC-DAE Consortium for Scientific Research, Indore, Madhya Pradesh, India. Diseased chilli fruit tissues were cut into small segments using a sterilized blade, surface sterilized with 0.1% mercuric chloride (HgCl₂) for 30 seconds, followed by three successive washings with sterile distilled water. After blotting dry, the tissues were transferred onto sterilized potato dextrose agar (PDA) plates and incubated at 27±1 °C and pathogen was purified using the single spore isolation technique and maintained on PDA slants at 4 °C. Pathogenicity of the fungus (*Colletotrichum capsici*) was confirmed on detached chilli leaves and fruits using the pin-prick method fulfilling Koch's postulates. Albizia fruits and mint leaves were thoroughly washed, shade-dried, powdered and aqueous plant extracts were prepared following by Awwad *et al* (2022). For synthesis of Sulphur nanoparticles 100 ml of 0.01 M sodium thiosulphate (Na₂S₂O₃·5H₂O) dissolved in 10 ml of each plant extract under constant stirring for 2 h at room temperature. Hydrochloric acid was added drop wise to allow uniform precipitation of sulphur. The reaction mixtures were autoclaved, centrifuged at 5000 rpm for 25 min. and repeatedly washed with deionized water and oven-dried at 60 °C for 24 h. Sulphur nanoparticles synthesized using Albizia extract and mint extract were designated as SNP-A and SNP-M respectively. Characterization of nanoparticles was performed using XRD, PSA, SEM and TEM (Kulkarni *et al.*, 2015). Antifungal efficacy was evaluated in vitro using the poison food technique at seven concentrations (25, 50, 100, 150, 250, 500 and 1000 ppm) in a completely randomized design with three replications. Wettable sulphur 80 WP (2000 ppm) and carbendazim 50 WP (500 ppm) served as check and standard check, respectively. Percent growth inhibition was recorded on the 10th day. The three most effective treatments were further evaluated on detached fruits of susceptible chili cultivar Pusa Jwala using a spore suspension of *C. capsici* (1 × 10⁶ spores ml⁻¹) and observations

on incubation period and lesion development were recorded up to 16 days after inoculation.

3. Result and Conclusion

Pathogen was confirmed after study the morpho-cultural characteristics like acervuli diameter, setae length and conidial length and breadth. Among the synthesised nanoparticles, highest mycelial growth inhibition of 96.38% was recorded in SNP-A @1000ppm followed by 90.68% in SNP-M @1000ppm and 88.37% in SNP-A @ 500 ppm over the standard fungicides, wettable sulphur 80WP @2000ppm showed 72.69% while as carbendazim 50WP @500ppm showed 68.09% mycelial growth inhibition. In detached fruit method, the inhibition of pathogen was significantly high when nanoparticles were applied before inoculation of pathogen as compared to when applied after inoculation of pathogen. This study demonstrates a straightforward, cost-effective and environmentally friendly approach for producing sulphur nanoparticles using extracts from *Albizia lebbeck* and *Mentha piperita* plants. This method stands out due to the accessibility of plant materials, affordability, uncomplicated reaction conditions, and the absence of expensive, hazardous, and toxic substances, making it environmentally benign. The sulphur nanoparticles exhibited significant antifungal properties, effectively inhibiting the growth of *Colletotrichum capsica* at concentrations of 500 and 1000 ppm, surpassing the efficacy of conventional fungicides. Additionally, these nanoparticles demonstrated remarkable effectiveness in extending the incubation period of the disease and controlling lesion length and numbers when tested on detached chili fruits. The green-synthesized nanoparticles functioned both as a protectant and an eradicator, showcasing their potential in managing plant pathogens.

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7.5 Awareness of Rice-Wheat farmers of Subtropical Jammu region regarding crop residue management practices and their effect on climate

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Key-words: Crop residue, Awareness, Crop Residue Management Practices

1. Background

India produces huge quantities of rice and wheat to meet the country's food security needs but, this very success has created a growing challenge in the form of crop residue management. Large amounts of paddy and wheat residue remain in the fields after harvest and much of it is burned. This practice leads to serious environmental and health problems. Moreover, this practice harms soil productivity by destroying vital nutrients present in the soil (Singh *et al.*, 2020). It also decreases the soil's organic carbon content and reduces the population of beneficial microorganisms that are essential for soil health. Several crop residue management options are available for handling residues more effectively and sustainably (Singh *et al.*, 2020). Crop residue burning is prohibited under Section 144 of the Civil Procedure Code (CPC). Farmers are somewhat aware of restrictions and the penalties imposed for burning activities (Chongloi *et al.*, 2021). However, despite the use of both incentive-based measures and punitive actions to discourage this practice, it continues to be widely followed in the rice-wheat growing regions of India. Therefore, it is important to understand farmers' awareness about crop residue burning and the factors that influence their views and decisions regarding this practice.

2. Materials and Methods

The study was conducted in three districts from subtropical Jammu region namely Jammu, Samba and Kathua. From these districts, three blocks, one from each district was purposively selected as these blocks were having maximum number of farmers practicing rice-wheat cropping system. Multistage random sampling technique was used for sample selection. Three blocks namely Bishnah from district Jammu, Ramgarh from district Samba and Marheen from district Kathua were selected having the maximum number of farmers from these blocks cultivating rice and wheat crops. From each block, forty farmers were selected randomly by using random number generator. Thus, the total sample size comprises of 120 respondents.

3. Result and Conclusion

The results indicate that farmers of the study area have strong awareness of the utilitarian and livestock-related uses of crop residues, but comparatively limited understanding of their economic and soil enrichment benefits. A large majority of respondents are aware about crop residues as valuable resource for livestock feed during lean seasons (70-83%), livestock bedding (63-77%), and roof thatching (55-85%), fruit ripening (73-93%) as well as for traditional practices such as house construction (80-85%) Table 1. This indicates that crop residues are deeply embedded in rural livelihood systems beyond crop production alone. More than half of the farmers also recognized the market potential of rice stubbles as packaging material (55-65%), reflecting awareness of income-generating opportunities. Moderate level of awareness was observed about

soil-related applications, including the use of chopped straw as mulch (30-50%) and residue use in vermicomposting (27-40%) which clearly indicates that farmers have partial knowledge of residues' contribution to soil improvement. In contrast, only a small proportion of respondent farmers have awareness of crop residue management can increase crop yields (8-25%) Table 1. Thus, the study highlights a significant knowledge gap among farmers of Jammu subtropical region about residue management despite scientific evidence that residue retention enhances soil moisture conservation, organic matter content, nutrient cycling and long-term soil productivity. Therefore, it is suggested that capacity building programmes should be organised on regular basis to educate farmers about the benefits of crop residue management.

Table 1: Awareness of the farmers regarding crop residue management practices

S. No.	Particulars	District Jammu		District Samba		District Kathua	
		Frequency	%	Frequency	%	Frequency	%
1	Crop residue management can increase crop yields	04	10	10	25	03	08
2	Chopped straw can be used as mulch	12	30	20	50	18	45
3	Crop residue can be used as livestock feed in lean seasons	33	83	28	70	29	73
4	Crop residues can be used for vermicompost making	14	35	11	27	16	40
5	Rice stubbles can be sold in the market as packaging material	22	55	24	60	26	65
6	Crop residue (stubbles) can be utilize for roof thatching	26	65	22	55	34	85
7	Crop residue can be utilized as livestock bedding material	31	77	25	63	30	75
8	Can be used as material use for climacteric fruit ripening	37	93	35	87	29	73
9	By mixing straw in soil can be use in traditional house making	34	85	32	80	33	83

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7.6 Time Series Modelling and Forecasting of Area, Production and Productivity of Walnut Fruit Crops of Kashmir

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Keywords: Kashmir, Walnut, Trend, ADF test, ARIMA model, Forecasting.

1. Background

The UT's of Jammu and Kashmir (J&K) and Ladakh are rich territories that provide a conducive atmosphere for the abundant production of both fresh and dried fruits. Jammu and Kashmir occupy nearly 90% of India's walnut industry, producing 206.43 thousand metric tons across 69.24 thousand hectares in 2016-17. In contrast, the rest of India produced 21.8 thousand metric tons of walnuts, covering an area of 22.85 thousand hectares during the same period (Anonymous 2017). In the dry fruit category, the Kashmir region produces the most walnuts (63.41 percent), followed by the Jammu region (32.79 percent) (Ahmed et al, 2021). Climate change, including less rainfall, higher temperatures, and events like 2015-16 flooding, causing walnut cultivation area to shrink by 53%, has severely impacted production and exports amid rising demand. These developments underline the need to examine long-term trends in walnut area and production in Kashmir and to forecast near-term production to support planning, risk management, and policy interventions.

Trend analysis in agricultural studies is commonly conducted using both linear and non-linear models to examine the growth pattern of area and production over time. Linear models capture constant changes, while non-linear (exponential or compound) models better reflect multiplicative growth trends often observed in horticultural crops. For forecasting purposes, time series models are widely used due to their ability to account for temporal dependence and fluctuations in data. These models provide reliable short-term projections based on historical patterns. Hence, linear and non-linear models are employed for trend analysis, and time series models are used for forecasting walnut production in the present study

2. Materials and Methods

The study utilized secondary data on area, production, and productivity of walnut in the UT of Kashmir for a period of 27 years (1995–96 to 2022–23), collected from the Directorate of Horticulture, Kashmir. Descriptive statistics were employed to understand the structural characteristics of the data. Trend analysis was carried out using both linear and non-linear models to examine growth patterns over time. For forecasting, the ARIMA model was applied. The selected models were validated for two years, and the best-fit models were identified based on higher R^2 and lower error measures, including RMSE, MSE, MAPE, MAE, Max APE, Max AE, and BIC, and were found suitable for forecasting area, production, and productivity of walnut

3. Result and Conclusion

The summary statistics revealed that the average productivity of walnut in Kashmir during the study period was 2.47 MT/ha. Prior to trend analysis, the data were tested for randomness, normality, and the presence of outliers, and the time series was found suitable for further analysis. To examine trends in area, production, and productivity, both linear and non-linear models were fitted, and the best-fit models were selected based on higher R^2 and lower RMSE, MSE, and MAPE

values. The quadratic model was found to be the best fit for area and productivity, while the cubic model best explained production trends. For forecasting, ARIMA models were employed; since the series was non-stationary according to the ADF test, first-order differencing was applied to achieve stationarity. Based on R^2 , RMSE, MAPE, MAE, Max APE, Max AE, and BIC, ARIMA (1,1,1), ARIMA (3,1,2), and ARIMA (3,1,2) were identified as the best-fit models for area, production, and productivity, respectively. Model validation over two years confirmed their suitability for forecasting, which indicated a declining trend in walnut area but an increasing trend in production and productivity in the coming years.

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7.7 Influence of Climate Variability on the Outcomes of Cluster Front Line Demonstration Programme in Pulse Crops

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Keywords: CFLD, Climate Variability, Pulses.

1. Background

Climate change-induced variability in rainfall patterns has become a major challenge for agricultural production, particularly in rain-fed regions. Pulse crops are highly sensitive to climatic fluctuations, especially during the germination stage, where excess or untimely rainfall can severely affect crop establishment and yield. The Cluster Front Line Demonstration (CFLD) programme is an important extension intervention aimed at enhancing pulse productivity through the dissemination of improved production technologies. However, the success of such programmes is closely linked to prevailing climatic conditions. In regions like Rajouri district, where pulse cultivation largely depends on monsoon rainfall, untimely precipitation events can significantly influence the performance of demonstration programmes. The present study was undertaken to assess the impact of the CFLD programme on pulse crop cultivation, particularly untimely rainfall, observed during the implementation of the programme.

2. Materials and Methods

The study was conducted in Rajouri district and was based on primary data collected through a field survey. A total of 40 pulse-growing farmers were randomly selected from villages covered under the CFLD programme. These farmers were beneficiaries of CFLD interventions and had adopted recommended production technologies. Data were collected using a structured questionnaire covering information related to adoption of improved practices, crop performance, and climatic experiences during the cropping season. The collected data were analyzed using descriptive statistical tools such as frequency and percentage analysis to assess the impact of the CFLD programme and to identify climate-induced constraints affecting pulse crop establishment.

3. Result and Conclusion

The results of the study indicated that the CFLD programme contributed to improved adoption of recommended pulse production practices among participating farmers. However, climatic variability significantly affected crop establishment in some cases. Out of the 40 farmers surveyed, 6 respondents (15.0%) reported complete crop failure due to untimely rainfall during the germination stage of pulse crops. Excess rainfall immediately after sowing resulted in waterlogged field conditions, leading to seed decay and poor germination. The remaining 34 farmers (85.0%) did not report total crop failure; however, several of them experienced partial germination problems and delayed crop emergence due to irregular rainfall patterns. These findings indicate that although improved technologies were adopted under the CFLD programme, climatic factors played a critical role in determining crop establishment and early growth.

Table 1. Impact of Untimely Rainfall on Pulse Crop Germination

S.No		N=40	Percentage (%)
1.	Complete crop failure due to untimely rainfall at germination	6	15.00
2.	No complete crop failure	34	85.00
Total		40	100.00

Table 1 indicates that 15 per cent of the farmers experienced complete crop failure due to untimely rainfall during the germination stage of pulse crops, highlighting climate-related vulnerability even under CFLD interventions.

The study concludes that the CFLD programme has a positive influence on the adoption of improved pulse production technologies; however, its effectiveness is highly sensitive to climatic conditions, particularly rainfall variability during the germination stage. The occurrence of complete crop failure among a proportion of farmers highlights the growing impact of climate change on rain-fed pulse cultivation. The findings emphasize the need to integrate climate-responsive measures, such as appropriate sowing windows, improved drainage management, and weather-based agro-advisories, within CFLD interventions. Incorporating climate resilience into extension programmes is essential to ensure sustainable pulse production and to enhance the overall effectiveness of demonstration-based agricultural development initiatives under changing climatic conditions.

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7.8 Development, Validation and popularization of Novel Multipurpose Pyrolyser cum Cooker for Climate Change Adaptation and Air Pollution Mitigation

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Keywords: Validation, Multipurpose, climate change, adaptation

1. Background

Himalayan highlands contribute 80% of the total national apple production, area under apple cultivation is 167000.67 ha with 1882000 MT production. Normal spacing in apple 7.5 by 7.5 m consists of 178 trees per ha, on average 50 kg of pruning residue is produced annually. As per above estimate at end of each crop cycle, we are left with 14, 86, 300 tons of Apple residues. Most prevalent residue management strategy presently is open air burning and burning in traditional stoves, both of which produce large quantity of greenhouse gases. There is a significant and clear upward trend in mean maximum and minimum temperature indicating clear climate change in fragile temperate Himalayas. If the problem of residue burning in Kashmir Valley remains as such and unattended, this can aggravate the situation further. Climate is very important variable to decide economic development of any region, everything else will be at stake if climate is not considered. Kashmir Himalayas are very fragile, a small variation in climate results in much greater implications to agriculture due to complex and rugged topography. This all motivated us to innovate and develop novel Multipurpose pyrolyser cum cooker for sustainable and eco-friendly management of residues.

2. Material and Methods

The study evaluated seven organic amendments to determine their effects on soil and crop performance. The amendments tested included a control (A1), apple biochar produced at 400°C (A2), apple biochar at 600°C (A3), apple woodchips (A4), Dalweed biochar at 400°C (A5), Dalweed biochar at 600°C (A6), and Dalweed (A7). Each treatment was applied at three rates—Low, Medium, and High—and in combination with two fertilizer treatments: No Fertilizer and Fertilizer. These dried materials were then introduced into a locally fabricated pyrolyser cum cooker which is Patented. The biochar was produced at two specific temperatures: 400°C and 600°C. The pyrolysis process was carried out over three hours, with the temperature rising gradually at a rate of 8°C per minute. Following the completion of pyrolysis, the resulting material was cooled and passed through a 1 mm mesh to produce the final biochar. To characterize the biochar, a proximate analysis was performed to measure various parameters, such as moisture content, volatile matter, ash, and fixed carbon, along with elemental compositions of carbon, hydrogen, oxygen, and nitrogen. The Van Krevelen diagram was utilized to evaluate the biochar's structural properties, while pH and electrical conductivity (EC) were measured using suitable meters. Field trials were conducted using a Randomized Complete Block Design (RCBD) to evaluate the effects of different treatments. The trials began in the 2020-21 season with maize (Variety C-4) as the test crop. The experimental design included a range of biochar types, application rates, and inorganic fertilizers, with the field layout organized based on soil fertility gradients determined by quick soil testing.

3. Results and Conclusion

The results indicated that biochar properties were significantly influenced by pyrolysis conditions. Apple biochar yielded 37.4% at 400°C and 17.4% at 600°C, with pH levels of 11.7 and 10.3, respectively. Nutrient content in biochar increased with higher pyrolysis temperatures. Soil physical and chemical properties were affected by the type of amendment, application rate, and fertilizer presence. Biochar generally increased soil pH, electrical conductivity (EC), and cation exchange capacity (CEC), while also improving mean weight diameter (MWD), bulk density (BD), porosity, and penetration resistance. Hydrological properties such as moisture holding capacity (MWHC), water content (WC), and hydraulic conductivity (HC) improved with both biochar and organic residues, enhancing water availability during dry spells. Application rates had a significant impact on these properties, with more pronounced effects in the following growing season. Soil biological and enzymatic activities were also positively impacted. Biochar provided an optimal environment for microbial growth, increasing populations of bacteria, fungi, and actinomycetes with higher application rates. Soil nutrient levels, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), improved with the organic amendments. Carbon sequestration was highest with apple biochar at 600°C (A3). Soil erodibility was reduced with organic residues and biochar, with apple biochar showing superior results. Both biochar and residues enhanced plant growth and yield, with apple biochar being the most effective.

We have successfully developed Pyrolyser cum cooker which worlds first such technology and has been granted patent by Indian Patent Office. Our technology has potential to avert 2,675,340 tons of CO₂ annually from Himalayan Highlands (Wani et al 2023, Wani et al 2024). We have validated and tested this technology in field conditions. Overall carbon and energy footprints have been drastically improved making Himalayan highlands sustainable and climate friendly hence securing whole subcontinent because it is affected by Himalayan highlands for water and other crucial resources.

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7.9 Mapping the Research Landscape of Farmer Producer Organisations (FPOs) in India: A Bibliometric Perspective

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Keywords: *Bibliometric analysis, Biblioshiny, FPOs, FPC*

1. Background

Farmer Producer Organisations (FPOs) have emerged as key institutional mechanism for enhancing market access, income and collective action among small and marginal farmers in India. The amendment to the Indian Companies Act, 2002 led to the emergence of the Producer Company model, blending cooperative principles with corporate flexibility, and later paved the way for the promotion of FPOs. With rapidly expanding but fragmented research on FPOs, a bibliometric analysis is essential to systematically map research trends, key themes and knowledge gaps, thereby guiding future scholarship and policy directions.

2. Materials and Methods

This study employed a bibliometric approach to systematically analyse research on Farmer Producer Organisations (FPOs) in India. Data were retrieved from Lens.org using a structured Boolean search strategy, focusing on English open-access articles published between 2016 and 2025, resulting in 865 records. Following PRISMA 2020 guidelines, records were screened for relevance and 156 documents were selected for final analysis. Bibliometric analysis was conducted using MS Excel, VOSviewer (v1.6.20), and R Bibliometrix (Biblioshiny) to examine publication trends, citation networks, thematic clusters and the intellectual structure of FPO research in India.

3. Result and Conclusion

Explaining only the ‘Annual scientific production’ the bibliometric findings indicate a clear and accelerating growth in annual scientific production on Farmer Producer Organisations (2016–2025). Publications remained limited during 2016–2018, reflecting an exploratory phase. A steady rise was observed from 2019 onwards, coinciding with increased policy focus, particularly the Government of India’s “Formation and Promotion of 10,000 FPOs” initiative. A significant surge during 2022–2024, with a peak in 2023, highlights the consolidation of FPO research as a distinct and expanding domain, further driven by post-COVID concerns on supply chain resilience and inclusive agribusiness as shown in Fig.1. The comparatively lower output in 2025 is attributed to incomplete data coverage. Overall, the trend demonstrates the rapid institutional and academic strengthening of FPO research in India.

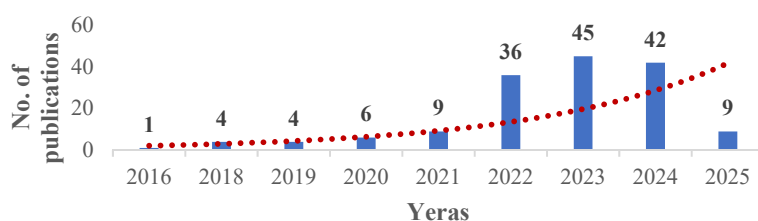


Fig.1: Annual growth of publications on FPOs

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7.10 Performance of soybean [*Glycine max* (L.) Merrill] varieties under different phosphorus levels along with inoculation of PSB

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Keywords: Soybean, Phosphorus, PSB, Varieties, Yield, Nutrient management

1. Background

Soybean (*Glycine max* L. Merrill) is an important legume crop valued for its high protein (40–41%) and oil (20–21%) content, contributing significantly to food, feed and industrial sectors. In India, it also plays a key role in improving soil fertility through biological nitrogen fixation. Varietal selection is a critical factor influencing soybean productivity, as genotypes differ in growth characteristics, nutrient use efficiency and yield potential. These variations affect parameters such as plant growth, nodulation, biomass accumulation and seed yield, and determine their response to nutrient management practices. Phosphorus is an essential macronutrient involved in energy transfer, root development and nodulation; however, its availability in soils is often limited due to fixation. Although phosphorus fertilization improves soybean growth and yield, excessive use may lead to environmental and economic concerns. Phosphate-solubilizing bacteria (PSB) enhance phosphorus availability by converting insoluble forms into plant-available forms, thereby improving nutrient uptake, nodulation and yield. Their integration with phosphorus fertilization offers a sustainable approach to nutrient management. The present study evaluates the interaction of soybean varieties, phosphorus levels and PSB inoculation to identify efficient and sustainable strategies for improving productivity and nutrient use efficiency.

2. Materials and Methods

The field experiment was conducted during the summer season of 2024 at Dusty Acre Farm, College of Agriculture, JNKVV, Jabalpur (M.P.). The experiment was laid out in a **Factorial Randomized Block Design (FRBD)** with four replications. It comprised three soybean varieties:

V1: JS 20-34

V2: JS 20-98

V3: JS 20-116

Six phosphorus management treatments:

P1: 100% recommended dose of nitrogen (control)

P2: 100% N & K + 75% P

P3: P2 + seed treatment with PSB @ 10 g kg⁻¹ seed

P4: P3 + soil application of PSB @ 5 kg ha⁻¹

P5: 100% NPK + PSB seed treatment

P6: 100% NPK + PSB seed treatment + soil application

Observations were recorded on growth parameters (plant height, branches, LAI, nodulation),

yield attributes (pods plant⁻¹, seeds pod⁻¹, seed index), and yield (seed and stover yield). Statistical analysis was carried out using analysis of variance (ANOVA).

3. Results and Conclusion

The results revealed that among varieties, JS 20-116 (V3) consistently performed superior in terms of growth parameters. Phosphorus levels combined with PSB significantly influenced plant growth. Treatment P6 (100% RDF of NPK + PSB seed + soil application) produced the highest values for plant height, branching, LAI, and nodulation, indicating enhanced nutrient availability and improved root activity due to microbial inoculation. Yield attributes were also significantly affected. Variety JS 20-116 recorded the highest number of pods per plant (62.14), seeds per pod (2.93) and seed index (12.86 g). Among phosphorus treatments, P6 resulted in maximum pods per plant (54.83) and seeds per pod (2.83). The highest seed yield was recorded with variety JS 20-116 (1354 kg ha⁻¹), followed by JS 20-98 (1024 kg ha⁻¹) and JS 20-34 (727 kg ha⁻¹). Among phosphorus treatments, P6 produced the maximum seed yield (1212 kg ha⁻¹), followed by P5 (1147 kg ha⁻¹). The interaction effect between varieties and phosphorus levels was highly significant. The combination V3 × P6 recorded the highest seed yield (1649 kg ha⁻¹) and stover yield (2446 kg ha⁻¹), indicating that high-yielding varieties respond more efficiently to integrated phosphorus and PSB application. The results clearly demonstrate that PSB inoculation enhances phosphorus availability, improves root nodulation, and increases nutrient uptake, thereby boosting growth and yield. The synergistic effect of phosphorus fertilization and PSB inoculation confirms their importance in sustainable soybean production. The study concluded that integrated phosphorus fertilization and PSB inoculation significantly enhanced soybean growth, nodulation and yield. Variety JS 20-116 performed superiorly, while treatment P6 maximized productivity. Significant variety × phosphorus interaction indicated improved nutrient use efficiency and synergistic effects.

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7.11 Analysis of Economics and Constraints of Production in Rapeseed-Mustard Under Agro-Climatic Conditions of Jammu

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Keywords: Rapeseed-mustard, cost and returns, marketing, production and constraints.

1. Background

In the Indian agricultural economy, Oilseeds occupy an important position as they account for 14 per cent of the gross cropped area and contribute more than 4 per cent to the Gross National Product (GNP) as per Directorate of oilseed Development (DOD). During 2020-21, domestic edible oil production was 9.5 million tonnes while domestic oil consumption was 22.5 million t/ year. Thus the gap of 13 million tonnes is filled with imports that cost the country US\$ 13.5 billion (Rs.1.17 lakh cr). Mustard is the highly important crop among the oilseed crops grown in the country. It is the most important oil seed crop of the country because of its utility as food and also as raw material for some industries viz. soaps, textiles and lubricants etc. Indian mustard had an area of 9.20 million ha and the production was 11.4 million tonnes during 2022-23. At the same time yield remained only 1203 kg per ha. The major problem faced by India is that an increase for domestic production is not keeping pace with the increasing demand and population growth. The demand and supply gap in oilseed production calls for the systematic research in the area. Lack of awareness, lack of technical know- how, crop management, unavailability of improved varieties, uncertainty in the returns to investment, lack of credit facilities, and cultivation in rainfed areas etc. are some of the factors that obstruct the production process. A thorough analysis of economics of production and constraints that obstruct the production can help in understanding the problems and bridging in the gap between demand and supply. All the technical and financial constraints need to be thoroughly examined. Based on the data above a study was designed to analyse the economics and constraints in the production of rapeseed mustard crop by the growers during agriculture year 2022 and 2023 (Rabi Season). Primary data was collected from 60 growers of Jammu District from a cluster of 6 villages from three blocks. Very few studies have been conducted in the past to examine the production and marketing of rapeseed mustard in Jammu district and so looking to the above facts, a study was essential to undertake a detailed insight into economics and constraints of production of rapeseed-mustard in the district with the following specific objectives: 1. To estimate the cost and return of rapeseed mustard cultivation in the sampled households. 2. To identify the major constraints in production and marketing of rapeseed-mustard

2. Material & Methods

Cost of cultivation

To work out the cost of cultivation standard method of cost of cultivation employed by Commission on Agricultural Costs and Price (CACP), Directorate of Economics and Statistics, Government of India was adopted. To estimate the marketable surplus of produce, total quantity used for different purposes was estimated as under: $MS = P - (C + W + Cf)$

Where, MS – Marketable Surplus

P – Total Production

C – Family Consumption

W - Quantity use for Wage

C f – Quantity used for cattle feed

Constraints faced by rapeseed-mustard growers related to production were prioritized by using Garrett Ranking Technique

3. Results and Conclusion

Yield, cost and return and marketable surplus of rapeseed-mustard at the sampled farms. The yield, value of output per hectare and cost of production per quintal of rapeseed-mustard on the sample farms have been worked out in table 1 and 2. It indicates that the average yield per hectare of rapeseed-mustard came to 19.81 qtl./ha. where higher yield was found at medium farms (20.30 qtl./ha.) and the lowest was observed at marginal farms (19.28 qtl./ha.). The average gross return estimated was Rs. 95104/ha which varies from Rs. 92544/ha. at marginal farms and Rs. 97440/ha. at medium farms. The average net return was calculated as Rs. 45917/ha which varies from Rs. 43824/ha. at marginal farms and Rs.47560/ha. at medium farms. The average cost of production was calculated as Rs. 49187/ha. The marketable surplus of rapeseed-mustard was observed as 1.15 quintal, 1.92 quintal and 2.71 quintal per farm of marginal, small, and medium farms respectively. The average marketable surplus of rapeseed-mustard was found to be 1.92 quintal per farm. Out of all major problems identified for rapeseed-mustard cultivation, were lack of improved varieties of seed which ranked first with Garrett score of 75.04 followed by agro-ecological constraints with Garrett score of 73.59. Lack of market information had occupied the 3rd position with Garrett score of 68.52.

Table 1: Yield, cost and return of rapeseed-mustard on the farmers field (Rs./ha).

S. No.	Particulars	Farm size			
		Marginal	Small	Medium	Average
1.	Yield (Q/ha)	19.28	19.86	20.30	19.81
2.	Gross return (Rs)	92544	95328	97440	95104
3.	Net Return (Rs.)	43824	46368	47560	45917
4.	Cost of Production (Rs/Qtl)	48720	48960	49880	49187

Table 2: Marketable surplus of rapeseed-mustard of sampled households. (In quintal per farm)

S.No.	Particulars	Farm size			
		Marginal	Small	Medium	Average
1.	Total quantity of seed produced	1.20	2.00	2.80	2.0
2.	Quantity retained for seed	0.01	0.02	0.03	0.02
3.	Quantity used for home	0.04	0.06	0.06	0.05
4.	Total quantity utilised	0.05	0.08	0.09	0.07
5.	Marketable surplus	1.15	1.92	2.71	1.92

The constraints faced by the sample farmers across study area and among different categories of farmers were identified, ranked and presented in table 3. Out of all major problems identified for rapeseed-mustard cultivation, were lack of improved varieties of seed which ranked first with Garrett score of 75.04 followed by agro-ecological constraints with Garrett score of 73.59. Lack of market information had occupied the 3rd position with Garrett score of 68.52. The other problems associated with rapeseed-mustard production were low market price, high cost of inputs, High transportation cost, insect pest and weed management and non availability of crop insurance scheme, lack of cooperatives, High fluctuation in market prices and non availability of labour in the season respectively. The study suggested that urgent attention must be paid towards enhancing the productivity and marketing of rapeseed-mustard by providing improved and high yielding varieties, technology, irrigation, price support and effective extension.

7.12 Influence of Climate Variability on Apple Scab Infection Dynamics and Development of a Novel Decision Support System for Temperate Himalayan Agroecosystems

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Keywords: Apple scab; *Venturia inaequalis*; climate variability; infection dynamics; Ascospore release; disease forecasting.

1. Background

Apple (*Malus domestica*) is one of the most important fruit crops grown in the Himalayan region of India, especially in Jammu and Kashmir, where Horticulture economy of whole state is dependent on Apple. However, apple production in this region is heavily affected by apple scab, a disease caused by *Venturia inaequalis*, which is widely recognized as one of the most damaging diseases of apple worldwide. The development of this disease is closely linked to environmental conditions such as temperature, rainfall, humidity, and the duration of leaf wetness. With changing climate patterns, these factors are becoming more variable, making it increasingly important to understand how climate influences disease outbreaks. With this, this study aims to investigate how climate variability affects apple scab infection dynamics in Kashmir Region

2. Material and Methods

This study was carried out in apple orchards located at experimental sites of SKUAST Shalimar. The hourly weather data was collected on temperature, rainfall, relative humidity, leaf wetness, and wind parameters, allowing us to capture the microclimatic conditions within apple orchards. Additionally data on ascospore activity was also recorded from 2024 to 2025. The data is further statistically analyzed to identify periods when environmental conditions were favourable for infection and examined how different climatic factors influenced disease development. Statistical methods were used to explore relationships between weather variables and ascospore activity, which is a key indicator of infection risk.

3. Results and Conclusion

From the results it is revealed that the Infection risk generally began in late February to early March, as temperatures gradually increased and moisture became available after winter. The risk rose quickly during March and reached its peak between late March and mid-April. This critical period was characterized by moderate temperatures (around 10–15°C), frequent rainfall events, and prolonged leaf wetness, creating highly favourable conditions for disease development. The highest ascospore activity was observed during mid-April (Weeks 15–16), with peak counts of 28 spores in 2024 and 30 spores in 2025. Among all climatic factors, rainfall emerged as the most important driver of infection, showing a strong positive relationship with ascospore activity. Rainfall events not only triggered spore release but also resulted in extended leaf wetness periods, sometimes lasting from 10 to 100 hours, which significantly increased the likelihood of infection. Although temperature was not the primary trigger, it played an important role in determining how efficiently infections occurred, with the most favourable range being 10–18°C, where shorter wetness durations were sufficient for infection. Relative humidity also contributed by maintaining moist conditions, although its effect was less pronounced compared to rainfall. The study further highlighted noticeable year-to-year variations, reflecting the influence of climate variability. For

instance, in 2025, infection began slightly earlier and persisted longer than in 2024 due to more favourable spring weather conditions.

These findings underline the importance of identifying critical infection periods, particularly between late March and mid-April, which consistently showed the highest risk. Focusing disease management efforts during this window can greatly improve control efficiency. Overall, the study demonstrates that apple scab dynamics in the Himalayan region are strongly influenced by climatic factors, especially rainfall and temperature, and emphasizes the value of weather-based forecasting systems for timely, efficient, and sustainable disease management.

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7.13 Front Line Demonstrations: An Effective Tool for enhancement of Mash (*Vigna mungo*) productivity under Intermediate Zone of Rajouri District

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Keywords: Mash, Rainfed, Yield, Economics, mid-hills, Rajouri

1. Background

Mash (*Vigna mungo* L.) commonly called as *Urad*, is the most important pulse crop in India. India is its primary origin and is mainly cultivated in Asian countries including Pakistan, Myanmar and parts of Southern Asia. About 70 per cent of the world's mash production comes from India. India is the world's largest producer as well as consumer of black gram. Blackgram area accounts for about 19 per cent of India's total pulse average which contributes 23 per cent of total pulse production (Mash Outlook report, 2021). It contains about 20% protein, which is almost three times that of cereal and other minerals and vitamins. In pulse crops there are a number of diseases, insect and pest, which cause heavy losses resulting in poor production. The productivity of black gram per unit area could be increased by adopting improved practices in a systematic manner along with high yielding varieties (Rai *et al.*, 2015).

Yield of pulses has declined over last few decades as these are primarily grown on marginal and infertile dry lands; whereas the fertile and irrigated belts are focused to grow maize/rice/wheat or other economical crops. The yield of mash is quite low in the hilly region; which might be mainly due to policy negligence and some other reasons. Mash is one of the major pulse crop grown in the mid hills of Rajouri district of Jammu and Kashmir, sown in *kharif* season. The scientists of KVK, Rajouri worked hard to convince the farmers of this hilly district to grow mash.

2. Materials and Methods

Present study carried out in the adopted villages (10 nos.) and front line demonstrations conducted in *kharif* 2022, 2023 and 2024 at the farmers' fields in Nowshera, Seri and Rajouri blocks of district Rajouri. Improved varieties of mash seed provided to the farmers along with other scientific know how and knowledge of improved management of mash which includes various production technologies, insect-pests and disease management, *etc.* About 176 FLDs conducted in 21.10 hectares area at different locations of district Rajouri. Locally cultivated varieties were used as local check. Scientists conducted a base line survey regarding the various management practices, plant protection measures and other techniques which were adopted by the local farmers. Farmers on the other hand were permitted to carry out their own practices as a local check. Field days, farmers' scientist interaction meetings conducted at the villages to learn about the benefits of the varieties and technologies on display. The data on several parameters were gathered separately from both improved and farmers' practices.

3. Results and conclusion

In all the years (*kharif* 2022, 2023 and 2024) under study, yield of mash was higher in demonstrated fields than in the local practice. It was observed from the three years data that better technical intervention lead to 31.9% higher mash production to the tune of 4.34 q/ha as compared to 3.39 q/ha recorded with the farmers practice. This yield increase in demonstration plot might be due to recommended production technology and various other scientific interventions followed

under the supervision and technical guidance of the KVK's scientists. The usage of improved and recommended variety of mash (Mash-114 and PU-31), proper seed treatment, recommended dose and proper time of fertilizer application under FLDs enhanced the yield of mash as compared to the farmers' practices. A higher net returns of Rs. 20802/-ha and a B:C ratio of 1.50 was noted in demonstration plots as compared to the farmers' practice which amounted to Rs. 13947/-ha and 1.13, respectively. However, interventions made through front line demonstrations accrued an enhancement of 49.1 per cent as compared to the income under farmers' practice.

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Theme 8:

Market Linkages, Agri- Entrepreneurship, Startups, and Sustainable Food Systems



8.1 Evaluation of NABARD-Sponsored Farmer Producer Organizations in Jammu and Kashmir: Implications for Market Linkages and Agri-Entrepreneurship

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Keywords: Farmer Producer Organizations, Market Linkages, Production

1. Background

Farmer Producer Organizations (FPOs) have gained prominence in recent years as an institutional mechanism for addressing structural challenges faced by small and marginal farmers, particularly in relation to market access, and price realization. By enabling collective production, aggregation, and marketing of agricultural produce, FPOs aim to strengthen farmers' bargaining power, reduce transaction costs, and enhance participation in organized markets. In the context of Indian agriculture, FPOs are increasingly viewed as instruments for promoting agri-entrepreneurship and improving the economic sustainability of farming systems.

In Jammu and Kashmir, agriculture is characterized by small landholdings, limited market integration, and dependence on traditional marketing channels, which often constrain farmers' ability to obtain remunerative prices. NABARD-sponsored FPOs have been promoted in the region to facilitate collective marketing, improve access to inputs and services, and create stronger linkages with markets. While policy initiatives have emphasized the expansion of FPOs, empirical assessment of their performance and impact on farmers' economic outcomes remains limited, particularly at the regional level.

Against this background, the present study evaluates the effectiveness of NABARD-sponsored Farmer Producer Organizations in Jammu and Kashmir with a focus on their impact on production economics and market access of Mushqbudji growing farmers. The study seeks to generate empirical evidence on the role of FPOs in strengthening market linkages, thereby contributing to the discourse on agri-entrepreneurship and economically sustainable food systems.

2. Material and Methods

The study was conducted in Anantnag district of Jammu and Kashmir, where one of NABARD-sponsored Farmer Producer Organization namely Sagam Mushqbudji Farmer Producer Company Ltd. is operational. A multistage sampling technique was adopted, and 40 FPO members were selected for the study. Primary data was collected using a structured and pre-tested interview schedule. The impact of FPO membership was assessed by comparing key indicators related to cost of cultivation, price realization, and market access before and after joining the FPO. Market access was analyzed in terms of marketing channels, number of buyers contacted, and distance to market. The collected data was analyzed using descriptive statistics.

3. Results and Conclusion

The results indicated a significant improvement in the economic performance of farmers after joining NABARD-sponsored FPOs. The average selling price of paddy increased from ₹5,208.33 per quintal before joining the FPO to ₹14,200 per quintal after joining. Market access indicators also showed substantial improvement. The average number of buyers contacted increased from 2 to 4, while the average distance to market declined from 9 km to 6 km, reflecting improved accessibility and reduced dependence on local intermediaries. Despite these positive outcomes, farmers reported several constraints in the functioning of FPOs. Major constraints included

inadequate storage and transport facilities (68.3%), delayed payments (54.2%), limited managerial efficiency (47.5%), and insufficient access to timely market information (43.3%). The respondents suggested strengthening infrastructure facilities, improving professional management, and enhancing institutional support to improve the effectiveness and sustainability of FPOs. The study demonstrates that NABARD-sponsored Farmer Producer Organizations have contributed significantly to improving price realization, and market access of Mushqbudji growing farmers in Jammu and Kashmir. Collective marketing through FPOs has reduced farmers' dependence on intermediaries, expanded their market reach, and enhanced economic efficiency. Despite these positive outcomes, constraints related to infrastructure, managerial capacity, and timely payments continue to limit the full potential of FPOs. Strengthening institutional support, improving market-related infrastructure, and promoting professional management within FPOs are essential to ensure their long-term viability. Overall, FPOs emerge as an effective institutional mechanism for strengthening market linkages and promoting agri-entrepreneurship, thereby contributing to economically sustainable farming systems in the region.

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8.2 Availability of Public and Private Agricultural Extension Services for Vegetable Cultivation: An Empirical Study from Punjab

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Keywords: Availability, Extension Services, Public, Private, Vegetable Cultivation

1. Background

Agriculture remains vital to India's economy by ensuring food and nutritional security, employment, and rural livelihoods, despite its declining share in gross value added. Agricultural extension services are central to enhancing productivity, profitability, and sustainability by transferring scientific knowledge and innovations to farmers. In Punjab, vegetable cultivation has emerged as a key diversification strategy due to its high income potential and nutritional importance, but it is highly knowledge- and input-intensive, increasing farmers' dependence on effective extension support. Limitations of the public extension system have encouraged greater participation of private organizations, leading to a pluralistic extension framework. However, empirical evidence on the availability and nature of public and private extension services in vegetable cultivation in Punjab remains limited, necessitating the present study.

2. Material and Methods

The study was conducted in Punjab state. Two districts with maximum area under vegetable cultivation were selected purposively i.e. Ludhiana and Malerkotla. All extension organizations actively engaged in agricultural extension activities in the selected study area were identified through a preliminary survey. A total of 53 organizations were identified, comprising 19 public and 34 private organizations. Extension Organizations were divided into two sub parts i.e. public and private. Public organizations included the State Departments of Agriculture, State Agricultural University, Krishi Vigyan Kendras (KVKs), cooperatives, corporations, public sector banks, etc. Private organizations comprised input supply companies, contract farming firms, marketing companies, and private banks, etc. From these organizations, a total sample of 120 officials was selected i.e. 60 from public and 60 from private organizations to identify the problems faced by them while delivering various extension services. To ensure adequate representation, a minimum of 2 officials from each organization were included, subject to their availability and willingness to participate. Primary data were collected using a structured interview schedule developed specifically to capture the availability of different agricultural extension services.

3. Results and Conclusions

The results reveal a clear differentiation in the nature and scope of extension services provided by public and private organizations. Private organizations dominated service provision in vegetable cultivation, particularly in input supply, advisory services, training, publications, and ICT-based dissemination, reflecting their service-specific and market-oriented approach. In contrast, public, cooperative, and corporate organizations were fewer in number but offered relatively diverse services under a single institutional framework. Input and advisory services were largely privatized, indicating increasing commercialization of extension delivery. Farm machinery, processing, storage, and marketing services were generally weak across all categories, highlighting poor

forward and backward linkages within the extension system. ICT-based services showed overwhelming private sector dominance, demonstrating rapid digitalization of private extension. Public organizations, though constrained by manpower and operational limitations, provided broader subject coverage in training and publications. Both public and private extension personnel faced significant constraints, including heavy workload, manpower shortages, institutional rigidity, farmer-related challenges, and limited capacity-building opportunities, adversely affecting effective service delivery.

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8.3 Women-Led Self-Help Groups as Sustainable Micro-Enterprises: Marketing Practices and Structural Constraints

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Keywords: Climate-smart agriculture; climate resilience; Agroecosystems; Himalayan agriculture; Rainfed farming; Sustainability

1. Background

Women-led Self-Help Groups (SHGs) have become an integral component of India's rural development architecture, particularly in the context of inclusive growth and women's economic empowerment. Initially conceptualized as collective savings and credit institutions, SHGs have gradually evolved into grassroots entrepreneurial units engaged in diverse income-generating activities. In recent years, many SHGs have moved beyond financial intermediation to undertake value addition, food processing, and small-scale production, thereby contributing directly to household income diversification and local economic resilience.

In hill states such as Himachal Pradesh, where geographical constraints and limited industrial presence restrict formal employment opportunities, SHG-based micro-enterprises play a crucial role in livelihood sustenance. Women's participation in food value addition not only enhances household income but also strengthens their decision-making capacity and social visibility within rural communities. However, the transition of SHGs from subsistence-oriented production units to sustainable micro-enterprises depends largely on their marketing systems, institutional support structures, and infrastructural accessibility.

Enterprise sustainability in rural contexts is closely linked with market integration, logistical efficiency, access to timely information, and institutional guidance. The nature of marketing channels adopted by SHGs determines their price realization and market reach, while transportation facilities influence delivery efficiency and geographical expansion. Similarly, extension contact and mass media exposure shape awareness regarding branding, packaging, consumer preferences, and emerging market opportunities. Inadequate institutional linkage or limited information flow may confine enterprises to localized markets, thereby restricting growth potential.

Despite the increasing recognition of SHGs as engines of rural entrepreneurship, empirical examination of their marketing structures and operational conditions remains essential for understanding the constraints that influence their long-term sustainability. Against this backdrop, the present study analyses the marketing practices, transportation arrangements, extension contact, and mass media exposure of women-led SHGs in Hamirpur district of Himachal Pradesh to understand the structural conditions shaping their enterprise functioning.

2. Material and Methods

The study was conducted in Hamirpur district of Himachal Pradesh and selection of respondents was carried out through complete enumeration. In the Hamirpur district, there are a total of 2,436 Self-Help Groups (SHGs), were engaged in different occupations such as tailoring, handicrafts, and related enterprises. Out of which 218 were identified as actively involved in agricultural activities 103 were found to be specifically involved in value addition of food products. For the present study complete enumeration was followed by and all 103 SHGs selected for the study. Each SHG was treated as a single sampling unit, resulting in a total of 103 Sampling unit

associated with food product value addition being included in the study. Primary data were collected through structured interviews using a pre-tested schedule. Descriptive statistical tools were employed to analyze marketing channels, transportation practices, institutional exposure and operational constraints influencing enterprise sustainability.

3. Results and Conclusions

The findings reveal a pronounced dominance of localized marketing structures. A substantial majority (88.35%) of SHGs adopted the Producer-Consumer channel, reflecting reliance on direct selling and short value chains. While this approach enables immediate cash realization and closer customer interaction, it also suggests limited integration with formal and distant markets. Multi-tier channels involving retailers and wholesalers were comparatively less adopted, indicating restricted market penetration. The use of online platforms was minimal, highlighting limited digital engagement and weak participation in emerging e-commerce opportunities. Transportation patterns further reveal infrastructural constraints. About 66.02 per cent of SHGs relied on public transportation for product delivery, whereas only a small proportion owned or hired vehicles. Dependence on public systems reflects limited asset ownership and operational flexibility, potentially affecting timely delivery and restricting expansion beyond local markets. Institutional and informational exposure remains moderate. Around 58.25 per cent of SHGs reported medium levels of extension contact, while only 3.88 per cent exhibited high contact. Similarly, 62.14 per cent demonstrated medium mass media exposure, with a negligible proportion under the high category. The limited presence of SHGs in the high-contact and high-exposure categories suggests constrained access to advanced market information, branding support, and digital marketing opportunities. Collectively, these patterns indicate that enterprise operations remain largely localized and resource-constrained.

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8.4 Women markets: Its linkages and product chain system in Imphal valley, Manipur

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Key-words: Economy, Markets, Products, Transportation, Women.

1. Background

Markets form an integral part of the socio-economic and cultural landscape of any region. The market system of Imphal valley has unique features and is exclusively run by the womenfolk only. Situated at the heart of the state capital, Imphal, the '*Ima Keithel*' is the largest women market in India. The word '*Ima*' means Mother and '*Keithel*' means Market in Manipuri language. Women of Manipur are renowned for their economic participation and contribution to the overall economy of the state. The numerous markets jutting the Imphal valley also act as a social institution with the women market vendors playing an active role in socio-economic and political affairs of the state (Devi, 2012). The nature and dynamics of participation in different markets and financial contribution of the Manipuri women vendors are more noticeable in and around the Imphal valley of the state. The socio-economic conditions of the women vendors vary due to their differences in educational level and their work skill. The demand and supply of products among the major markets of Imphal valley has unique linkage system. The women market vendors nonetheless are facing different kinds of challenges that adversely affect their livelihood. The market structure of developing countries has significant role on economic growth, distribution of income, production and distribution of agricultural commodities (Miracle, 1970). The study attempts to measure the linkages system of different markets of Imphal valley and product supply chain system and services. The research work also to explore the better understanding of the financial condition of the women vendors as well as influence of Information and Communication Technology (ICT) and digital marketing system among the women market vendors who are mostly illiterate and unskilled. In the context of Manipur, market is not only a workplace for socio-economic empowerment of the women community but also way of life.

2. Materials and Methods

The study is based on both primary and secondary data sources. The secondary data published by various government departments and agencies of both central and state government have been used. The primary data have collected through questionnaires, Focus Group Discussion (FGD), personal interview of women vendors, economists and emerging young entrepreneurs in the field of agriculture. For locational analysis of market places and transportation network of the product supply chain system using GIS and Google Earth maps. The methodology adopted for this study is descriptive research design to describe the linkages and product chain system of women markets in Manipur.

3. Result and Conclusion

The contribution of Manipuri women in economic affairs of the family and society are very significant and not less by any means from their counterpart men in prevailing patriarchal society. All major and minor markets of the different districts of the Imphal valley are permanent or daily market type. Generally, most of the markets of Imphal valley are located at junction of routes, along the highways and near water bodies. All the markets are closely inter-related to each other in numerous ways such as mobility pattern of the women market vendors, product supply chain flows

among the markets. Women who do not get service in organized sector usually try to find jobs at available market for livelihood earning for themselves and their dependents. The products of women markets are mostly local and indigenous products. Especially, vegetables mainly produce from fertile soils of riverine areas of the valley and fishes both fresh and dry produce from Loktak Lake in Bishnupur district. Hence, markets in the valley has huge prospect for economic empowerment of Manipuri woman. The number of rural-urban migration is increasing among the women vendors mainly for business purposes. The role of Information and Communication Technology (ICT) is also significant for the effective functioning of these markets (i.e. e-marketing, digital money transfer, online payment and e-banking etc.). Further, the financial benefit schemes provided by central/state government and business loans by the banks to the women vendors are not accessed properly due to lack of financial literacy and awareness. The differential educational level, rural-urban divide, transportation, lack of parking system in major markets areas, congestion, lack of sanitation and garbage facility in market places, bandh-blockade on national highways, impact of globalization, increasing numbers of unemployment, intensive labor, mental and physical stress at workplace are the major challenges faced by the women vendors. Women of Manipur are also actively involved in socio-political issues of the state through various movements which are mainly supported from major markets of the valley districts. The study highlighted that the management of environment pollutions and hazard materials in sustainable ways is utmost necessary action to be need in marketplaces. These findings of the study will be very helpful to implement the policy programs of market management and economic development strategy of the state.

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8.5 Factors Influencing Farmers' Decision in Selling Their Surplus Rice at Procurement Centres in Jammu Region

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Keywords: Jammu region, Procurement centres, rice

1. Background

Food grain procurement is one of the important elements for implementation of food management policy of the Government of India (GoI) and for catering to the need of public consumption of food grains in the country. In the Union territory (UT) of Jammu and Kashmir (J&K), there was no established policy for procurement of rice at MSP prior to 2010. This impelled the authorities in the J&K Agriculture Production Department (APD) to intervene and involve the FCI in setting up temporary PCs in the districts of Jammu, Kathua and Samba. In 2011-12, government of J&K has established six PCs at different locations for rice procurement and the total procurement of rice at these PCs during *kharif marketing season* (KMS) 2011-12 was 19722.10q. In 2023, the number of PCs were increased by eleven with a total procurement of 335787.38q. A pilot study was conducted in 2023 by revisiting the farmers who sold their surplus rice at PCs in 2011-12 to see the impact of PCs on rice procurement. The present study explores the factors that contribute in selling the surplus rice of farmers at the government established PCs.

2. Material and Methods

The study was purposively conducted in Jammu, Samba and Kathua districts of Jammu region as PCs for rice procurement were set up in these districts only. The data was conducted in 2023 from the farmers with the help of personal interview method.

3. Result and Conclusion

To identify the factors affecting farmers' decision in selling their surplus rice, binary logistic regression analysis was employed. Out of seventeen independent variables namely, age, education, possession of a mobile phone, registration in the procurement portal, farming experience, distance from the market, distance from the PC, satisfaction with the functioning of the PC, satisfaction with the location of the PC, main occupation, possession of KCC, land holding, total production, sale rate of coarse grain at the PCs, profitability of cultivating coarse rice, proximity of the PC to the home and assured payment were selected out of which four variables i.e. satisfied with the functioning of PC ($p=0.000$), possession of KCC ($p=0.003$), land holding ($p=0.001$) and total production ($p=0.000$) were found statistically significant (Table 1). The R^2 value of 0.786 indicates that 78.6 per cent variation in selling marketable surplus of rice at PC was caused by these variables. Satisfaction with the functioning of PCs and total production showed a positive and significant influence on selling at PCs, whereas possession of KCC and landholding size exerted a significant negative influence on the decision to sell at PCs. These findings are consistent with those of (Alam *et al*, 2013) who revealed that high price of coarse rice at procurement centres significantly influences farmers to sell their rice surplus at PCs.

Table 1: Factors affecting rice procurement at procurement centres

Variables	B	S.E.	Wald	df	P value	Model Summary
Constant	-4.134	1.221	11.462	1	0.001	-2 log likelihood- 57.217 a Nagelkerke R Square 0.786
Satisfied with functioning of PC	4.383	1.106	15.695	1	0.000	
Possession of KCC	-2.260	0.750	9.081	1	0.003	
Land holding	-1.991	0.583	11.663	1	0.001	
Total production	0.097	0.024	16.633	1	0.000	

Significant at 5% level of significance

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8.6 Empowering Punjabi Youth: The Role of Documentary Films in motivating young wards of Farm Families towards Agri-enterprises

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Keywords: Documentary films, case studies, agri-entrepreneurs, potential entrepreneurs, validation, etc.

1. Background

Agri-entrepreneurship can create value for primary agriculture and make it more attractive for the younger generation to stay in this sector. It also has the capability to generate growth, reduce poverty, generate employment and improve nutrition as well as food security (Uplaonkar and Biradar 2015). Punjab, historically regarded as the "Granary of India", is currently confronting a severe problem as rural youngsters gravitate to urban careers, considering agriculture a less viable and less respectable profession. This transformation puts Punjab's agriculture sector's sustainability and modernization at risk. In this context emphasis on documenting the experiences of agri-entrepreneurs has become crucial for understanding the challenges, successes and innovations within the sector. Documentary filmmaking has risen dramatically during the last few decades due to its ability to change attitude and perception and stimulate action. The documentation of the entrepreneurs and enterprises through case studies and documentary films can serve as a powerful medium to capture the dynamic and evolving nature of agricultural entrepreneurship in the region (Levie et al 2010). Hence, the present study was conducted to document successful agri-entrepreneurs in order to motivate potential users of the state to opt for agriculture and the allied sector as a profession. Such documentation not only helped to celebrate the achievements of individuals contributing to the agricultural renaissance of the region but also acted as a source of inspiration and guidance, change perception, and stimulate the interest of young generations towards agri-enterprises.

2. Material and Methods

The study was carried out in Punjab state using a structured, multi-stage approach. Purposive sampling technique was used for the identification and selection of information- rich cases for conducting case studies and documentary films. Ten successful agri-entrepreneurs were identified for detailed case studies using predetermined criteria, including enterprise growth, innovation, infrastructure, motivating value, and success rate. For documentary production, five out of the ten entrepreneurs were selected based on their availability and consent for filming videos. The selected entrepreneurs were from five food crop categories viz., Fruits and vegetables processing (Zaika Products), Cereals and millets processing (FarMative), Oilseeds processing (Ekam Agro Processing), Pulses processing (Khalsa Soy Foods) and Sugarcane processing (SardarJi Gur).

Individual scripts for each enterprise were developed through systematic planning involving research on entrepreneurs, concept development, filming, interviews, voice-over recording, editing and background music design. The documentaries were validated through content, predictive, and product validation by experts and potential entrepreneurs and the data were analyzed using descriptive statistics such as mean scores and ranking.

3. Results and Conclusions

Content and Predictive Validation

Results revealed that Video I (Zaika Products) got highest overall mean (3.70) indicating that it is perceived best for its content. However, overall mean of all the videos for content validity was above 3.46, which indicated appropriateness of the content, relevance, clarity, and presentation quality of all the videos. These findings can help in understanding the strengths and weaknesses of each video and guide decision-making for selection and usage for specific purposes.

For predictive validity, Video 1 (Zaika Products) and video 2 (FarMative) have the highest mean score (4.80) for motivating budding entrepreneurs to overcome challenges. Video 5 (Sardar Ji Gur) has the highest mean score (4.60) for providing a deeper understanding of the potential rewards of agri-entrepreneurship, suggesting that it offers valuable insights into the benefits of pursuing agricultural ventures. The highest mean score (5.00) obtained by Video 3 (Ekam Agro Processing) for inspiring and promoting action in the desired direction, indicating that it motivates the trainees to take positive steps to start agri enterprises.

Product Validation by Potential Entrepreneurs

Overall mean for Product validity was 2.55 (out of 3) which shows that respondents agreed with the potential of videos in motivating the youth of rural Punjab. The two statements that got rank I. First is that documentaries motivated viewers to delve into agriculture. This is significant as it shows that videos have been successful in inspiring people to think about farming as a potential career and another was that the documentaries provoked the desire to meet the successful entrepreneurs for seeking more knowledge. This shows overall positive influence on potential agri-entrepreneurs. The next closely followed statement was that these films encouraged individuals to start their own agricultural businesses (Rank II) which again depicts the impression videos have created about agri-entrepreneurship.

The findings concluded that documentary films can serve as an effective tool for agricultural extension and youth motivation. By showcasing real life success stories of local agri-preneurs, the documentaries potentially ignited interest toward agri-entrepreneurship among rural youth.

Table 1: Overall Validation Scores of Documentary Films in terms of content and predictive validity

No. of videos	Content Validity Assessment (Mean Range 1-4)		Predictive Validity Assessment (Mean Range 1-5)	
	Overall Mean	Rank	Overall Mean	Rank
Video I- Zaika products (Fruits & vegetable)	3.70	1	4.57	3
Video II- FarMative (Cereals & millets)	3.57	2	4.69	1
Video III- Ekam Agro Processing (Oilseeds)	3.46	5	4.60	2
Video IV- Khalsa Soy Foods (Pulses)	3.56	3	4.47	4
Video V- SardarJi Gur (Sugarcane)	3.50	4	4.45	5

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8.7 Constraints in the Production and Marketing of Kaladi in Jammu and Kashmir

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Keywords: Kaladi, Constraints, Production, Marketing

1. Background

Dairy farming provides supplementary and often year round income for smallholders, landless labourers and especially women, making it a key livelihood strategy in rural India (Vekariya *et al.* 2021). Traditional and small-scale processing of products like dahi, ghee, khoa, pedha, paneer, shrikhand etc. creates local employment and profitable value addition opportunities for village women and self-help groups (Brown *et al.*, 2022). In Jammu and Kashmir, Kaladi is a well-known indigenous milk-based product predominantly produced in the Chenani and Ramnagar regions of Udhampur district. It is traditionally prepared from buffalo milk and commonly consumed in the form of Kaladi Kulcha, which has become a popular street food and regional delicacy. The product has also received a Geographical Indication (GI) tag in 2023 and remains an authentic handcrafted product reflecting culture and tradition of the region. Despite its growing popularity and demand, the production and marketing of Kaladi remain largely unorganized and reliant on traditional practices. The value chain dominated by producers faces several operational and marketing challenges that limit market expansion and profitability which have been considered for this study.

2. Materials and Methods

The study was conducted in Udhampur district of Jammu and Kashmir, the recognized place of origin of Kaladi. The Chenani and Ramnagar blocks were purposively selected due to their prominence in Kaladi production and their recently recognized GI status. Primary data were collected from 100 Kaladi producers using a pre-tested structured questionnaire. A convenience sampling technique was adopted, selecting 50 respondents from each block. Garrett Ranking technique was the used for analysing the constraints faced by the stakeholders for preparation and marketing of Kaladi, the formula for which is as follows;

$$\text{Percent position} = \frac{(R_{ij} - 0.5)}{N_j} \times 100$$

where,

R_{ij} = Rank given for i^{th} constraint by j^{th} individual and

N_j = Number of constraints ranked by the j^{th} individual

3. Results and Conclusion

The study revealed that the Kaladi value chain faces several production and marketing constraints that affect the efficiency and expansion of the enterprise.

The most critical constraint in the production process as identified was the very short shelf life of Kaladi (with average score of 77.84) limiting its storage and transportation to distant markets. Other significant constraints included the lack of high-quality milk, weather-related factors affecting production, limited storage facilities and issues related to milk quality and consistency.

On the marketing side, lower market prices emerged as the most significant constraint, ranking first with an average score of 70.66 followed by exploitation by middlemen (61.28), which reflects inefficiencies and unequal bargaining power within the marketing system. In comparison, high transport charges and losses during transportation were perceived as relatively less severe constraints by the producers. Therefore, addressing these challenges through improved preservation techniques, enhanced storage infrastructure and the development of more organized and transparent marketing systems can significantly improve market access and profitability for Kaladi producers.

Table 1: Production Constraints faced by producer

S.No.	Constraints	Average Score	Rank
1	Limited Shelf life	77.84	I
2	Lack of storage facilities	34.46	VIII
3	Inadequate milk quantity	49.12	V
4	Lack of high quality milk	67.50	II
5	Adulteration in milk	36.78	VII
6	Lack of production facilities	47.16	VI
7	Weather constraints	56.92	IV
8	Moist product receiving lower price	60.62	III

Table 2: Marketing constraints faced by the producers

S.No.	Constraints	Average Score	Rank
1	High transport charges	41.64	V
2	Losses in transportation	38.12	VI
3	Lack of processing units	52.26	III
4	Exploitation by middleman	61.28	II
5	Lower market prices	70.66	I
6	Unorganised marketing	48.88	IV

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8.8 Innovative Agri-Enterprises: Catalysing Resilience against Climatic adversities and shock in Dharashiv district, Maharashtra

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Keywords: Innovative technologies, Agro based enterprise, climate resilience agriculture, rural development, regional diversities

1. Background

Agri-entrepreneurship emerges as a vital catalyst for fostering climate-resilient agriculture amid escalating environmental challenges such as erratic monsoons, soil degradation, and extreme weather events in regions like India's rain fed agrarian belts. This study explores innovative entrepreneurial models that empower smallholder farmers to adopt resilient practices, including drought-tolerant seed varieties, precision irrigation systems, and diversified cropping with agroforestry integration. Dharashiv (formerly Osmanabad) district in Maharashtra hosts several agri-based innovative enterprises, driven by collectives, tech pilots, and women-led groups amid semi-arid challenges like drought and soil degradation.

2. Material and Methods

By leveraging digital platforms for market linkages and value-added processing—such as organic vermin-compost production and climate-smart sericulture—agri-entrepreneurs can enhance farm incomes by 25-40% while reducing vulnerability to climate shocks. There are various innovative models of the agri based enterprises, such as tech driven initiatives, floriculture producer groups, women led ventures etc. The paper is based on the secondary data sources, where the successful models of Dharashiv (Osmanabad) has been studies and documented.

3. Results and Conclusion

It was reported in Hindustan times, in 2015, In Osmanabad, a district that is seen as the epicentre for farmer suicides (59 this year), these groups are setting a new trend. The district has 14,620 registered groups with 2.88 lakh farmers as its members that sell everything from cauliflower and tomato to gerberas directly to the market. There are various tech-Driven Initiatives, these are, Upla village runs India's first AI soybean pilot (2025, Rahuri Krishi Vidyapeeth): Weather stations and soil sensors deliver real-time alerts via mobile, optimizing yields for 100+ farmers, ICRISAT's 2023 project in nearby Latur (bordering Dharashiv) restored degraded lands via sustainable intensification, boosting productivity through mixed cropping. Floriculture and Producer Groups are, Padoli village's Lok Kalyan group (12 floriculturists) earned Rs 50 lakh profit in 2014 from 1.5 lakh gerbera flowers across 5 acres in polyhouses, sold to Hyderabad/Delhi markets. Dharashiv Osmanabad Vegetable FPC (reg. 2018) trains in pearl culture, hydroponics, mushroom, and organics; supports urban veggie clusters under VIUC scheme. There are also 28 farmers companies set up under Registration of Companies Act that sell agriculture goods, equipment and function as agents for agriculturists. The Women-Led Ventures are Narishakti Women FPC and Madhuri Jadhav (SSP-supported): Shifted to organic one-acre models with vermicompost/Azolla, selling value-added produce/milk for household gains. Suresh Lakhe's Pargaon agri-input shop supplies low-cost materials locally, generating lakhs in rural revenue. These align with RKVY agri-preneurship programs for youth employment.

Apart from the, adaptation to Climate Challenges, raising donkeys fits seamlessly into climate-adaptive farming, as these tough animals endure dry spells in India's countryside with little water or fodder, while their manure serves as natural soil enricher. Organiko's chemical-free methods promote eco-friendly supply networks, cutting reliance on synthetic inputs and improving land fertility through waste reuse—crucial for drylands in Maharashtra. Organiko - Beautifying Life stands out as a pioneering rural enterprise in India, started by TISS Tuljapur alumni and mentored by the author, in 2018. It converts donkey milk into high-end natural cosmetics, such as soaps and facial masks. There is another Pune-based entrepreneur launched India's first private equine semen lab in 2021, using ICAR-NRCE tech for cryopreservation and AI, producing over 1,000 frozen semen straws from top lineages. Niche areas for the agriculture and allied based enterprises in the climatic challenging areas, include equine milk for medicinal/ cosmetics, vermin-compost from dung, and tourism safaris etc. On another side, there are challenges too in the emerging equine sectors, such as population of draft animals decline due to mechanization; opportunities in climate-resilient indigenous breeder high altitudes. Findings underscore the need for hybrid public-private ecosystems to scale agri-startups, promoting sustainable livelihoods and food security. Ultimately, agri-entrepreneurship not only builds adaptive capacity but also drives rural economic transformation toward a resilient, self-reliant agrarian future.

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8.9 Constraints faced by hi-tech Horticultural Guava Nurseries in Upscaling Technology of Protected Cultivation in Jammu Region

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Keywords: Garrett ranking, Protected structure, Constraints, Skilled labour

1. Background

Protected cultivation ensures a perfect microclimate through the regulation of temperature, humidity, light intensity, and air movement which reduces the environmental stress experienced in the open field nurseries. The cultivation of quality plant material of the guava variety (*Psidium guajava*) using protected structures such as green houses, net houses, and shade nets is paramount for the production of excellent horticultural practices. India's total land area as of 2023–2024 is 328.7 Mha from which approximately 140.6 Mha make up the net sown area and around 204.3 Mha is the gross cropped area (Indiastat, 2023). Records from the Director Horticulture J&K show guava cultivated on 2,800 hectares with a production level ranging from 10,000 to 12,000 MT every year.

Though a relatively small share of J&K production as opposed to temperate fruits like apple, cherry, or strawberry, Guava is an important commercial crop for the sub-tropical part of J&K. Protected growing environments reduce the risk of diseases such as wilt, anthracnose, fruit rot and root rot by regulating soil pH, humidity levels and pathogen exposure. According to a study the survival and plantlets growth under polyhouse was always better than that of open nursery conditions irrespective of IBA concentrations (Rymbai and Reddy, 2010). Economically, protected structures can reduce the loss of rejects, initiate an increase in farmer income by 25% to 40%, and match the trends of precision horticulture practices by making the structure climate-resilient and robust.

2. Materials and Methods

The present study was conducted in Jammu region of Union Territory of Jammu and Kashmir (J&K). The Government nurseries undergoing protected cultivation of guava were selected purposively in consultation with Department of Horticulture, Jammu. A comprehensive list of private guava nurseries were prepared with the help of the Department of Horticulture, Jammu. From this list, selection of private nurseries with protected structure was carried out using the stratified random sampling technique.

For ranking the constraints faced by protected government and protected private nurseries, the Garrett ranking technique which was given by Garret and Woodworth (1969) was followed. The following formula was used to convert the ranks provided by the respondents to the percent position.

$$\text{Percent position} = 100(R_{ij} - 0.5)/N_j$$

where,

R_{ij} =Rank given for i th constraint by j th individual.

N_j =Number of constraints ranked by j th individual.

3. Results and Conclusion

The constraints "High initial infrastructure setup cost" ranked as the most severe limitation and occupied Rank I with an average score of 81.08. The "Non availability of skilled labour" ranked

as the second most severe limitation and occupied Rank II with an average score of 57.76. The unavailability of technically skilled human labour results in inefficient functioning on the part of nurseries. The factor “High dependence on private sources for polyhouse inputs,” with an average ranking of 44.84, engaged Rank III. The factor “Heavy expenses on maintenance” with an average ranking of 37.92, was placed by Rank IV. Finally, “Unreliable electricity supply” was ranked as the least severe constraint (Rank V) with an average score of 28.40. Overall, the results reveal that capital-intensive nature, labour constraints and dependence on private input sources were the major challenges faced by government hi-tech guava nurseries under protected conditions.

The general conclusion drawn from nursery restrictions is that a critical infrastructure finance gap and a knowledge vacuum in technical expertise are the main limiting factors in growing hi-tech crops. Dependence for inputs on a high level in the private sector further pushes infrastructure costs. There thus exists a serious demand to establish a holistic approach to building a public-private partnership mechanism that is in a better position to supply standardized inputs and greater awareness regarding existing support schemes on the part of governments.

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8.10 Growth Trends in Apple Exports from Jammu and Kashmir

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Keywords: Apple, CAGR, Exports

1. Background

India is endowed with abundant natural resources and diverse agro-climatic conditions that support the production of a wide variety of fruits and vegetables. Among horticultural commodities, apples have emerged as an important export-oriented fruit, with India gradually strengthening its presence in the global market. Apple export value increased from USD 8.6 million in 2014–15 to USD 14.45 million in 2020–21, while export quantity reached around 32 thousand metric tonnes in 2022, indicating a steady growth trend (Statista, 2022). The Union Territory of Jammu and Kashmir, contributing nearly 77 percent of India's total apple production, has been designated as an Agri Export Zone (AEZ) for apples. In this context, it is important to examine the growth in apple exports from Jammu and Kashmir to understand its role in India's horticultural export sector.

2. Materials and methods

The relevant secondary data regarding the amount of apples exported from the UT of J&K in metric tonnes from the year 2014-15 to 2022-23 was collected from Directorate Horticulture Planning and Marketing (P&M), Narwal, Jammu. For computing compound annual growth rate for export of apple in J&K over a period of time, the exponential function of the following form was used.

$$Y = ab_t U_t$$

where, $Y = \text{Export}$

$a = \text{constant}$

$U_t = \text{Disturbance term in year 't'}$

The compound growth rate was calculated from the fitted exponential regression parameter b and the Average Annual Compound Growth Rate was computed by using the following formula.

$$\text{CAGR} = [(\text{Antilog}(\log b - 1))] \times 100$$

Source: (Sharma *et al.* 2014)

3. Results and Conclusion

The compound annual growth rate for the volume of apples exported from UT of J&K helped in understanding the trends of apple exports. The progression in exports for the available data indicate positive growth rate of 3.18 per cent per annum. The export data further reveal considerable year-to-year fluctuations. The highest export volume was recorded in 2018–19 at 20.71 lakh metric tonnes, whereas the lowest was observed in 2020–21 at 11.86 lakh metric tonnes. The sharp decline during 2020–21 can largely be attributed to the COVID-19 pandemic, which disrupted production, supply chains, and international trade activities. Relatively lower export volumes were also observed in 2014–15 (12.54 lakh metric tonnes) and 2016–17 (12.88 lakh metric tonnes) compared to other years in the study period. The reduced exports in 2014–15 may be linked to the flash floods in the region, which adversely affected apple production, while the decline in 2016–17 could be associated with regional disturbances in parts of Kashmir, which likely disrupted normal production and marketing activities.

Table 1: Exports of Apple from the UT of J&K (2014-15 to 2022-23)

Years	Quantity exported (Lakh MT's)
2014-15	12.54
2015-16	14.58
2016-17	12.88
2017-18	18.51
2018-19	20.71
2019-20	19.39
2020-21	11.86
2021-22	17.13
2022-23	18.31
CAGR	3.18

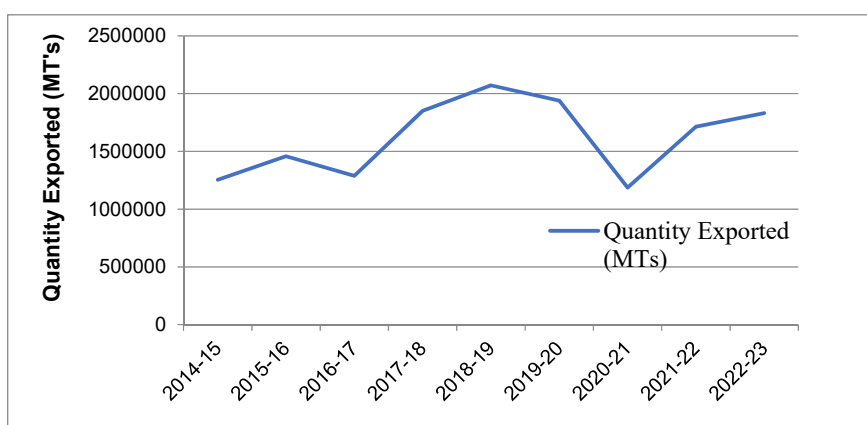


Figure 1: Exports from J&K from 2014-15 to 2022-2

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8.11 Supply Chain and Marketing Barriers Faced by Agri-Startups in Himachal Pradesh

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Keywords: Agri-startups Supply, Chain Constraints, Marketing Barriers

1. Background

Agriculture continues to serve as the backbone of India's economy, supporting the livelihoods of over 58 per cent of the population. Despite its critical role, the sector has historically been constrained by challenges such as fragmented landholdings, low productivity, heavy dependence on climatic conditions, outdated technologies, volatile markets and inadequate infrastructure (KisanVedika, 2024). In recent years, however, the emergence of agri-startups has introduced a transformative shift, fostering innovation-driven growth within the agricultural landscape. By 2024, India is home to approximately 6,500 agri-startups, accounting for 4.2 per cent of the country's total startup ecosystem. This wave of entrepreneurial activity is particularly significant in Himachal Pradesh, where agri-startups are redefining traditional farming systems through advancements in processing, distribution, marketing, and sustainable agricultural practices. According to the Startup Himachal initiative, the state has supported over 120 registered startups by 2023, with nearly 30 per cent operating in agriculture and allied sectors (Government of Himachal Pradesh, 2023). These enterprises are actively exploring niche domains such as organic farming, nutraceuticals, value-added food products and agri-tourism, thereby diversifying rural income sources and enhancing value chains. The rapid growth of agri-startups in Himachal Pradesh highlights their potential to transform the agricultural sector however, these enterprises continue to face significant challenges, particularly in supply chain management and marketing. Identifying and addressing these barriers is crucial for ensuring their sustainability, scalability and long-term impact on rural livelihoods.

2. Materials and Methods:

The present study was conducted in Himachal Pradesh, which is located in the northernmost part of India, between 30°22'40" N to 33°12'40" N latitude and 75°45'55" E to 79°04'20" E longitude. The state comprises twelve districts, however, only eight districts have active agri-startups, while the remaining four districts do not have any agri-startups. Out of a total of 270 identified startups in the state, 40 are agri-startups. Among these, 26 are currently operational, while 14 have shut down. Therefore, 26 operational agri-startups were selected for the present study.

3. Results and Conclusion

The findings of the study reveal that agri-startup founders in Himachal Pradesh face significant constraints across both supply chain and marketing domains. Among supply chain constraints, the most critical issue identified was inconsistent raw material supply (MS=57.69), which ranked first. This was followed by high transportation and storage costs (MS=56.92), lack of efficient distribution channels (MS=56.34), perishability of agricultural products (MS=55.58) and weak supplier networks and dependencies (MS=55.19). These constraints collectively highlight inefficiencies in procurement, logistics, and distribution systems that hinder smooth operational functioning.

Similarly, in the marketing domain, the most severe constraint was the absence of dedicated market intermediaries or agents (MS=60.58), indicating a lack of linkage with wholesalers, distributors, or institutional buyers, limited access to market facilitators, and low participation in exhibitions or trade fairs, ultimately restricting market expansion and product outreach. This was followed by limited brand awareness (MS=59.23), lack of effective marketing strategies (MS=58.85), weak customer trust in new or unknown brands (MS=58.46), and limited marketing budget (MS=58.07). These findings underscore the challenges related to market access, promotion, and consumer acceptance faced by agri-startups.

Table no. 1: Supply Chain Constraints as reported by respondents (n=26)

S. No.	Supply chain constraints	Mean Score	Rank
1.	Inconsistent raw material supply	57.69	I
2.	High transportation & storage costs	56.92	II
3.	Lack of efficient distribution channels	56.34	III
4.	Perishability of agricultural products	55.58	IV
5.	Weak supplier networks & dependencies	55.19	V
Marketing constraints			
6.	Absence of dedicated market intermediaries or agents	60.58	I
7.	Limited brand awareness	59.23	II
8.	Lack of effective marketing strategies	58.85	III
9.	Weak customer trust in new or unknown brands	58.46	IV
10.	Limited marketing budget	58.07	V

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8.12 Environmental Cost of Excessive Fertilizer Use in India: A Life Cycle Assessment Approach

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Keywords: Environmental cost, Fertilizer, Life Cycle Analysis

1. Background

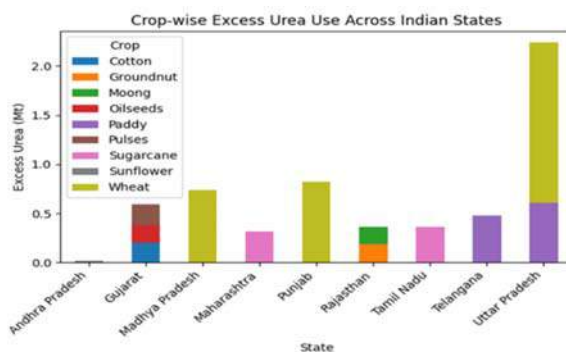
Agriculture is a cornerstone of the Indian economy supporting two-thirds of the population and contributing 20.2% to GDP in 2021. Rising food demand has increased dependence on fertilizers particularly nitrogenous fertilizers like urea as India is the second-largest global consumer. However, excessive and imbalanced use reflected in the NPK ratio of 6.7:2.7:1 against the recommended 4.3:2.0:1 has led to soil degradation, nutrient deficiencies and declining long-term soil health (Gholkar *et al.*, 2022). Overuse also contributes to nitrate contamination of groundwater and public health risks. Fertilizer consumption has risen sharply from 0.7 lakh tonnes in 1950–51 to over 629 lakh tonnes in 2020–21 (Ministry of Chemicals and Fertilizers, 2023). Environmental impacts also arise from fertilizer production contributing to greenhouse gas emissions, eutrophication and pollution. Addressing these challenges is essential for achieving sustainable agriculture and climate goals. This study estimates excessive fertilizer use in India and its environmental cost. However, it is limited by its macro-level focus and reliance on CACP survey data excluding important micro-level insights and states not covered in the dataset.

2. Materials and Methods

The study relies primarily on secondary data sources. State-wise fertilizer consumption data were obtained from the Commission for Agricultural Costs and Prices (CACP) plot-level survey for the agricultural year 2020–21. Recommended nutrient application rates were compiled from agro-advisories issued by the Indian Council of Agricultural Research (ICAR) and State Agricultural Universities.

A life cycle assessment approach was employed to estimate emissions across three components: (i) emissions at the factory gate during fertilizer production, (ii) logistics-related emissions from truck and maritime transport (iii) soil emissions following fertilizer application. Transport emissions represent cumulative district-level movements of fertilizers from production facilities and ports to final points of use, rather than single aggregate state-level flows.

3. Result and Conclusion



Substantial inter-state variation is observed in fertilizer-related emissions across all life cycle stages with production emissions remaining below 10 Mt CO₂ for most states while transport-related emissions are highly concentrated in a few large agricultural states. Truck-based transport of urea dominates logistics emissions with Madhya Pradesh (707.3 Mt CO₂) and Uttar Pradesh (128.1 Mt CO₂) accounting for a major share whereas maritime emissions are more evenly distributed across coastal regions. Soil emissions from urea and DAP further contribute particularly in intensively cultivated states like Uttar Pradesh, Madhya Pradesh. Although absolute estimates depend on assumptions such as transport distance and load capacity, the relative ranking of states remains robust highlighting the potential of improved logistics, decentralized storage and balanced nutrient use in reducing emissions. This study demonstrates that the environmental cost of fertilizer use in India extends well beyond production and on-farm application. Logistics-related emissions particularly from truck-based transport of urea represent a major and underappreciated source of greenhouse gas emissions. Addressing fertilizer overuse and improving spatial efficiency in distribution are critical for reducing the carbon footprint of Indian agriculture and aligning fertilizer policy with climate mitigation goals.

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8.13 Growing Organic, Knowing Little? Unpacking Awareness Gaps and PKVY's Influence in J&K

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Keywords: Organic farming; Paramparagat Krishi Vikas Yojana (PKVY); Jammu & Kashmir; Sustainable agriculture

1. Background

India's agriculture faces the challenge of balancing productivity with environmental sustainability. The intensive use of chemical inputs has led to soil degradation, ecological imbalance, and health concerns, thereby necessitating a shift toward sustainable practices such as organic farming. Organic agriculture is increasingly recognized for its ecological and economic benefits, including biodiversity conservation and sustainable food systems (Miguel A. Altieri, 1999; Catherine Badgley *et al.*, 2007). Government initiatives like the Paramparagat Krishi Vikas Yojana (PKVY) aim to promote organic farming through cluster-based approaches and capacity building. However, the effectiveness of such programs depends largely on farmers' awareness regarding production and marketing aspects of organic produce, as well as their ability to integrate into value chains (Abebe *et al.*, 2022).

2. Materials and Methods

The study was conducted in the Union Territory of Jammu & Kashmir covering three agro-climatic zones: sub-tropical, intermediate, and temperate. Both primary and secondary data were utilized. Secondary data were collected from government publications such as the Economic Survey and Digest of Statistics, while primary data were obtained through personal interviews of farmers.

A multistage random sampling technique was employed. Three blocks from each agro-climatic zone were selected, followed by ten villages from each block, and finally 12 farmers from each village, resulting in a total sample size of 1080 farmers.

The study compared awareness levels of PKVY beneficiaries and non-beneficiaries regarding both production (minimum area, seed, fertilizers, pesticides) and marketing aspects (packaging, certification, prices) of organic farming. Statistical tools such as descriptive analysis and two-sample t-test were used to assess differences in awareness levels and thereby evaluate the impact of PKVY.

3. Results and Conclusion

The results indicate that PKVY beneficiaries exhibit significantly higher awareness levels regarding organic farming practices compared to non-beneficiaries. Awareness related to production aspects—such as input use and cultivation requirements—is relatively higher among beneficiaries, reflecting the effectiveness of training and extension efforts under the scheme.

However, awareness of marketing dimensions, including certification systems (PGS and NPOP), packaging, and price realization, remains low across both groups. This finding aligns with earlier studies highlighting gaps in market integration and value chain development in organic farming systems (Cacek & Langner, 1986; Burnett & Stack, 2009).

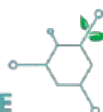
The statistical analysis reveals a substantial and significant difference in awareness levels between beneficiaries and non-beneficiaries, confirming the positive impact of PKVY. Nevertheless, persistent knowledge gaps, particularly in marketing, indicate the need for stronger institutional support, improved extension services, and targeted capacity-building initiatives. Strengthening these aspects will be critical for enhancing adoption, improving farmer incomes, and ensuring the long-term sustainability of organic farming in the region.

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