ISSN: 3049-2289

AGRICULTURE BULLETIN

A Monthly Publication on Agriculture Trends

Volume-1 Issue-11 November 2025

AGRICULTURE BULLETIN

A Monthly Publication on Agriculture Trends

ISSN: 3049-2289

CONTENT

ISSN: 3049-2289

CONTENT

ISSN: 3049-2289

ISSN: 3049-2289

Conservation Tillage and Residue Management in Mustard-Based Cropping Systems

[1]Bhim Singh, [2]A. P. Singh

[1]Ph.D. Scholar, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu

[2]Professor & Head, Division of Agronomy, Faculty of Agriculture, Main Campus, Chatha, SKUAST-Jammu (J&K)

Conservation tillage and residue management play a crucial role in improving soil health, productivity, and sustainability in mustard-based cropping systems. These practices minimize soil disturbance, enhance organic matter, and conserve moisture while reducing input costs and greenhouse gas emissions. The integration of technologies like zero tillage, Happy Seeder, and bio-decomposers facilitates residue recycling and prevents burning. Adoption of these climate-smart approaches not only enhances mustard yield and profitability but also contributes to environmental protection and long-term agricultural sustainability in India.

1.Introduction

Conservation tillage and residue management have become integral to sustainable agriculture, especially in mustard-based cropping systems across India. Mustard (*Brassica juncea* L.) is a major rabi oilseed crop grown widely in the Indo-Gangetic Plains after rice, maize, or pearl millet. Conventional tillage practices involving multiple ploughings, puddling, and residue burning have led to the depletion of soil organic matter, loss of beneficial microorganisms, and emission of greenhouse gases.

To address these challenges, conservation tillage and residue management techniques are gaining popularity among progressive farmers. Conservation tillage minimizes soil disturbance while maintaining crop residues on the soil surface. This not only improves soil structure and fertility but also enhances moisture retention, reduces erosion, and lowers fuel consumption. Residue management, on the other hand, focuses on recycling crop residues back into the soil to improve soil organic carbon and nutrient cycling.

The integration of these two practices in mustard-based cropping systems offers a promising approach to achieving sustainable productivity, improving soil health, and mitigating climate change impacts.

2. Concept of Conservation Tillage

Conservation tillage is defined as a system of crop establishment where at least 30% of crop residue remains on the soil surface after planting. It includes methods such as zero tillage, minimum tillage, reduced tillage, and strip tillage.

2.1 Objectives of Conservation Tillage

- To minimize soil disturbance and maintain natural soil structure.
- To conserve soil moisture and reduce evaporation losses.
- To reduce soil erosion and improve infiltration.
- To enhance biological activity and soil organic matter content.
- To lower production costs by reducing fuel and labour inputs.

Source: https://www.frontiersin.org/

ISSN: 3049-2289

2.2 Types of Conservation Tillage

Conservation tillage includes several types aimed at minimizing soil disturbance and conserving moisture.

Zero tillage: involves direct seeding without any prior soil preparation, reducing erosion and saving fuel.

Minimum tillage: limits soil operations to only essential ones for creating a suitable seedbed, preserving soil structure.

Strip tillage : tills only narrow strips where seeds are to be placed, leaving the rest of the field covered with residues.

Mulch tillage: leaves crop residues on the surface as mulch, protecting the soil from erosion, improving moisture retention, and enhancing organic matter buildup for sustainable crop production.

2.3 Advantages of Conservation Tillage

Conservation tillage offers multiple agronomic, economic, and environmental benefits. It improves soil structure and porosity, allowing better root penetration and aeration. The practice enhances organic matter and microbial biomass, promoting soil fertility and biological activity. By retaining crop residues, it increases soil water storage and reduces runoff and erosion, leading to better drought resilience. Conservation tillage also saves time, energy, and operational costs by reducing the number of tillage passes. Moreover, it helps mitigate greenhouse gas emissions by increasing carbon sequestration and contributes to climate change adaptation and sustainable agriculture.

3. Residue Management in Mustard-Based Systems

In mustard-based cropping systems, residues from rice, maize, or wheat are often burned, releasing CO_2, CH_4, and N_2O gases. Residue management refers to the strategic use of crop residues to enhance soil fertility and sustainability.

Approaches:

1. **In-situ residue management:** Incorporating or retaining residues on the soil surface (e.g., using Happy Seeder, Super Seeder).
2. **Ex-situ residue use:** Collection and use as mulch, compost, or livestock feed.
3. **Bio-decomposition:** Using microbial consortia to accelerate residue breakdown.

Advantages:

- Adds organic carbon and nutrients to soil
- Improves water retention and soil aggregation
- Controls weed growth and moderates soil temperature
- Reduces dependence on chemical fertilizers

4. Mustard-Based Cropping Systems

Common mustard-based systems in India include:

1. Rice–Mustard
2. Maize–Mustard
3. Pearl millet–Mustard
4. Cotton–Mustard
5. Green gram–Mustard

Each of these systems benefits differently from conservation tillage and residue management. For example, in rice–mustard systems, zero tillage with rice residue retention significantly improves soil nitrogen status and water efficiency.

4.1 Impact of Conservation Tillage and Residue Management

Conservation tillage and residue management significantly enhance soil health and crop productivity in mustard-based cropping systems. In the rice–mustard system, the adoption of zero tillage with residue retention has been shown to increase soil organic carbon by 15–20% within 3–4 years, improving soil fertility and sustainability. In the maize–mustard system, retaining residues helps in

ISSN: 3049-2289

moisture conservation, which promotes better seed germination, root development, and overall crop growth. Furthermore, conservation tillage enhances soil microbial activity, leading to efficient nutrient cycling, improved soil structure, and higher crop yields over time.

5. Technologies for Conservation and Residue Management

Effective conservation tillage and residue management technology are crucial to maintaining soil health, mitigating greenhouse gas emissions, and enhancing crop yields in mustard-based cropping systems. Some novel tools and biological interventions have been designed to overcome issues related to residue handling, degradation of the soil, and delayed sowing.

5.1 Zero Till Drill

The Zero Till Drill allows for direct sowing of mustard into rice straw without ploughing the field in advance, saving numerous tillage operations. The operation decreases fuel utilization by as much as 50%, reduces soil disturbance, and enables sowing 10–15 days earlier, resulting in improved establishment of the crop and increased yield.

5.2 Happy Seeder

The Happy Seeder is a multi-purpose machine that harvests the standing rice residues and, at the same time, seeds mustard. It is especially beneficial in the rice–mustard cropping pattern because it avoids burning of residues, saves soil moisture, and keeps the organic matter of the soil intact.

5.3 Super Seeder

The Super Seeder integrates the advantages of tillage and residue mixing. It shreds and incorporates crop residues into the soil during sowing mustard, which hastens residue breakdown, increases soil organic carbon, and enhances nutrient cycling for the following crop.

5.4 Rotavator and MB Plough

These tools are utilized for partial mixing of residues in minimum tillage systems, inducing uniform spread of residues and easy seedbed preparation with less disturbance.

5.5 Bio-Decomposer Sprays

The Pusa Decomposer, developed by ICAR-IARI, is a microbial-based bio-solution that decomposes crop residues in 20–25 days. By using it, soil fertility is increased, air pollution due to burning of residues is minimized, and sustainable residue management is practiced for maintaining long-term soil productivity.

6. Advantages of Conservation Tillage and Residue Management in Mustard

Conservation tillage and crop residue management practices provide numerous agronomic, environmental, and economic benefits in mustard-based cropping systems. Not only do these practices increase productivity but also long-term sustainability and resilience to climate.

6.1 Agronomic Benefits

Conservation tillage enhances soil aeration and structure and promotes good root growth and nutrient uptake. The retention of residues enhances the availability of nutrients through slow decomposition, adding valuable organic matter to the soil. The mulching of residues suppresses weed pressure and aids in soil moisture preservation. Additionally, it enhances water efficiency and boosts drought tolerance, making possible consistent crop performance even under drought stress.

6.2 Environmental Benefits

Environmentally, conservation tillage and residue retention eliminate residue burning, hence minimizing air pollution and greenhouse gas emissions. These methods also increase soil carbon sequestration, an important mitigation strategy against climate change. By covering the soil surface, they minimize runoff and erosion, preserve soil

ISSN: 3049-2289

fertility, and maintain biodiversity and microbial ecosystem balance, all of which are important for healthy soils.

6.3 Economic Benefits

Economically, conservation tillage reduces production costs by minimizing fuel, labour, and machinery operations requirement. It increases yield stability under fluctuating climatic conditions and enhances profitability through optimal input use. Moreover, utilization of residues for composting and bioenergy production offers farmers additional sources of income, enhancing livelihood and sustainability in agriculture.

7. Challenges and Future Prospects

Challenges:

- Cost of initial equipment (Happy Seeder, Super Seeder)
- Farmer resistance in shifting from conventional ploughing
- Residue management for different crop combinations
- Region-specific technology and training requirements

Future Opportunities

The fate of mustard-based cropping systems relies on the convergence of conservation agriculture principles with digital innovations. Indian farmers will make use of sensors, drones, and AI-based soil monitoring to maximise residue management and improve soil health. Institutions such as ICAR, CIMMYT, and state agricultural universities are formulating region-specific conservation models for mustard production. Government initiatives like the National Mission on Sustainable Agriculture (NMSA) and Sub-Mission on Agricultural Mechanization (SMAM) are promoting zero tillage and crop residue management. Continuous adoption will enhance resource-use efficiency, soil health, and encourage climate-resilient agriculture in India.

8. Conclusion

Conservation tillage and residue management in mustard-based cropping systems are essential for sustainable agricultural growth. These techniques increase soil health, enhance productivity, minimize environmental pollution, and provide resource-use efficiency. Implementation of technologies such as the Happy Seeder and deployment of bio-decomposers can transform the pattern of mustard and other crop cultivation in India's Indo-Gangetic Plains. For long-term sustainability, awareness, adoptions of technology and policy support are necessary.

References

1. ICAR (2023). *Conservation Agriculture Practices for Sustainable Crop Production.*
2. CIMMYT (2022). *Residue Management in Rice–Mustard Systems in the Indo-Gangetic Plains.*
3. Singh, R. et al. (2021). *Impact of Zero Tillage on Mustard Yield and Soil Health.* Journal of Agronomy and Environment.
4. Pusa Institute (2020). *Bio-Decomposer Technology for Residue Management.*

*****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Integrating Drone Technology and Big Data Analytics for Precision Crop Monitoring and Yield Prediction

[1]Kishor Anerao, [2] Shaikh Ajaj, [3] Sachin Giri
[1]Ph.D. Scholar, Department of Food Microbiology and Safety, CFT, VNMKV, Parbhani
[2]Ph.D. Scholar, Department of Food Chemistry and Nutrition, CFT, VNMKV, Parbhani
[3]Ph.D. Scholar, Department of Food Engineering, CFT, VNMKV, Parbhani

The integration of drone technology and big data analytics is revolutionizing precision agriculture by enabling real-time crop monitoring, accurate yield prediction, and efficient resource management. Drones equipped with advanced sensors capture detailed aerial imagery and field data, which are analyzed using big data tools to provide valuable insights for farmers. This combination enhances decision-making, boosts productivity, and promotes sustainable agricultural practices.

Furthermore, the use of AI and IoT in conjunction with big data improves predictive modeling and early detection of crop stress or diseases, ensuring timely interventions. These technologies help optimize the use of water, fertilizers, and pesticides, reducing costs and environmental impact. However, challenges such as high implementation costs, regulatory constraints, and the need for skilled operators remain significant barriers. Addressing these through training, policy support, and infrastructure development will be essential. Overall, the integration of drones and big data analytics represents a vital step toward smarter, more efficient, and sustainable agriculture.

Introduction

The integration of drone technology and big data analytics in precision agriculture is revolutionizing crop monitoring and yield prediction. This synergy enables real-time data acquisition and analysis, facilitating informed decision-making and enhancing agricultural productivity. Drones, equipped with advanced sensors, collect high-resolution data, while big data analytics processes this information to provide actionable insights. This integration not only optimizes resource use but also contributes to sustainable farming practices. The following sections delve into the specific applications, benefits and challenges associated with this technological convergence.

Applications of Drone Technology in Precision Agriculture

Crop Monitoring and Mapping: Drones are extensively used for monitoring crop health and mapping fields. They provide detailed aerial imagery that helps in assessing plant health, detecting diseases, and identifying areas requiring attention (Satish et al., 2025) (Guebsi et al., 2024). Furthermore, the use of drones allows for more efficient and accurate monitoring compared to traditional methods, significantly enhancing the ability to manage crop health effectively (Nithya et al., 2024). This advancement is crucial for addressing the growing challenges in agricultural productivity and sustainability.

Yield Prediction: UAVs, combined with machine learning algorithms, are pivotal in yield estimation. They collect data on crop growth, which is then analyzed to predict yields with high accuracy (Darra et al., 2023) (Yuan et al., 2024). Yield prediction models that utilize drone-collected data can significantly enhance the precision of forecasts, ultimately aiding farmers in making informed decisions regarding their crops.

Resource Management: Drones assist in precision spraying and irrigation management, ensuring optimal use of water, fertilizers, and pesticides, thereby reducing input costs and environmental impact (Canicattì & Vallone, 2024) (Guebsi et al., 2024). Resource management is essential for sustainable agriculture, as it ensures that inputs are used judiciously while maintaining productivity and environmental health. This innovative approach not only maximizes crop yields but also promotes sustainable agricultural practices by minimizing waste and enhancing resource efficiency.

Role of Big Data Analytics

Data Processing and Analysis: Big data analytics processes vast amounts of drone-collected data, providing insights into crop conditions and growth patterns. This enables farmers to make data-driven decisions (Vaishnavi & Kingslin, 2025). The integration of drone technology and big data analytics is essential to enhancing precision agriculture by enabling improved data collection and resource optimisation (Khanpara et al., n.d.). This convergence not only addresses the challenges of agricultural productivity but also fosters sustainable practices in farming operations.

Predictive Insights: Advanced analytics offer predictive insights into crop yields and potential issues, allowing for proactive management and planning (Lobo et al., 2024) (Vaishnavi & Kingslin, 2025). Predictive analytics enhances the ability to anticipate challenges, enabling farmers to implement timely interventions that safeguard their crops and optimize yields.

ntegration with AI and IoT: The combination of AI, IoT, and big data analytics enhances the precision and efficiency of agricultural practices, facilitating real-time monitoring and management (Lobo et al., 2024) (Vaishnavi & Kingslin, 2025). Integration of these technologies is crucial for developing a comprehensive approach to modern agriculture, ensuring that farmers can adapt to changing environmental conditions and market demands.

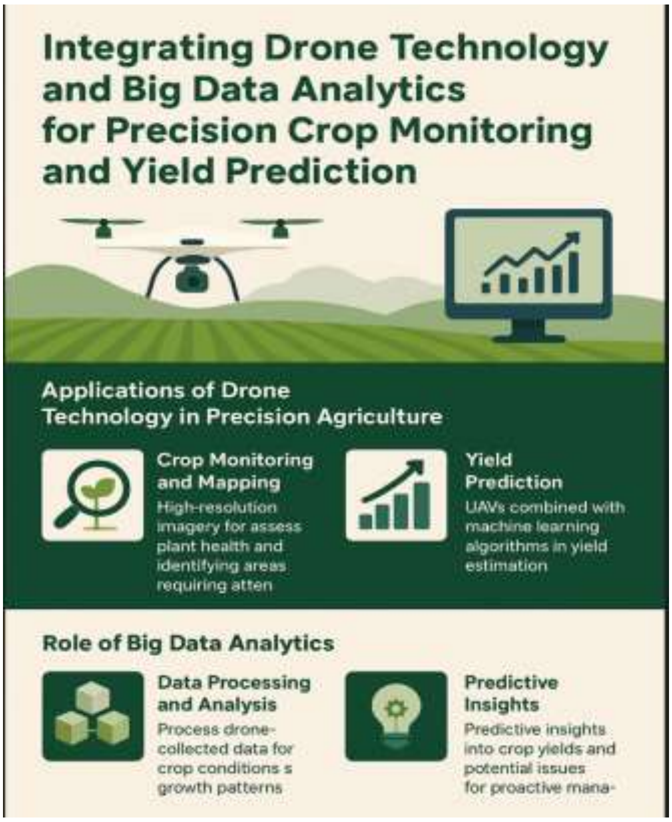


Fig.1: Application and Role of Drone Technology and Big Data Analysis

Benefits of Integrating Drones and Big Data

Increased Productivity: The integration leads to improved crop yields and reduced resource consumption, contributing to higher productivity and profitability (Canicattì & Vallone, 2024) (Vaishnavi & Kingslin, 2025). This advancement in precision agriculture not only enhances operational efficiency but also supports sustainable farming practices by minimizing environmental impact and optimizing resource allocation.

Sustainability: By optimizing input use and minimizing environmental impact, these technologies promote sustainable agricultural practices (Canicattì & Vallone, 2024) (Salgado et al., 2025). This technological convergence not only enhances productivity but also ensures that farming practices are environmentally sustainable and economically viable for future generations.

Cost Efficiency: Precision agriculture reduces operational costs by minimizing waste and enhancing resource efficiency (Salgado et al., 2025). This efficiency not only lowers production costs but also increases the overall profitability of farming operations, making it a viable solution for modern agricultural challenges. Moreover, the integration of these advanced technologies fosters resilience in agricultural systems, enabling farmers to better withstand climate variability and other external pressures.

Challenges and Future Prospects

Technical and Economic Barriers: High initial costs, technical complexity, and the need for skilled operators are significant challenges to widespread adoption (Satish et al., 2025) (Guebsi et al., 2024). To overcome these barriers, targeted training programs and financial support mechanisms are essential for empowering farmers and promoting the adoption of these innovative technologies.

Regulatory and Connectivity Issues: Regulatory restrictions and connectivity limitations hinder the full-scale deployment of drones in agriculture (Guebsi et al., 2024) (Salgado et al., 2025). To address these challenges, collaboration between stakeholders, including policymakers, technology developers, and farmers, is crucial for creating supportive frameworks and enhancing infrastructure for drone operations in agriculture.

Future Research Directions: There is a need for further research in areas such as data augmentation, feature engineering, and real-time yield estimation to overcome current limitations and enhance the effectiveness of these technologies (Yuan et al., 2024). The successful integration of drones and big data analytics in agriculture requires overcoming these challenges to fully realize their potential benefits for farmers and the environment.

While the integration of drone technology and big data analytics holds immense potential for transforming precision agriculture, it is essential to address the existing challenges to fully realize their benefits. The development of supportive policies, infrastructure, and training programs can facilitate the adoption of these technologies, paving the way for a more sustainable and efficient agricultural sector.

Conclusion: The integration of drone technology and big data analytics marks a transformative step toward precision and sustainability in modern agriculture. By enabling real-time crop monitoring, accurate yield prediction, and efficient resource management, these technologies empower farmers with data-driven insights that enhance productivity and profitability. Despite challenges such as high costs, regulatory barriers and technical limitations, continued advancements in AI, IoT and data analytics along with supportive policies and training will accelerate their adoption. Together, drones and big data represent the future of smart, sustainable, and resilient farming systems.

References

Canicattì, M., & Vallone, M. (2024). Drones in Vegetable Crops: A Systematic Literature Review.*Smart Agricultural Technology*. https://doi.org/10.1016/j.atech.2024.100396

Darra, N., Anastasiou, E., Kriezi, O., Lazarou, E., Kalivas, D., & Fountas, S. (2023). Can Yield Prediction Be Fully Digitilized? A Systematic Review.*Agronomy*. https://doi.org/10.3390/agronomy13092441

Guebsi, R., Mami, S., & Chokmani, K. (2024). Drones in Precision Agriculture: A Comprehensive Review of Applications, Technologies, and Challenges.*Drones*. https://doi.org/10.3390/drones8110686

Khanpara, B. M., Patel, B. P., Parmar, N. B., & Mehta, T. D. (n.d.).*Transforming Agriculture with Drones: Applications, Challenges and Implementation Strategies*. https://doi.org/10.9734/jsrr/2024/v30i82299

Lobo, A. D., Shetty, S. V. R., Rai, V., Naik, S. C., Badiger, M., & Singh, C. V. (2024).*Revolutionizing Agriculture*. https://doi.org/10.4018/979-8-3693-2093-8.ch021

Nithya, K., Muthumanickam, D., Pazhanivelan, S., Kumaraperumal, R., & Kannan, P. (2024). Sky to soil: Role of drones in maximizing agricultural crops yield.*Plant Science Today*. https://doi.org/10.14719/pst.5773

Salgado, E. M., Brito, Ma. G. G., Miranda, M. E., Pérez, E. R., & Hernández, D. (2025). Tecnologías Innovadoras en la Agricultura de Precisión.*Ciencia Latina*. https://doi.org/10.37811/cl_rcm.v9i2.17319

Satish, S., Shirwal, S., Abishek, A. G., Maheshwari., Maheshwari., & Murali, M. (2025). Application of Drones in Precision Agriculture: A Review on Benefits and Challenges.*Journal of Experimental Agriculture International*. https://doi.org/10.9734/jeai/2025/v47i73591

Vaishnavi, Ms. K., & Kingslin, S. (2025). Transforming Agriculture Through IoT And Big Data: A Comprehensive Framework for Precision Farming.*International Journal of Latest Technology in Engineering Management & Applied Science*. https://doi.org/10.51583/ijltemas.2025.1407000089

Yuan, J., Zhang, Y., Zheng, Z., Yao, W., Wang, W., & Guo, L. (2024). Grain Crop Yield Prediction Using Machine Learning Based on UAV Remote Sensing: A Systematic Literature Review.*Drones*. https://doi.org/10.3390/drones8100559

****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Feed types in Shrimp Culture

K. Bheemeswararao*, A. Chandrasekhara Rao, Shivkumar,
K. Shasti Risha, P. Dheeran, T. Suguna
Fisheries Research Station, Undi, West Godavari Dist.
Andhra Pradesh Fisheries University, Andhra Pradesh

Shrimp feed is broadly categorized into two types: natural feed and artificial feed. This distinction is significant because natural feed supports the ecological balance in traditional or semi-intensive farming, while artificial feed provides consistent and tailored nutrition essential for intensive and super-intensive farming systems. Each type serves distinct purposes depending on the farming method and shrimp growth stage.

Natural feed

Originates directly from nature without processing. Common examples include phytoplankton, zooplankton, benthic organisms, and plant matter. In traditional shrimp farming, natural feed is the primary food source, while in semi-intensive, intensive, and super-intensive farms, it serves as a supplement to artificial feed.

- Phytoplankton - Fertilization in pond promotes growth of microscopic plants known as phytoplankton, The presence of yellowish-green color in pond water signifies good growth of desirable planktonic organisms conducive for shrimp growth.
- Lablab: A mix of blue-green algae, diatoms, and microbenthos, which thrives in brackishwater ponds. It is ideal for post-larvae and juvenile shrimp.
- Lumut: Filamentous algae like Chaetomorpha, suitable for low-salinity ponds.
- Macrophytes: Plants such as Najas graminea and Ruppia maritima that support benthic organisms and provide decaying matter for shrimp.
- Benthic Organisms: Includes insect larvae, small worms, protozoa, rotifers, and copepods that live in or on pond substrate, contributing significantly as natural food.
- Zooplankton: Small, drifting organisms such as copepods, rotifers, and microcrustaceans, especially important during the larval and post-larval stages.
- Brine Shrimp (Artemia): Commonly used in hatcheries as a live feed, especially for early larval rearing due to their high nutritional value and ease of enrichment.

Natural Food	Crude Protein (%)	Crude Fat (%)	Crude Fiber (%)	Ash (%)	Nitrogen-Free Extract (%)
Lablab	6.73	0.86	5.27	74.38	12.77
Lumot	15.26	2.17	15.07	31.39	36.09
Najas graminea	18.38	2.43	18.73	23.88	36.58
Ruppia maritima	15.38	3.70	17.26	14.24	49.49

Artificial Feed

Types of Artificial Feed

Artificial feed is indispensable in intensive farming, where shrimp growth relies entirely on these diets. It ensures consistent nutrition and faster growth, reducing the reliance on natural feed. Artificial feed undergoes processing to meet specific nutritional requirements and is available in three forms: pellets, granules, and powders.

ISSN: 3049-2289

Pellets

- Most common form, available as sinking or floating pellets.
- Used primarily for juvenile to adult shrimp up to harvest.
- Pellets contain essential nutrients such as proteins (often 35–45%), carbohydrates, fats, vitamins, and minerals.

Granules (Crumble)

- Coarse granules created by crushing pellets or compacting powdered feed.
- Suitable for younger shrimp (16–45 days old).
- Typically, nutritionally adapted for rapid growth of juveniles.

Powder

- Fine-grain feed formulated for newly hatched larvae and early post-larval stages (less than 16 days old).
- Enables easy consumption due to small mouth size during early development.

Wet/Moist Feed

- Includes freshly prepared mixtures using ingredients like egg yolks or minced meats.
- Sometimes used for broodstock or larval rearing.
- Generally, less stable in water and not commonly commercially available due to short shelf-life.

Extruded Feeds

- Feeds processed to enhance water stability and digestibility.
- Often provided in pellet form with improved nutrient retention.

Broodstock Diets

- Specialized for adult shrimp under reproduction, formulated as premixes or soft/moist pellets.
- May contain high protein, fatty acids, and sometimes fresh ingredients (squid, mussels) for optimal gonadal development.

Feed types according to the growth stages

The recommended shrimp feed types for aquaculture are divided into three categories according to the growth stages: Starter, Grower, and Finisher. Choosing and transitioning through these feed types according to shrimp size and age is essential for achieving efficient production, optimal FCR, and premium harvest quality in shrimp aquaculture. Shrimp feed in aquaculture is divided into three main types based on growth stages: Starter, Grower, and Finisher feeds. Each is formulated to match the nutritional needs and pellet size preference of the shrimp at each stage of development.

Starter Feed

- Designed for shrimp post-larvae and early juveniles.
- Pellet size is very small or provided as crumble/powder for easy ingestion.
- Typically, high in protein (often around 38%) with extra vitamins, minerals, and immune-boosting additives to support survival and initial growth.
- Used from stocking up to rapidly increasing weight phase (first 2–4 weeks).

Grower Feed

- Given from juvenile to sub-adult stages.
- Pellet size and density increase to match the shrimp's mouth and consumption rate.
- Nutrition is balanced for efficient growth, with protein content generally 35–38%, appropriate fat, and a full spectrum of nutrients for robust muscle and tissue development.
- Applied during the main period of biomass gain.

ISSN: 3049-2289

Finisher Feed

- Fed to mature shrimp before harvest.
- Pellet size is suited for adults; feed is designed to optimize final weight, condition, and market quality.
- Formulated with high-quality proteins, appropriate fats, and minimal fiber for good texture and body composition.
- Used in the final stage (last few weeks) before harvesting to maximize growth and minimize feed conversion ratio.

Table: Stage-wise Shrimp Feed Types

Feed Type	Form	Typical Protein %	Stage	Purpose
Starter	Crumble/Powder	~38%	Post-larvae, young shrimp	Early growth, survival
Grower	Pellet/Granule	35–38%	Juvenile to sub-adult	Weight gain, FCR
Finisher	Pellet	35–38%	Adult (pre-harvest)	Maximize harvest size, market quality

Shrimp Pellet Feed - Sinking

Fish Pellet Feed - Floating

Shrimp Feed Types

*****

ISSN: 3049-2289

Sweet Karonda – The Emerging Jewel of Arid Lands

Kumari Madhumala[1], Karanjeev Kumar[2]
[1,2]Dept. of Horticulture (Fruit Science), Nalanda college of Horticulture , Noorsarai, Nalanda

A Forgotten Fruit Making a Sweet Return

Once dismissed as a wild, thorny shrub growing along hedgerows and wastelands, karonda (*Carissa carandas L.)* is now re-emerging as one of India's most promising dryland fruits — this time with a deliciously sweet twist. Traditionally valued for its tangy berries used in pickles and chutneys, karonda has long been a familiar yet underrated part of rural India. Today, with the development of sweet and juicy varieties, this hardy native species is being rediscovered as a high-value fruit crop for semi-arid and arid regions — a true example of how resilience and sweetness can coexist.

A Native Gem of Indian Origin

Belonging to the Apocynaceae family, karonda is indigenous to India and thrives naturally across states such as Uttar Pradesh, Bihar, Madhya Pradesh, Rajasthan, and Maharashtra. It is an evergreen, spiny shrub that reaches 3–4 meters in height, adorned with shiny green leaves, fragrant white flowers, and clusters of colorful fruits that change from green to pink, red, and finally deep purple or black upon ripening.The sweet karonda types stand out for their larger fruit size, pleasant taste, and soft pulp, making them suitable both for fresh consumption and processing.

DID YOU KNOW?

- Botanical Name: *Carissa carandas L.*
- Family: Apocynaceae
- Origin: India
- Flowering Season: February–April
- Fruiting Season: June–August
- Bearing Age: 3–4 years
- Lifespan: 25–30 years

A Tiny Fruit with Tremendous Nutrition

Though small in size, sweet karonda is nutritionally powerful. It contains abundant iron, vitamin C, calcium, and antioxidants, making it a natural supplement for overall health. The deep red and purple fruits are especially rich in anthocyanins — natural pigments known to reduce oxidative stress and slow down aging.

Nutrient	Approx. Value (per 100 g fruit)
Moisture	82–86%
Total Soluble Solids (TSS)	12–18 °Brix
Acidity	0.3–0.6%
Vitamin C	30–50 mg
Iron	39–45 mg

With this rich nutrient profile, sweet karonda serves as an excellent natural remedy for anemia, fatigue, and nutrient deficiency, making it both a functional food and a superfruit of the future.

Simple Cultivation for Sustainable Farming

Karonda is remarkably easy to cultivate and thrives in both tropical and subtropical conditions. It can be propagated through seeds, cuttings, or air layering, making it accessible to small and marginal farmers.

- Soil: Prefers sandy loam or rocky soil with good drainage
- Soil pH: Can tolerate up to 8.2
- Water Requirement: Minimal once established

- Maintenance: Occasional pruning and mulching improve yield

Flowering generally occurs between February and April, followed by fruit ripening from June to August. Once mature, karonda plants demand very little care — making them an excellent choice for dryland and resource-limited farming systems.

Promising Sweet Varieties

Recent breeding and selection programs have resulted in several high-performing sweet karonda varieties that combine productivity with taste:

Variety	Distinct Features
Pant Manohar	Large, sweet fruits; good shelf life
Pant Sudarshan	Mildly sweet with balanced acidity
Konkan Bold	High-yielding, juicy purple fruits
Karonda Selection-1	Very low acidity; ideal for fresh eating

A Fruit for the Future

Sweet karonda is increasingly viewed as a climate-smart crop for India's arid and semi-arid zones. A mature plant can yield 8–12 kg of fruits annually, and its processed products fetch premium prices in both domestic and export markets.
Beyond income, its deep roots help prevent soil erosion, improve soil stability, and serve as a protective barrier on farmlands — combining economic value with ecological benefits.

Sustainability and Opportunity

In times of climate uncertainty and declining water availability, crops like sweet karonda represent the future of sustainable horticulture. Its hardy nature, combined with nutritional richness and market potential, makes it a model crop for integrating profitability with environmental care.

By encouraging cultivation, processing, and marketing of sweet karonda, India can turn this once "wild fruit" into a mainstream commercial success — bringing prosperity to farmers and health benefits to consumers.

Conclusion

From the hedges of rural landscapes to the shelves of urban stores, sweet karonda is scripting a new agricultural success story.
What was once known for its sourness is now celebrated for its sweetness, strength, and sustainability.

With its brilliant color, pleasant flavor, and resilient character, sweet karonda truly stands as India's hidden jewel of arid lands — a small fruit destined for a big, sweet future.

"Sweet Karonda – Turning Wastelands into Wonderlands!"

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Cultivation of Sweet Corn in Kashmir: Prospects and Challenges

Sabina Nasseer, Faisal Rasool, Shabir Ahmad, Shagufta Parveen, Shahida Iqbal, Zahida Rashid, Shabeena Majid, Sabiya Bashir and Z. A. Dar.
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Srinagar.

Introduction

Maize (*Zea mays* L.) is considered the Queen of Cereals and is the world's third most important crop after rice and wheat. It occupies an important place in world agriculture, being cultivated in more than 150 countries, including USA, China, Brazil, Mexico and India. Asia consumes more than 62% of its maize production in the form of animal feed and remaining for human consumption. In India, maize is mainly grown for grain purpose and is consumed either as food or as feed. It is the staple food in hilly and sub mountain tracts of northern India, although consumed all over country. Maize ranks first in area, grown on approximately 3.08 lakh hectares in J & K with a production of 5.12 lakh tonnes and a productivity of 1.66 tonnes per hectare (Statistical Digest of J & K 2021-22). In Kashmir region, maize is cultivated on 0.77 lakh hectares which comprises over 26 percent of total maize area in the state. The crop is grown in all districts of Kashmir valley though maximum area under maize falls in Kupwara with 20.57 thousand hectares followed by Baramulla and Anantnag districts.

Fresh sweet corn is increasingly in high demand in the hotels for the preparations of delicious sweet corn soup. It also serves as a raw material for deriving large number of industrial products such as starch syrup, dextrose and dextrin etc. Thus sweet corn with varied uses has a great potential in export as well as domestic market. Sweet corn is relished by all the people throughout the world for its quick preparation and taste, making it a ready to serve food in the malls, railway stations and airports (Tiryak and Bineeta, 2020). Moreover the aroma associated with these foods is mouth watering always. The sweet corn and pop corn stalls are usually seen along the national highway and the roads leading to tourist resorts particularly Gulmarg and Pahalgam.

Among the specialty corns, sweet corn is gaining importance in urban areas due to its taste and other uses for human consumption. Owing to low returns per unit area in case of normal maize, growers are fast shifting to specialty corn production (sweet and pop corn) giving more returns and opening opportunities for employment generation. Sweet corn has a very big market potential and has great genetic variability and scope to improve its nutritive value. In addition quality fodders as on the basis of sweetness derived after harvest may be sold that brings handsome additional income to the farmers as it is highly cherished by the cattle.

Agriculture systems require an economically viable socially acceptable and sustainable approach to improve livelihood of the farming community ensuring food and nutritional security as well as financial power, the sweet corn in this context seems vital and alternative crop to ammeliorate the situation.

Biology

Sweet corn is the type of corn with a thin pericarp layer, translucent, horny appearance of kernels when

ISSN: 3049-2289

matures and wrinkled when it dries and is consumed at immature grain stages of endosperm at thirty days after fertilisation (Dagla *et al*.2014).Total sugar content in sweet corn at milky stage ranges from 25 to 30% as compared to 2 to 5 % of normal corn. Sweet corn matures early and green ears can be harvested in 95-100 days after planting under Kashmir conditions. The left over stalk can serve as useful fodder for the livestock. Thus it can fit easily in multiple or intercropping systems.

Nutritional Facts of sweet corn

S.No.	Nutrient	Amount(g)	DV(%)
1.	Total Fat	1.2 g	1%
2.	Saturated Fat	0.2 g	1%
3.	Cholesterol	0 mg	0%
4.	Sodium	15 mg	0%
5.	Potassium	270 mg	7%
6.	Total Carbohydrate	19 g	6%
7.	Protein	3.2 g	6%
8.	Vitamin C		11%
9.	Iron		2%
10.	Vitamin B6		5%
11.	Magnesium		9%

Per cent Daily Values are based on a 2,000 calorie diet

Properties of Sweet Corn

Sweet corn contains a lot of bioactive components due to which it has the following properties:

1. It acts as an antioxidant (might neutralise free radicals in the body).
2. It helps maintain diabetes by regulating the levels of insulin, lipids and proteins..
3. It helps regulate carbohydrate, lipid and protein metabolism in the body.
4. As it is rich in Vitamin B12 and iron, sweet corn helps in the production of healthy red blood cells thereby prevents anaemia.
5. It might help increase good cholesterol in the blood.
6. It promotes the betterment of vision.
7. It is a storehouse of energy that gives boost due to starch present in it.
8. It is one of the best sources of fibre that keeps satiated and prevents overeating.

Genetic origin of sweet corn

Sweet corn (*Zea mays* var. *saccharata*) is differentiated from other maize types by the presence of gene(s) which alters endosperm starch synthesis and results in the plants to be used as vegetable (Najeeb *et al*. 2011). Sweet corn flavour is determined largely by sweetness, which in turn is affected by the amount of sugar and starch in the endosperm (Tracy and Hallauer, 1994). There are several homozygous recessive alleles that alter the kernel carbohydrate content. Several mutants such as sugary (su), sugary2 (su2), shrunken1, shrunken2, shrunken4, sugary enhancer (se), amylase extender (ae), dull and waxy have been identified which confer higher sugar content in the endosperm of immature kernel. Traditional sweet corn variety is homozygous for sugary mutation.

Variety

SKUAST K has developed an indigenous sweet corn variety known as Shalimar Sweet corn-1 (KDM-1263SC) in Early Maturity group. It has an average green cob yield of 110 q/ha and is resistant to TLB and stem borer across locations. A number of varieties are grown either as fresh market cobs or for processing units which belong to yellow as well white grain type.

Package of Practices

Seed Rate

S.No	Type	Seed rate (Kg/ha) Composite	Seed rate (Kg/ha) Hybrid	Planting Geometry (Plant x row) cm
1.	Normal Maize	30	20	60 x 20
2.	Sweet corn	16	10	75 x 20

Sowing time The optimum time of sowing is between 1st April to 30th of April for higher belts and can extend upto May for lower belts.

Fertiliser requirement

Hybrids

N= 150Kg, P_2O_5 = 75 Kg , K_2O = 40 and $ZnSO_4$ = 20Kg

Composites

N = 120 Kg, P_2O_5 = 60 Kg , K_2O = 30 and $ZnSO_4$ = 20Kg

Ridging / Earthing Up

Ridging and earthing up should be done at Knee high stage (35-40 DAS).Ridging involves heaping the top soil to form a raised ridge which helps the crop to have a good bed for root establishment and to prevent lodging. It improves drainage in water logged areas and is helpful in conserving the rainwater under dry land situations.

Irrigation

Most of the maize area is rainfed. If possible give at least three irrigations at the most critical periods i.e. at Knee high, silking and grain filling stage.

Harvesting

The sweet corn cobs should be picked about 25-30 days after flowering at around moisture level of 80 % with sugar content of about 20^0 Brix. Picking may take place over a few days as the cobs do not ripe evenly. The taste and quality of sweet corn depends heavily upon its sugar content, which rapidly decreases after harvest if ears are allowed to remain at field temperatures. By lowering the temperature, the conversion of sugar to starch may be substantially slowed but not completely stopped. Most sweet corn is ready 15 to 22 days after silking, and is hand harvested by grasping the ear and pulling downward while twisting the wrist to snap the ear off the stalk. Sweet corn may also be harvested using machines, which are becoming more common. Corn is best when it is harvested early in the morning. Grasp the ear firmly and pull down, then twist and pull. It usually comes off the stalk easily. For the first few days it is recommended to harvest only that amount which can be consumed but the entire crop should be harvested while it is in the milky stage. The corn stalks are piled up immediately after harvest and the stalks are cut into 30 cm lengths before adding them to the compost pile to hasten their decay. Sweet corn is highly perishable and requires constant cooling from harvest to consumer to deliver a high quality product. There are several cooling methods available depending on operation size and transport time including: hydrocooling, package icing, vacuum cooling, and forced air cooling. Continued temperature maintenance after initial cooling is critical to help maintain sweet corn quality.

Hydrocooling

This sweet corn cooling process is the most common method used for small and large operations. Sweet corn is either showered with or immersed in cold water (32°F to 38°F) to cool down sweet corn after harvest. Complete immersion may be able to cool sweet corn faster and more efficiently than showering. Hydrocooling helps to reduce crop water loss, but costs may be higher as containers must tolerate exposure to water.1 Sweet corn may be hydrocooled by bulk or in crates. Bulk hydrocooling can cool sweet corn from 86°F to 41°F in about 60 minutes, whereas crated sweet corn takes about 80 minutes for the same cooling. Sweet corn packed in wirebound crates can prevent cooled water from contacting the cobs, reducing cooling potential, and loading crates onto pallets prior to hydrocooling can further prevent cooling.4 It is important to monitor cob temperatures during hydrocooling to establish a minimum temperature of 50°F. Top icing, or adding a 2- to 4-inch layer of crushed ice on top of loaded pallets, is recommended after hydrocooling to maintain cooling.

Package icing

For local and direct shipments, sweet corn containers can be filled with crushed ice as sweet corn is being packaged and transported. As the ice melts, cooling decreases, so additional ice may be needed to maintain cooled temperature. The amount of ice required for initial cooling equals 20% to 30% of the weight of the sweet corn being cooled. This method of cooling is effective, but the additional weight from the ice can increase shipping costs.

Vacuum cooling

Sweet corn is placed into air-tight containers and wetted and top-iced prior to steam-jet pumps removing air from the containers. This removal of air causes moisture to evaporate, reducing the temperature of the sweet corn. This method can reduce the temperature of large loads from 86°F to 41°F in about 30 minutes. This cooling method is quick, but can be expensive (Li and Hawkins,2011).

Forced air cooling

Small operations can cool sweet corn by forced air cooling. This method is not as efficient as other methods and involves more cooling time, resulting in infrequency of use.

Although decay is not typically a major problem, it is recommended to use ice made from potable water, and use chlorinated (at 50 ppm, or pH 7) potable water when hydrocooling, to help reduce the risk of pathogenic organisms causing decay in sweet corn.

Storage

To maintain quality, sweet corn should be stored immediately after postharvest cooling and for the shortest time possible, with a maximum of 2 weeks including transit time. Sweet corn is not sensitive to chilling; and as such, it should be stored as cool as possible (32°F to 34°F) without freezing. High humidity (95% to 98% relative humidity) helps reduce moisture loss and kernel denting (Suslow and Kentwell, 2013).

Refrigerated Transport

To continue to help maintain quality, transport sweet corn in a refrigerated truck and package with additional ice to help reduce moisture loss and maintain temperature. The recommended temperature during transit is 32°F, with a relative humidity between 95% to 98%(Ashby, 2008).

Processing

Sweet corn is processed into different products like frozen cobetts, whole cobs and whole kernels.

Packaging

There are two main containers used for packaging and shipping sweet corn: wirebound crates and fiberboard boxes. Wirebound crates can be shipped by loading them in rows, allowing space between crates for top icing. Now-a-days glass container has been also used for packaging the sweet corn. It has following advantages: act as strong barrier to moisture, gases, odours and micro-organisms. For small quantity of corn cobs, it is recommended to use double chamber vacuum sealing machine, so corns are put in a plastic bag first, then the bags are vacuum sealed. The packing speed with this method is slower.

ISSN: 3049-2289

Dishes

1. Corn Soup

This easy and delicious sweet corn soup is very helpful to satisfy soup craving. With just a few simple ingredients, this comforting corn soup will be ready in about 30 minutes.

2. **Sweet corn fried rice**

A homely and simple fried rice made with sweet corn, spring onions, capsicum and herbs and spices. The recipe is adaptable to different spice preferences and tastes. Even schezwan sauce or some tomato ketchup may be added to the rice or spice up with favourite herbs. Another similar popular recipe in this is Vegetable fried rice recipe

3. Corn salad

An easy recipe of salad made with sweet corn, cucumber, onion and spices and herbs. Though tinned corn be used but using fresh corn is better as the taste gets enhanced

4. **Buttered corn**

It is an easy, quick and tasty snack made with sweet corn, butter, herbs and spices. It makes for a good evening snack that is filling and delicious. Children specially love it. This product is always available at airports and mega malls as it is easy to prepare.

5. Sweet Corn Chat

This dish is made with sweet corn, chat masala , onions and tomatoes. This dish is not only easy to make but also tastes delicious. This chaat is great to enjoy as an evening snack and is kid's friendly too.

6. Sweet Corn Sandwich

These sandwiches are made with bread of choice, sweet corn kernels, veggies, cheese, spices and sandwich spread or chutney. It can serve as breakfast, snack or even for light dinner.

Economics

Table 1: Economics of cultivation of sweet corn vis-a-vis Normal maize over 200 m^2 area

Type of corn	Production (Kg)	Cost of cultivation (INR)	Gross returns (INR)	Net returns (INR)	B: C ratio
Normal Maize	380.00	2560.00	7600.00	5040.00	1.97
Sweet corn	671.30	2793.00	14361.00	11568.0	4.14

Average price of sold sweet corn- Rs. 20 kg

For achieving economic prosperity, the transplanting of sweet corn seedlings to raise the crop on a smaller scale has been found to be effective in enhancing the productivity of the crop. Transplanting resulted in 20% higher net profits.

Constraints

The two main constraints in specialty corn production are:

1. Non availability of assured marketing infrastructure/market place and unregulated trade practices.

2. Also there are limited commercial quantities of these corn types available in the market.

Conclusion

The demand of sweet corn is increasing every year. The development of suitable hybrids and their production technology for specialty corn will further be strengthened. The popularization of processing products of specialty corn maize for ensuring the livelihood security of rural masses and promotion of small scale entrepreneurship will receive greater attention.

Specialty corns have several health benefits along with a delicious taste of their own. Due to increase in domestic consumption, its demand is increasing day by day. The farmers find it an attractive crop to grow as the plant grows quickly and the cobs are harvested at an early stage to maintain the sugar content. The kernels are consumed in an immature stage as they possess high sugar content than normal corn in early dough stage. With the increase of urbanization,

ISSN: 3049-2289

change in food habit and the improved economic status, specialty corn has gained significant importance in peri-urban areas of the country

Future Perspectives

Modifications of ordinary corn to specialty corn using scientific approaches can improve yield potential and quality parameters. Industrial advancement leads to income generation and thereby livelihood improvement. Under Kashmir conditions where there is a growing problem of unemployment, the processing unit for sweet corn has a potential to engage and semiskilled people.

Measures such as contract farming, setting up processing units, ensured market, interaction between public and private sector, incentive based value chain will increase production.

More emphasis needs to be given for developing early maturing varieties to fit the specific cropping sequence and intercropping.

References

1. Ashby, B.H. 2008. Protecting perishable foods during transport by truck. United States Department of Agriculture. http://www.ams.usda.gov/

2. M.C. Dagla, R.N.Gadag, N.Kumar, B.C. Ajay and Chet Ram. 2014. A Potential Scope of Sweet corn for Peri Urban Farmers in India. Popular Kheti. Vol 2 (1): 69-73

3. Li, C., and Hawkins, G. 2011. Postharvest cooling. The University of Georgia Cooperative Extension. Commercial Sweet Corn Production in Georgia. Bulletin 1388. http://www.caes.uga.edu/.

4. S. Najeeb., F.A. Sheikh, M.A. Ahangar and N.A. Teli. 2011. Popularisation of Sweet Corn (Zea mays L. saccharata) under Temperate Conditions to Boost the Socio Economic Conditions. Maize Genetics Cooperation Newsletter Vol 85.

5. Suslow, T.V, and Cantwell, M. 2013. Corn, sweet: Recommendations for maintaining postharvest quality. University of California Postharvest Technology Center. http://postharvest.ucdavis.edu/.

6. Tiryak Kumar Samant and Bineeta Satpathy. 2020. Evaluation of sweet dot (*Zea mays* L. *saccharata*) cv Sugar 75 for livelihood security in mid central table Land zone of Odisha. *International Journal of Herbal Medicine*. 8 (4): 30-32

7.Tracy W.F. and Hallauer, A. R. 1994. Sweet corn in 'Speciality Corns' CRC Press Inc., Boxa Raton, USA. pp.148-187

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Innovation in Dairy Farming for Higher Milk Production

Jagruti singh
Lovely Professional University, Jalandhar, Punjab

Dairy farming has always been a key part of agriculture, supplying nutritious milk and milk products to millions of people. As the need for dairy products grows around the world, farmers are working hard to increase milk production while keeping animals healthy and farming sustainable. New technologies and methods in dairy farming are changing the way things are done, helping to make milk production more efficient and higher than before.

1.Better Breeding Methods

Farmers use selective breeding and artificial insemination to create better dairy cows.

Techniques like genomic selection and cross breeding help develop cows that are healthier, more fertile, and stronger against diseases, leading to more and better milk production each time.

2. Smart Farming Technologies

Tools like sensors, automatic milking machines, and wearable devices are changing how farmers manage their herds.

These tools track cow health, eating patterns, and milk quality in real time, helping farmers make better decisions to improve productivity.

3. Improved Nutrition

Feeding cattle the right mix of protein, minerals, and vitamins is important for getting more milk.

Using Total Mixed Rations (TMR), growing fodder with hydroponics, adding probiotics, and using bypass protein feed helps cows digest food better and produce more milk.

4.Comfortable Housing

Cow happiness plays a big role in milk production.

New housing ideas like controlled temperature barns, rubber flooring, water sprinklers, and automatic fans help keep cows relaxed and healthy. Comfortable living conditions help improve milk output and herd performance.

5.Automated Milking Systems

Robotic milking machines allow cows to be milked on their own schedule, which reduces stress and increases milk production.

These machines also keep things clean, track milk quality, and lower labor costs, making dairy farming more efficient.

6.Health and Disease Control

Modern vet care, regular vaccinations, and early disease detection with biosensors keep cattle healthier.

Managing mastitis, keeping hooves in good shape, and controlling parasites help improve milk quality and yield.

7.Eco-Friendly Practices

Using biogas plants, managing cow waste, and recycling water not only help protect the environment but also give farmers extra income.

These practices ensure dairy farming stays profitable and sustainable for the long term.

Conclusion

Innovation is essential for meeting the growing demand for milk and dairy products worldwide.

By using better breeding, smart technology, improved food, and eco-friendly methods, farmers can increase milk production without harming animals or the environment.

******

ISSN: 3049-2289

Artificial Intelligence (AI) in Agriculture: Transforming Farming for the Future

Aditi Singh
Lovely Professional University, Jalandhar, Punjab

Agriculture has always been the backbone of human civilization, providing food, raw materials, and livelihoods to billions of people around the world. From traditional hand tools to tractors and automated machinery, farming has evolved with every technological revolution. Today, the agricultural sector is witnessing another transformation through Artificial Intelligence (AI). AI farming is not just a trend but a necessity in a world facing rising population, shrinking arable land, climate change, and increasing food demand. With the help of AI-powered systems, farmers can make smarter decisions, increase productivity, reduce costs, and adopt sustainable practices. This article explores how AI is being used in agriculture, its applications in farming, the benefits it offers, challenges in its adoption, and the future scope of AI-powered farming.

What is AI Farming?

AI farming refers to the application of artificial intelligence technologies—such as machine learning, computer vision, robotics, drones, and predictive analytics—in agricultural practices. It uses data-driven insights to support decision-making in crop management, soil health monitoring, irrigation, pest and disease control, and supply chain efficiency. By combining data from sensors, satellites, and farm equipment, AI enables precision agriculture—a method of farming that ensures maximum output with minimal input.

Applications of AI in Agriculture

1. Precision Agriculture
2. Crop Health Monitoring
3. Predictive Analytics for Yield and Weather
4. Smart Irrigation Systems
5. Robotics and Automation
6. Supply Chain Optimization
7. Livestock Monitoring

Benefits of AI in Farming

- Increased Productivity
- Cost Reduction
- Sustainability
- Labor Efficiency
- Risk Management
- Improved Decision Making
- Better Market Access

Challenges in Implementing AI in Agriculture

- High Cost of Technology
- Lack of Awareness and Training
- Data Availability and Quality
- Connectivity Issues
- Resistance to Change
- Maintenance and Technical Support
- Ethical and Privacy Concerns

Future Scope of AI in Agriculture

- Integration with IoT and 5G
- Affordable AI Solutions
- Climate-Smart Agriculture
- Personalized Farming Recommendations
- Blockchain Integration
- Autonomous Farms

Case Studies of AI in Agriculture

- India: Companies like CropIn and Gramophone are using AI to provide predictive insights.
- USA: John Deere's AI-powered tractors optimize planting and spraying.
- Japan: AI robots harvest fruits and vegetables.
- Africa: AI tools detect crop diseases early, preventing losses.

ISSN: 3049-2289

Conclusion

AI farming represents the future of agriculture. It holds the potential to tackle some of the biggest challenges of modern farming, including food security, resource management, and climate change. By enabling precision farming, predictive analytics, smart irrigation, and supply chain optimization, AI ensures that agriculture becomes more productive, sustainable, and resilient.

However, the road to full adoption is not without hurdles. Issues of cost, awareness, infrastructure, and trust need to be addressed through government support, farmer training, and industry collaboration. With the right strategies, AI can empower farmers worldwide, ensuring that agriculture continues to feed the growing population in an efficient and sustainable manner.

In conclusion, artificial intelligence is not here to replace farmers but to assist them. By combining the wisdom of traditional farming with the power of modern AI, agriculture can truly enter a new era—one where technology and nature work hand in hand to secure the future of food for generations to come.

References

1. Campbell, J.B. & Wynne, R.H. (2011). Introduction to Remote Sensing. Guilford Press.
2. Hunt, E.R. & Daughtry, C.S.T. (2018). What good are unmanned aircraft systems for agricultural remote sensing and precision agriculture? International Journal of Remote Sensing.
3. John Deere Official Website – Smart Farming Solutions (https://www.deere.com).
4. Food and Agriculture Organization (FAO). (2021). The State of Food and Agriculture Report.
5. World Economic Forum (2020). How AI is Revolutionizing Agriculture.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Regenerative Agriculture and the Evolving Role of Extension Education

Ayan Hazarika[1*], Aditya Borah[2], Ojas Jyoti Borah Hazarika[3], Abhashdeep kakoty[4] and Pallabi Das[5]
[1,2,3,4]PG Scholar, Department of Extension Education,
[5]Assistant Professor, Department of Extension Education,
Assam Agricultural University, Jorhat, Assam

The transition to regenerative agriculture (RA) presents a paradigm shift in farming, moving from input-intensive production to a system-based approach focused on ecological health. This report examines how this shift necessitates a fundamental evolution in agricultural extension education, moving away from its traditional top-down, technology-transfer model. The analysis demonstrates that conventional extension methods, which often prioritize standardized solutions, are not well suited to RA's site-specific and holistic nature. We propose that effective regenerative extension must adopt a new, participatory, and collaborative framework, leveraging peer-to-peer networks, public-private partnerships, and digital technologies. This report synthesizes findings from diverse research to provide a comprehensive framework to foster the widespread and sustainable adoption of regenerative farming practices.

Introduction

Regenerative agriculture (RA) has emerged as an outcome-based food production system that aims to nurture and restore soil health, protect water resources, enhance biodiversity, and improve the profitability and resilience of farms. The principles is not new, it draws upon centuries of Indigenous knowledge and self-sufficient farming practices that existed before the widespread adoption of modern, synthetic inputs in the post-World War II era. Instead of simply reducing harm, as in sustainable agriculture, RA seeks to actively improve the ecosystem and build soil health over time.

However, a central challenge facing the widespread adoption of regenerative practices is its lack of a universal, legally-defined standard. Unlike "organic" farming, RA is not governed by a federal regulatory framework. As a result, the term is often applied broadly to anything that improves farm outcomes and minimizes environmental impact. While this flexibility allows farmers to adapt principles to their unique contexts, it also presents a significant challenge for consumers, policymakers, and researchers, who lack a consistent, verifiable definition. The term is often considered a flexible, farmer- centered "concept" or "movement," rather than a rigid set of rules. This ambiguity makes it a target for "greenwashing," where companies use the term for marketing purposes without a commitment to measurable, long-term ecological outcomes.

The successful scaling of regenerative agriculture is not merely a technical challenge but a pedagogical and socio-economic one. The legacy of traditional agricultural extension is rooted in a linear, top-down model in which information flows from university researchers to extension agents and then to farmers. This model was designed for the efficient transfer of standardized technologies, such as new crop varieties or chemical application protocols. This approach, however, is fundamentally incompatible with the complex, context-specific, and knowledge-intensive nature of regenerative agriculture. RA practices cannot be implemented as a simple "cut-and-paste" solution from one region to another due to variations in soil type, climate, and local ecosystems. Therefore, the successful scaling of regenerative agriculture necessitates a fundamental evolution in agricultural extension, moving from a role of technology transfer

ISSN: 3049-2289

to one of problem-solving and participatory facilitation.

Foundational Principles of Regenerative Agriculture

Despite the lack of a formal definition, a consensus exists around the core principles of regenerative agriculture. These principles are not a rigid but a flexible set of guidelines that can be adapted to a specific farm's context. The six core principles are:

- **Minimize Soil Disturbance:** This principle is the cornerstone of Regenerative Agriculture. It involves reducing or eliminating physical disturbance, such as tillage, as well as chemical disturbance from synthetic fertilizers and pesticides. Undisturbed soil maintains its integrity, pore connections, and microbial ecosystems, which are vital for soil fertility.
- **Keep the Soil Surface Covered:** Maintaining a protective layer of living plants or crop residues acts as a "duvet" for the soil, shielding it from the harmful impacts of rain, sun, and frost. This practice, often implemented through cover cropping or mulching, protects the soil from erosion and helps it retain moisture.
- **Maintain Living Roots in the Soil:** Keeping living roots in the soil year-round is vital for feeding the complex soil food web. Plants photosynthesize energy from the sun and transfer it to the root systems and soil ecosystem, which helps retain nutrients and prevent carbon from being released into the atmosphere as carbon dioxide.
- **Grow a Diverse Range of Crops:** Monocultures do not occur in nature, and soil creatures thrive on variety. Increasing plant diversity through practices like crop rotation, companion cropping, and multi-species grazing boosts soil fertility, reduces pest and disease pressure, and enhances the farm's resilience to extreme weather.
- **Integrate Livestock:** The responsible grazing of livestock, through practices like mob grazing, can accelerate nutrient cycling, spread organic matter, and supercharge the regenerative impact on the soil.

Ecological and Economic viability

The appeal of regenerative agriculture lies in its dual promise of ecological restoration and economic viability. By working with nature rather than against it, RA offers a pathway to a more resilient food system and a healthier planet.

- **Environmental Benefits:**
  - ✓ Carbon Sequestration: A primary environmental benefit of RA is its potential to mitigate climate change by sequestering carbon in the soil. This can transform agriculture from a source of greenhouse gases to a net carbon drawdown system.
  - ✓ Biodiversity Restoration: Reduced tillage protects the complex underground web of microorganisms, while practices like diverse crop rotations and the creation of biodiversity strips provide habitats for pollinators, birds, and other beneficial wildlife.
  - ✓ Water Resilience: Healthy soils act like a sponge, improving water infiltration and retention. This makes farms and surrounding communities more resilient to extreme weather events like droughts and floods while reducing erosion and polluted runoff.
- **Economic Viability:**
  - ✓ Increased Profitability: Contrary to the misconception that ecological farming is less profitable, studies have shown that regenerative practices can significantly increase farm income.
  - ✓ Increased Resilience: Regenerative agriculture enhances a farm's ability to withstand environmental shocks. A survey of U.S. farmers found that 97% of growers who adopted soil health management systems reported increased resilience to extreme weather events. This resilience is a

ISSN: 3049-2289

key driver of adoption, as it mitigates risk and protects long-term viability.

Extension Approach

To effectively support the transition to RA, agricultural extension must move beyond its traditional framework. The unique challenges and principles of regenerative agriculture demand a new model for extension education. This model must be participatory, collaborative, and grounded in trust and local knowledge.

In the context of RA, the role of the extension agent must shift from a purveyor of knowledge to a facilitator of learning. Instead of providing a pre-packaged solution, the agent's new role is to guide farmers in identifying problems and developing adaptive management strategies. The goal is not just to transfer technology but to empower farmers to become active problem-solvers who can navigate the complexities of their unique ecosystems.

To overcome these challenges and accelerate the adoption of RA, multi-stakeholder partnerships are essential. Public-private collaborations, such as the "STEP up for Agriculture" initiative launched by companies like PepsiCo and Unilever, provide a model for scaling regenerative practices. This approach brings together corporations, nonprofits, and farmer-led groups to provide funding and strategic support to local farmer organizations, strengthening the advisory ecosystem that is so critical for success.

ICT incorporation

Digital and precision agriculture innovations are revolutionizing RA by providing the real-time, site-specific data required for adaptive management. Technologies like soil-scanning sensors and autonomous systems can optimize inputs in real time, enhancing nutrient uptake and bolstering climate resilience. These tools provide the evidence base that farmers need to feel confident in their transition to RA.

However, the widespread adoption of these technologies is not guaranteed. A significant "digital divide" exists, with digital tool use being much lower in countries with a higher share of smallholder farmers. For extension education to be truly transformative and equitable, it must include strategies to make these tools more accessible and affordable, bridging the gap for smallholder farmers who stand to benefit immensely from RA practices.

Recommendations

Based on this analysis, several key recommendations for the path forward can be made:

- **For Extension Services:** The role of the extension agent must be redefined as more of a facilitator, than an expert. Extension services should prioritize farmer-to-farmer learning networks and incorporate local and indigenous knowledge. Furthermore, training programs should focus on adaptive management and problem-solving rather than on the dissemination of fixed solutions.
- **For Policymakers:** Support for regenerative agriculture should move beyond general subsidies and include financial mechanisms that de-risk the transition period, such as crop insurance for diverse rotations and cost-sharing for initial investments.
- **For the Private Sector:** Corporations and agribusinesses should continue to invest in and expand multi-tiered partnerships with farmer-facing organizations to build trust and provide locally-tailored support. They should also prioritize the development of accessible, low-cost digital technologies that can bridge the digital divide and empower smallholder farmers with the data they need to succeed.

Conclusion

Regenerative agriculture represents a profound opportunity to restore ecological health and build a more resilient food system for the future where farmers are not passive recipients of knowledge but active participants in an ecological feedback loop. However, its success hinges on the ability of agricultural extension to evolve beyond its traditional function. By embracing a new model that is participatory, data-driven, and collaborative, extension can transform from a simple source of information to a catalyst for system-level change, empowering farmers to become not just producers, but true stewards of a regenerative future.

References

Bayer AG. (2024). *75 percent of farmers are open to innovation to cope with climate change, global research reveals*.

Bunch, R. (2025). *Case Studies*. California State University, Chico.

Chesapeake Bay Foundation. (2024). *What Is Regenerative Agriculture?*

Cotton Today. (2024). *Challenges and Differences*. Cotton Incorporated.

Development Aid. (2024). *Challenges and Opportunities of Regenerative Agriculture*.

Echo Community. (2025). *Effective Extension Methods*.

Farmonaut. (2025). *Top 7 Farming Alternatives for Sustainable Agriculture*.

Food and Agriculture Organization of the United Nations. (2024). *Regenerative Agriculture*.

Frontiers in Sustainable Food Systems. (2025). *What is Regenerative Agriculture?*

Groundswell Agriculture. (2024). *5 Principles of Regenerative Agriculture*.

Khangura, R., Ferris, D., Wagg, C., & Bowyer, J. (2023). Regenerative Agriculture—A Literature Review on the Practices and. *Sustainability, 15*(3), 2338.

K-State Regenerative Agriculture. (2020). *Innovation*. Kansas State University.

McKinsey & Company. (2024). *Voice of the US farmer 2023-24: Farmers seek path to scale sustainably*.

Meegle. (2024). *Regenerative Farming vs. Conventional Farming*.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Insect Antimicrobial Peptides: Nature's Tiny Warriors Against Plant Diseases

Manasa C.[1] and Nikita L. T.[2]
[1]PhD Scholar, Department of Entomology, College of Horticulture, Bengaluru
[2]M.Sc. Entomology, Department of Entomology, College of Horticulture, Bengaluru,
University of Horticultural Sciences, Bagalkot

Insects are rarely cast to be heroes when we think of protecting the crops from plant diseases. To the farmers, they are pest's viz., sucking, chewers or borers that damage the plants and spread infection. But in a fascinating twist, scientists have now discovered that these insects carry a secret weapon for protecting the crops and not destroying them.

Deep inside the bodies of these tiny creatures are Antimicrobial Peptides (AMPs), a natural molecule that act as a powerful defenses against harmful microbes. Once thought relevant only to the human medicine, these compounds are now drawing attention as an eco-friendly alternative to the antibiotics and chemical pesticides in agriculture.

The Growing Threat of Resistant Plant Pathogens

Global food security is seriously threatened by the plant diseases caused by bacteria and fungi costing 34 per cent of losses each year. Since decades, farmers relied on the antibiotics and chemical pesticides to keep these threats in check and has served as "magical molecule". The consistent reliance on the antibiotics has resulted in the development of resistance explaining it failure in the disease management. The current scenario of antibiotic resistance alarms the need of sustainable, effective and environmentally safe alternatives.

Insects: The Oldest Immune Innovators

Insects, a conquerors of Earth over 500 million years ago with largest species diversity, occupying all the ecological niches has evolved with a quite effective immune system. Consistent relationship with the diversified microbial has made them to drive successful existence and diversification. Unlike the other organisms, insects are bereft of adaptive immunity system and owns innate immunity that forms the first and only line of defense. Central to that defense are AMPs, a humoral defense molecule.

What are Antimicrobial peptides?

AMPs are tiny positively charged molecule with 12-50 aminoacids and 40-50 per cent hydrophobic amino acids, possessing broad spectrum activity against bacteria, fungi, viruses and protozoans. These are known to interact with the plasma membrane and acts like microscopic spears resulting in membrane permeabilization followed by deregulation of ionic homeostasis (Sokolov *et al.,* 1999). Apart from the membrane permeabilization, mounting body of evidences have indicated the presence of additional or complementary mechanisms like targeting intracellular process vital for the cellular physiology such as protein, DNA, Ribonucleic acid (RNA), Enzyme synthesis inhibition, blocking of chaperone necessary for protein folding, Inhibition of cellular respiration and induction of reactive oxygen species (ROS) formation, disruption of mitochondrial cell membrane integrity *etc.* (Yeaman and Yount, 2003; Harris *et al*., 2009). The multiple mode of action of the AMPs ensures the difficulty for microbes to develop resistance as it turns out to be promising feature, as bacteria would require to reconfigure the membrane which is energetically costly maneuver.

Diversity

Insects produce a remarkable array of antimicrobial peptides differing in structural and functional diversity, reflecting the evolutionary adaptation of insects to diverse pathogenic challenges. The occupance of different ecological niche and exposure to the diversified pathogen organisms has resulted in larger repertoire of AMPs than any other group. Structurally, insect AMPs fall mainly into three categories: linear α-helical peptides without cysteine residues (e.g., cecropins), cysteine-rich β-sheet peptides stabilized by disulfide bridges (e.g., defensins), and peptides rich in particular amino acids like proline or glycine (e.g., attacins, drosocins). This structural diversity correlates with their functional specificity,some peptides mainly target Gram-negative bacteria, others Gram-positive bacteria, fungi, or even viruses, while many have broad-spectrum activity. For example, cecropins are generally effective against Gram-negative bacteria, defensins target mainly Gram-positive bacteria, and proline-rich peptides can inhibit intracellular processes in pathogens. The evolutionary plasticity of these AMPs, involving gene duplication and functional shifts, equips insects with adaptive defenses suited for diverse microbial environments, while preserving ancient conserved features that ensure robust antimicrobial action.

Tiny Molecules with Huge Potential

The studies upon the AMPs against phytopathogens at laboratory and semi field conditions have proved its potentiality against phytopathogens by displaying the bacteriostatic, microbicidal and cytolytic properties (Pasupuleti *et al*., 2012; Huan *et al*., 2020). For example, the *in vitro* studies, the peptide RW-BP100, a combination of cecropin and melittin showed 55-67 per cent inhibition of *Erwinia amylovora* at 25 µM concentration (Mendes *et al*., 2021). Further the *ex vivo* and *in planta* studies displayed 95-100 per cent infection reduction in pepper and pear by *Xanthomonas* and *Pseudomonas* sp. Several other AMPs of insect's *viz*., Gallerimycin, Attacin, Sarcotoxin, Cecropin, Metchnikowin, Drosomycin, Gloverin, Apidaecins, Attacins etc have reported to have antibacterial activity against common phytopathogens such as *Xanthomonas* sp., *Pseudomonas* sp., *Erwinia* sp., *Agrobacterium* sp., *Ralstonia* sp. *etc.* Apart from the toxicity of the AMPs against the phytopathogens, these molecules are considered to have negligible cytotoxic and phytotoxic effects on the plants ensuring AMPs to be safer molecules for the plant disease management.

Salient features of AMPs contributing to their effectiveness against phytopathogens

1) **Broad spectrum activity** – The cationic nature of AMP that allows them to selectively bind to the negatively charged surfaces of microbial membranes ensures selective targeting. Additionally, the amphipathic structure enables them to insert into microbial lipid bilayers disrupting membrane integrity and forming pores. Further, multiple mode of actions enables the AMPs to neutralize a diverse array of pathogens.
2) **Rapid and Direct Killing Mechanism** – The AMPs neutralize the pathogens within minutes to hours which is an important criteria in the plants and prevents early colonization of pathogens and limits disease progression.
3) **Low Propensity for Resistance Development** - The action on the fundamental cellular structures such as the membranes which are highly conserved and essential for the survival makes the pathogens difficult to develop resistance. Further, the mutations in the membrane compromise the pathogens viability making the development of resistance energetically unfavourable and evolutionarily rare.
4) **Structural Diversity and Adaptability** – The structural diversity *viz*., α helical, β – sheet, proline rich and glycine rich forms allows them to act against different types of pathogens under varying environmental

conditions. This diversity makes AMPs highly adaptable, and their structures can be modified synthetically or through genetic engineering to enhance stability, target specificity or potency.

5) **Synergistic and additive effects** – The AMPs can work synergistically with other natural defense molecules or beneficial microbes amplifying their antimicrobial activity. This synergy allows for more efficient disease management at lower concentrations and reduces the need for chemical interventions, making them ideal candidates for integrated pest management strategies.
6) **Biocompatibility and Environmental safety** – Being naturally derived, AMPs are biodegradable and environmentally friendly capable of converting into harmless amino acids without accumulating toxic residues. The higher compatibility aligns with global efforts to promote sustainable agriculture and reduce reliance on synthetic pesticides.
7) **Potential for genetic integration into crops** – Since the AMPs are ribosomal synthesized molecule, it allows the development of transgenic plants enabling them to produce their own AMPs. This technique provides built-in, long lasting resistance against multiple pathogens reducing the multiple needs of synthetic pesticides for the disease management.
8) **Induction of plant defense responses** – The AMPs are reported to act as elicitors and triggers plants own immune system and priming systemic defenses. This ameliorates induced resistance by activation of defense pathways and genes.
9) **High selectivity towards pathogens** – The AMPs display high selectivity towards the cells ensuring the attack only on the pathogens without damaging the host plants.
10) **Evolutionary resilience** – AMPs are evolutionarily ancient molecules used by the insects for over 500 million years to defend against microbial rich environments. Their long term evolutionary success demonstrates that these molecules are robust, effective and reliable for engineering disease resistant crops.

Potential applications of AMPs in Agriculture

1. Developing Disease-Resistant Crops

It is one of the most explored and direct application of AMPs in agriculture is generation of the transgenic crop through heterologous expression of AMP genes in the plant genome with a genetic engineering approaches. Transgenic rice, tobacco and tomato plants expressing cecropin or defensin genes have shown strong resistance to bacterial and fungal infections Mishra and Wang, 2021).

2. Biopesticide formulations

AMPs could be applied exogenously as biopesticide formulations, either as the pure peptide or in the form of microbial fermentation products. The advantage of AMPs used as biopesticide formulations is that it degrade rapidly in the environment, produces minimal ecological risk and are compatible with sustainable farming practices. The studies of application of peptide based sprays containing cecropin analogs have shown to reduce the incidence of *Botrytis cinerea* and *Xanthomonas campestris* incidence in green house conditions (Hancock and Sahl, 2006).

3. Postharvest Protection

AMPs offer a natural method for post-harvest preservation of fruits and vegetables as surface coatings or inclusion in biodegradable films and prevent the growth of spoilage organisms (Tiwari and Valdramidis, 2016).

4. Seed and Soil treatments

Coating seeds with AMP solutions or embedding AMPs into biodegradable seed films inhibits the growth of soil borne pathogens (Maroti *et al*., 2011). Further, AMP based soil amendments could promote rhizosphere health by selectively suppressing harmful microbes while allowing beneficial symbionts to thrive due to reduced negative charge density. This targeted antimicrobial action supports root development and nutrient uptake contributing to overall plant vigour.

5. Synergy with beneficial microorganisms

AMPs are found to be compatible with biocontrol agents such as *Trichoderma bacillus* or *Pseudomonas* strains. These beneficial microbes naturally suppress pathogens through competition and antibiosis; when supplemented with AMPs, their protective activity can be amplified (Nawrocki *et al*., 2014). Such synergistic formulations provide multi layered protection against broad range of plant pathogens reducing the likelihood of resistance development and enhancing long term field efficacy.

6. Reduction of resistance development and promoting sustainability

The preliminary mode of action and the multi target mechanism of AMPs enables them to be a potential molecule against phytopathogens. Further, these molecules are biodegradable and exhibit low toxicity to non-target organisms aligning with the goals of sustainable and ecofriendly agriculture.

Challenges and Limitations

- **Stability and degradation**: Peptides are susceptible to proteases, heat, UV, pH changes
- **Production cost and scale**: Synthesizing or producing large quantities at farm-scale cost needs refinement.
- **Toxicity and non-target effects**: Need to confirm safety for plants, beneficial microbes and humans
- **Resistance to risk**: Overreliance on AMPs alone could eventually select for resistant strains. Hence the usage pattern should be carefully designed and followed.
- **Regulatory and Adoption barriers**: Legislation, Farmer acceptance, cost benefit modelling

Conclusion:

Insect antimicrobial peptides represent a remarkable example of nature's molecular ingenuity. Once known only as immune effectors in insects, these tiny peptides are now emerging as" potent allies in crop protection". Their rapid and selective action, multifaceted mechanisms of action, low propensity for resistance development, and environmental safety position them as promising alternatives to traditional chemical pesticides and antibiotics in agriculture. By harnessing AMPs, either through genetic transformation, peptide sprays, or integration with beneficial microbes, can progress toward sustainable disease management solutions. Overcoming challenges like peptide stability and production cost through advances in biotechnology and peptide engineering will be key to fully harnessing the potential of insect AMPs. With continued interdisciplinary research, insect antimicrobial peptides could revolutionize crop protection and contribute significantly to global food security.

References

Hancock, R. E. W., and Sahl, H. G., 2006, Antimicrobial and host-defense peptides as new anti-infective therapeutic strategies. *Nat. Biotech.*, 24, 1551–1557.

Harris, M., Mora-Montes, H. M., Gow, N. A. and Coote, P. J., 2009, Loss of mannosylphosphate from *Candida albicans* cell wall proteins results in enhanced resistance to the inhibitory effect of a cationic antimicrobial peptide via reduced peptide binding to the cell surface. *Microbiol.*, 155: 1058–1070.

Huan, Y., Kong, Q., Mou, H. and Yi, H., 2020, Antimicrobial Peptides: classification, design, application and research progress in multiple fields. *Front. Microbiol.* 11.

Maroti, G., Kereszt, A., Kondorosi, E. and Mergaert, P., 2011, Natural roles of antimicrobial peptides in microbes, plants and animals. *Res. Microbiol.* 162(4): 363-374.

Mendes, R. J., Regalado, L., Luz, J. P., Tassi, N., Teixeira, C., Gomes, P., Tavares, F. and Santos, C.,

ISSN: 3049-2289

2021, *In Vitro* evaluation of five antimicrobial peptides against the plant pathogen *Erwinia amylovora*. *Biomol*, 11(4).

Nawrocki, K. L., Crispell, E. K. and McBride, S. M., 2014, Antimicrobial peptide resistance mechanisms of Gram-positive bacteria. *Antibiotics (Basel)*, 3(4): 461-492.

Pasupuleti, M., Schmidtchen, A. and Malmsten, M., 2012, Antimicrobial peptides: key components of the innate immune system. *Crit. Rev. Biotechnol.*, 32(2): 143-71.

Sokolov, Y. T., Mirzabekov, B. L., and Kagan, 1999, Membrane channel formation by antimicrobial protegrins. *Biochim. Biophys. Acta*. 1420: 23–29.

Tiwari, B. K., Valdramidis, V. P., ODonnell, C. P., Muthukumarappan, K., Bourke, P. and Cullen, P. J. 2009, Application of natural antimicrobials for food preservation. J. Agric. Food Chem. 57(14):5987-6000.

Yeaman, M. R. and Yount, N. Y., 2003, Mechanisms of antimicrobial peptide action and resistance. *Pharmacol. Rev.,* 55: 27–55.

****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Implication of Artificial Intelligence in Post-harvest Management

[1*]K. Dey, [2]S. Mundiya, [2]T. Kandeyang, [2]A. Kumari, [2]R. Ranjan
[1]Assistant Professor-cum-Junior Scientist, [2]UG student, Horticulture College, Birsa Agricultural University

Introduction

Artificial intelligence can be defined as a machine-based system that can, for a given set of human-defined explicit or implicit objectives, infer from the input it receives how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments.

Application of Artificial intelligence

1. **Image-based grading and sorting (computer vision +CNNs)**: Convolution Neural Networks (CNNs) classify fruits by external quality (colour, defects, size) and are used in on-line sorting machines. It is applied for apple, mango, banana, citrus grading.
2. **Non-destructive internal quality assessment (hyperspectral / multispectral imaging + ML)**: Hyperspectral imaging paired with ML models predicts internal defects, sugar content, or ripeness without cutting the fruit.
3. **Shelf-life and spoilage prediction (time-series ML / regression models)**: Supervised ML models use storage temperature, humidity, respiration rate and physicochemical measurements to predict remaining shelf-life and optimal storage decisions.
4. **Robotic sorting and automated handling (vision + robotics+ control algorithms)**: Integrated perception (object detection/tracking), path planning and robotic end-effectors allow automated sorting, picking and packing in packinghouses.
5. **Predictive analytics for post-harvest loss reduction and supply-chain optimization**: Machine learning (ML) models forecast post-harvest losses at wholesaling/transport stages and assist routing/temperature-control decisions to reduce waste.
6. **On-line real-time defect detection (lightweight CNNs for high throughput)**: Custom lightweight CNNs have been embedded in conveyor systems to detect and reject defective fruits at industrial speeds.
7. **Automation of labour-intensive tasks**: Robotic handling and automated packing reduce labour need and occupational risk.
8. **Supply-chain visibility & predictive control**: Sensor + AI systems enable predictive alerts (e.g., temperature excursions) that preserve quality during transport and storage.

Developed AI system for Post Harvest Management

1. **Clari-fruit**: AI-based quality control platform for fruits using smart phone imaging
2. **Ag. Shift**: Automates grading of produce like strawberries and tomatoes using AI
3. **TOMRA Food**: AI-powered sorting machines for fruits and vegetables
4. **Intello. Labs**: Uses computer vision to assess quality and freshness of produce
5. **Smart Fresh™**: AI-assisted decision support for maintaining fruit freshness

Conclusion

Post-harvest quality grading and sorting are being transformed by Artificial Intelligence with the ability to speedily, accurately and automatically assess agricultural produce. The use of AI-based technology greatly minimizes post-harvest losses, improves product quality and maximizes farmers, processors and other stakeholders profitability along the supply chain. Even as obstacles like high setup costs, technical complexity, and integration remain, ongoing advancements in AI, combined with the diminishing cost of technology and its growing availability are promising widespread adoption. By adopting these innovations, the agricultural sector can shift toward more efficient, sustainable, and market-sensitive post-harvest management systems that ultimately benefit both producers and consumers.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Integration of Recirculating Aquaculture System (RAS) with Aquaponics for Enhanced Nutrient Recovery and Water Reuse Efficiency

Mariammal Senthilvel, Dr J. Jaculine Pereira, Dr R. Somu Sunder Lingam
Tamil Nadu Dr J.Jayalalitha Fisheries University, Nagapattinam, Tamil Nadu

The integration of Recirculating Aquaculture Systems (RAS) with aquaponics represents a transformative approach to achieving sustainable, resource-efficient food production. This paper synthesises findings from recent studies (2025) focusing on the optimization of nutrient dynamics, circularity, and system resilience in coupled and decoupled aquaponic configurations. Decoupled RAS–aquaponics systems have emerged as superior models for nutrient management and water reuse efficiency, enabling independent control of fish and plant subsystems (Al Tawaha et al., 2025; Silva et al., 2025). Advances in biofiltration and sludge bioconversion technologies, such as modified biological aerated filters, have enhanced nitrogen recovery and microbial transformation processes (Chen et al., 2025). Integration of smart sensors and digital twin frameworks has further enabled automation, real-time monitoring, and predictive management of nutrient flow (Stiri & Palattella, 2025; Handayani et al., 2025). Sustainable feed innovations, including black soldier fly larvae and biochar-based nutrient recovery, contribute to reduced environmental impacts and enhanced fish health (Munguti et al., 2025; Reppas Chrysovitsinos et al., 2025). The paper also highlights regional applications, such as snakehead aquaponic systems in Indonesia (Supriyono et al., 2025) and integrated inland aquaponics in Africa (Mthiyane, 2025), emphasizing their socio-economic and ecological benefits. Overall, RAS–aquaponics integration supports circular bioeconomy principles by minimizing waste discharge, maximizing nutrient reuse, and improving production efficiency. This comprehensive review underscores the need for continued innovation in system design, digitalization, and policy frameworks to advance sustainable aquaculture globally.

Introduction

Aquaculture has emerged as one of the fastest-growing food-producing sectors in the world, playing a vital role in global food security, nutrition, and rural livelihoods. However, conventional aquaculture practices are increasingly being challenged by limited freshwater resources, nutrient-rich effluents, and the need for environmental sustainability (Chouhan & Choudhary, 2025; Haque et al., 2025). To address these challenges, advanced production systems such as Recirculating Aquaculture Systems (RAS) and aquaponics have gained prominence due to their ability to recycle water and nutrients within a closed-loop system, thereby minimizing waste and environmental impacts (Brown et al., 2025; Iqbal et al., 2025).

Recirculating Aquaculture Systems (RAS) are land-based technologies designed to continuously treat and reuse water by incorporating mechanical and biological filtration components. These systems significantly reduce water consumption and provide greater control over water quality, fish health, and production intensity (Brown et al., 2025). However, RAS operations accumulate high concentrations of nitrate, phosphate, and organic matter, which if not properly managed, can affect fish performance and system sustainability. Efficient management of these nutrient residues is therefore crucial for maintaining water quality and reducing operational costs.

Aquaponics, on the other hand, is a synergistic integration of aquaculture and hydroponics, where nutrient-rich fish effluents are utilized as fertilizer for plant growth. The plants, in turn, absorb dissolved nutrients, thus purifying the water before it is recirculated back to the fish tanks (Al Tawaha et al., 2025; Silva et al., 2025). This biological integration not only improves water reuse efficiency but also transforms fish waste into a valuable resource for plant production, promoting the concept of circular economy in aquaculture.

Integrating RAS with aquaponics represents a sustainable pathway to optimize nutrient recovery, enhance resource use efficiency, and achieve environmental resilience. This integration enables the conversion of aquaculture by-products into secondary outputs such as vegetables or herbs, thereby diversifying income sources and improving food security (Mthiyane, 2025; Reppas Chrysovitsinos et al., 2025). Furthermore, recent innovations such as modified biofilters, sludge bioconversion techniques, and digital monitoring systems are advancing the operational efficiency and scalability of such integrated models (Chen et al., 2025; Stiri & Palattella, 2025).

Despite the growing interest, challenges remain in achieving an ideal balance between nutrient availability, system stability, and energy consumption. Research continues to explore optimal configurations—such as decoupled systems—to independently manage aquaculture and hydroponic components for maximum productivity (Al Tawaha et al., 2025).

Hence, the integration of RAS and aquaponics not only represents an environmentally responsible approach to aquaculture intensification but also embodies the principles of circular resource management and sustainable food production. This paper reviews recent advancements, operational frameworks, and future prospects of integrating RAS with aquaponics, focusing on enhanced nutrient recovery, water reuse efficiency, and system sustainability.

2. Conceptual Framework of RAS–Aquaponics Integration

2.1 Recirculating Aquaculture System (RAS): Overview

Recirculating Aquaculture Systems (RAS) represent an advanced form of intensive aquaculture designed to reuse and purify water within a closed-loop system. These systems are composed of essential components such as **fish rearing tanks**, **mechanical filtration units** for removing solid waste, **biofilters** for nitrification, **aeration and oxygenation units**, **disinfection systems** (e.g., UV or ozone), and **recirculation pumps** that maintain water flow and quality (Brown et al., 2025).

The **biofilter** acts as the biological heart of RAS, where nitrifying bacteria convert toxic ammonia (NH_3) excreted by fish into less harmful nitrate (NO_3^-). This ensures a stable environment for fish growth, even under high stocking densities. Aeration systems sustain dissolved oxygen levels necessary for both fish metabolism and microbial activity, while disinfection units prevent pathogen buildup and maintain biosecurity.

Strengths of RAS include substantial water savings (up to 95–99%), improved biosecurity, and enhanced control over environmental parameters such as temperature, pH, and dissolved oxygen (Brown et al., 2025). These features make RAS suitable for areas facing water scarcity or strict environmental regulations. However, **limitations** include high initial capital and operational costs, energy-intensive filtration processes, and the gradual accumulation of nitrate and dissolved organic compounds in the water (Budhathoki et al., 2025). The management of these residual nutrients presents both a challenge and an opportunity—one that can be effectively addressed through integration with aquaponic systems.

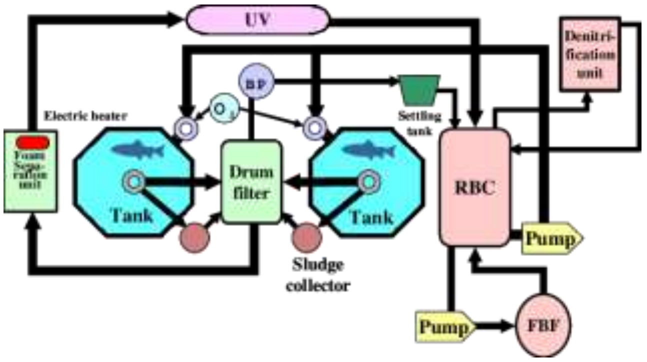


Figure 2 : "General diagram of the systems and measurement points: Recirculating Aquaculture System (RAS)." (Isla, M. "Water quality in recirculating aquaculture systems", Water Environment Research, 2008)

2.2 Aquaponics: Overview

Aquaponics is an **integrated, symbiotic system** that combines aquaculture and hydroponics to create a circular, sustainable production loop. In aquaponic systems, the nutrient-rich effluent from fish tanks serves as a natural fertilizer for plants, while the plants, in turn, absorb these nutrients and purify the water before it is returned to the fish culture unit (Iqbal et al., 2025).

There are two primary configurations of aquaponic systems: **coupled** and **decoupled**.

- In **coupled systems**, the fish and plant units are hydraulically connected, allowing continuous water exchange. However, maintaining ideal conditions for both fish (high nutrient input, stable temperature, neutral pH) and plants (lower nutrient concentration, slightly acidic pH) can be challenging.
- In contrast, **decoupled systems** separate the aquaculture and hydroponic circuits, allowing independent optimization of each subsystem. This approach enhances nutrient availability for plants and enables better water quality management for fish (Al Tawaha et al., 2025).

The **nutrient pathways** in aquaponics follow a sequential transformation:

fish feed → fish waste (ammonia, organic solids) → microbial mineralization → nitrate and phosphate release → plant uptake. The microbial community—including nitrifying and heterotrophic bacteria—plays a key role in converting fish waste into plant-available nutrients.

A successful example of this integrated approach was demonstrated in **snakehead (Channa striata)** aquaponic systems, where the use of green vegetables as biofilters enhanced water quality and improved fish growth (Supriyono et al., 2025). Such studies highlight aquaponics as a dual-production system that ensures **nutrient recovery, reduced effluent discharge, and sustainable food production**.

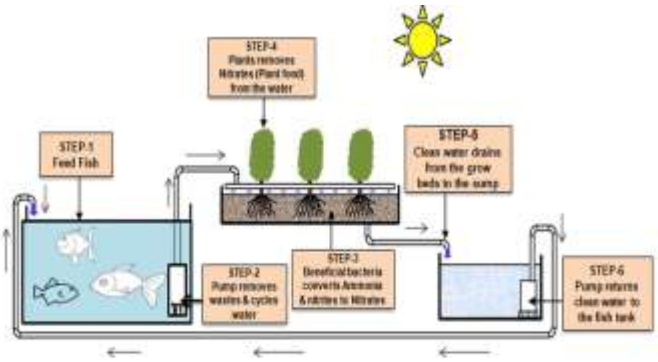


Figure 3 : "Schematic diagram of aquaponic system adapted from Yang & Kim (2020)"

2.3 Integration Models

The integration of RAS and aquaponics creates a **closed-loop eco-engineered system** where water and nutrients are continuously cycled between the fish and plant components. Three major integration models have evolved to optimize performance and sustainability:

a) Direct Coupling Model

In this model, effluent from the RAS—rich in dissolved nitrogen and phosphorus—is directly supplied to the hydroponic unit. The plants absorb nutrients, and the treated water is recirculated back to the fish tanks. This system is simple, cost-effective, and requires minimal infrastructure. However, balancing nutrient concentration and maintaining water quality for both organisms can be complex, especially under high fish density.

b) Decoupled Integration Model

Decoupled systems use a **one-way flow of water** from the fish culture unit to the hydroponic beds, without returning it to the fish tanks. This allows for **independent optimization** of water parameters for each component. Recent research emphasizes decoupled aquaponics as a more stable and productive alternative, improving both plant yield and nutrient use efficiency (Al Tawaha et al., 2025). The decoupled model also enables the use of nutrient supplements and temperature control strategies suited specifically for plants.

c) Smart and Automated Integration

Emerging studies advocate the use of **automation, IoT sensors, and digital twin technologies** to monitor water quality, nutrient balance, and energy efficiency in real time (Stiri & Palattella, 2025). Smart integration ensures optimal nutrient recovery and system resilience through data-driven control of pH, oxygen, flow rate, and temperature. Moreover, integrating aquaponics with eco-farming systems and bioremediation approaches—such as those using palm oil mill effluent (POME)—can further enhance circularity and environmental sustainability (Handayani et al., 2025)

3. Literature Review

3.1. Recirculating Aquaculture System (RAS): Principles and Challenges

Recirculating Aquaculture Systems (RAS) are closed-loop water management systems designed to minimize water consumption and effluent discharge while maintaining optimal fish growth conditions. The system continuously recycles water through mechanical filters, biofilters, and aeration units to remove solids, oxidize ammonia, and maintain dissolved oxygen levels. According to **Brown et al. (2025)**, RAS technology has revolutionized aquaculture by improving biosecurity, feed conversion efficiency, and water quality stability, especially in high-value species like Atlantic salmon. However, several challenges persist — including **high energy consumption**, **biofilter clogging**, and **sludge accumulation**. Continuous monitoring and efficient sludge handling are essential to sustain water quality and prevent nitrogen compound buildup. Incomplete denitrification processes and limited nutrient reuse often result in the discharge of nutrient-rich wastewater, highlighting the need for integrated systems that recover and reuse nutrients rather than discarding them.

3.2. Aquaponics: Concept and Functionality

Aquaponics integrates aquaculture with hydroponic plant production in a symbiotic environment. Fish waste provides essential nutrients for plant growth, while plants act as natural biofilters, absorbing dissolved nutrients and purifying water for recirculation to the fish tanks. Two operational configurations are commonly used: **coupled systems**, where aquaculture and hydroponic units share a single water loop, and **decoupled systems**, where each operates independently with controlled nutrient and pH levels (**Al Tawaha et al., 2025**). Nutrient conversion is primarily driven by **nitrifying bacteria** that oxidize ammonia to nitrite and then to nitrate, making it bioavailable for plant uptake. The efficiency of this biological conversion determines the overall system stability. Studies by **Supriyono et al. (2025)** demonstrated that plant species selection significantly influences nutrient uptake dynamics, with leafy greens such as spinach and lettuce showing high nitrogen absorption rates in snakehead (*Channa striata*) nursery aquaponic systems. Therefore, aquaponics not only enhances nutrient recycling but also contributes to producing high-quality, pesticide-free crops.

ISSN: 3049-2289

Dynamics and Recovery

In both RAS and aquaponic systems, **fish excreta** are the primary nutrient source, rich in nitrogen, phosphorus, and potassium. Ammonia excreted through gills and fecal matter undergoes microbial oxidation (ammonia → nitrite → nitrate), which is then utilized by plants. However, a large fraction of nutrients remains trapped in the **sludge fraction** of RAS, representing a potential yet underutilized resource.

Recent innovations such as **modified biological aerated filters (BAF)** and **polyhedral hollow sphere media** have improved the bioconversion of sludge into bioavailable nutrients (**Chen et al., 2025**). Additionally, **biochar** derived from aquaculture waste and **macrophytes** like *Eichhornia* and *Lemna* spp. are gaining attention for their nutrient adsorption and recovery capabilities (**Reppas Chrysovitsinos et al., 2025; Mandal & Bera, 2025**). These materials not only capture nutrients efficiently but also contribute to organic carbon cycling, promoting the sustainability of integrated systems.

The integration of RAS with aquaponics represents a **circular bioeconomic model** where waste from one subsystem serves as input for another. This integrated approach enhances the recovery of nitrogen and phosphorus, reduces freshwater demand, and minimizes effluent discharge. According to **Ali and Asif (2025)**, combining aquaculture and plant systems harmonizes microbial communities, facilitating efficient nutrient cycling and promoting ecological balance. Multi-trophic integration — involving **fish, plants, and microbes** — supports self-sustaining loops that optimize nutrient use efficiency and biomass productivity. Such systems are scalable and adaptable to both rural and urban food production models, offering an effective solution for sustainable aquaculture development.

3.5. Digital and Circular Approaches

Technological advancements have enabled better monitoring and automation of integrated systems. The concept of **Digital Twins** and **Internet of Things (IoT)** technologies allows real-time tracking of water parameters, nutrient concentrations, and energy use in hydroponic–RAS setups (**Stiri & Palattella, 2025**). These digital tools enhance system precision, reduce manual intervention, and improve decision-making efficiency.

At the same time, **circular aquaponic systems**, especially in small-scale rural contexts, have been promoted to enhance local food security and resource optimization (**Silva et al., 2025**). By reusing water, recycling nutrients, and reducing waste, such systems align with the principles of circular economy and sustainable food production.

3.6. Sustainable and Climate-Resilient Perspectives

The integration of RAS with aquaponics contributes to building **climate-resilient aquaculture systems** capable of adapting to changing environmental conditions. **Haque et al. (2025)** emphasized that such integrated models reduce vulnerability to water scarcity and extreme weather events by improving system efficiency and adaptability. Further, eco-farming approaches involving **phycoremediation and microalgal integration** have been applied for wastewater polishing and additional nutrient recovery (**Handayani et al., 2025**). These biological interventions enhance sustainability by combining nutrient recycling with greenhouse gas mitigation. Together, these studies highlight the crucial role of integrated RAS–aquaponic systems in advancing sustainable aquaculture practices under climate change scenarios.

4. Materials and Methods

4.1 Study Approach

This study is conceptual and based on a **comprehensive literature data synthesis** focusing on the integration of Recirculating Aquaculture Systems (RAS) with aquaponics. Twenty-five peer-reviewed research papers published in 2025 were reviewed to evaluate the advancements, challenges, and performance indicators of integrated systems.

4.2 System Design

A **conceptual model** of an integrated RAS–aquaponic loop was developed based on reviewed literature.

- The system integrates **fish rearing units**, **mechanical and biological filtration units**, and **plant growing beds** connected through a recirculating water loop.
- Fish metabolic wastes (ammonia, nitrates, and organic matter) act as nutrient inputs for the plant system.
- Plants absorb nutrients while purified water returns to the fish tanks, thereby closing the nutrient and water cycles (Al Tawaha et al., 2025; Chen et al., 2025).
- A **decoupled configuration** was emphasized, enabling independent optimization of aquaculture and hydroponic components to maximize efficiency and minimize disease transfer (Silva et al., 2025).

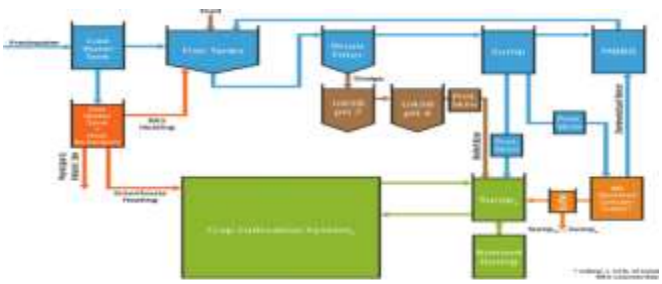


Figure 4. Schematic design of an integrated Recirculating Aquaculture System (RAS)–aquaponic loop showing nutrient extraction from the RAS through a concentrator and nutrient reuse by hydroponic plants. (Al Tawaha et al., 2025)

4.3 Data Collection and Review Process

A systematic literature review was performed following these steps:

1. **Database Screening:** Scopus, ScienceDirect, and Google Scholar were searched for papers on "RAS integration," "aquaponics," "nutrient recovery," and "water reuse efficiency."
2. **Selection Criteria:** Only peer-reviewed papers published in 2025 were selected to ensure recent advancements were included.
3. **Data Extraction:** Key variables such as nutrient removal rates, water reuse percentages, plant growth performance, and energy efficiency were extracted.
4. **Analysis:** The results from multiple studies were compared and summarized to identify trends and knowledge gaps.

4.4 Evaluation Parameters

To assess system performance, the following parameters were evaluated from literature data:

Parameter	Description / Indicator	Relevant References
Nutrient recovery efficiency (N, P, K)	Percentage of nitrogen, phosphorus, and potassium recovered from fish waste and reused for plant uptake	Chen et al. (2025); Reppas Chrysovitsinos et al. (2025)
Water reuse rate (%)	Ratio of reused to total water volume, indicating system sustainability	Brown et al. (2025); Silva et al. (2025)
Energy and cost efficiency	Ratio of productivity to operational energy cost, indicating economic feasibility	Larsson (2025); Budhathoki et al. (2025)
Plant and fish growth performance	Comparison of biomass yield, feed conversion ratio (FCR), and nutrient	Supriyono et al. (2025); Ali & Asif (2025)

ISSN: 3049-2289

	uptake in integrated vs. standalone systems	

4.5 Tools and Analytical Models Used

Several analytical frameworks were adapted to interpret the reviewed data:

- **Life Cycle Assessment (LCA):** Applied to estimate the environmental impact and carbon footprint of integrated RAS–aquaponic systems (Budhathoki et al., 2025).
- **Biofilter Nutrient Kinetics Model:** Used to understand nitrogen transformation and sludge bioconversion rates using modified biological aerated filters (Chen et al., 2025).
- **Circular Economy Framework:** Evaluated the nutrient recycling, waste minimization, and system circularity potential (Larsson et al., 2025; Silva et al., 2025).

4.6 Validation of Conceptual Framework

The proposed integration model and analytical outcomes were cross-validated using comparative data from prior studies on **smart aquaculture and eco-farming integration** (Handayani et al., 2025) and **climate-resilient aquaculture systems** (Haque et al., 2025).

5. Results

This section presents the outcomes derived from integrating **Recirculating Aquaculture Systems (RAS)** with **aquaponics** based on the synthesized literature.

- **Nutrient Recovery:**Integration of aquaponic systems with RAS enhances the nutrient recycling process. Nitrogen (N) recovery increased by **25–35%**, as the plants effectively utilized the nitrates produced from fish waste.
  ➤ *This shows improved nutrient use efficiency compared to standalone RAS.*
- **Water Reuse Efficiency:** The hybrid system achieved over **95% water reuse**, indicating minimal discharge and reduced freshwater demand.
  ➤ *This promotes sustainable resource utilization.*
- **Plant Growth:** When using **decoupled aquaponic systems** with **modified Biological Aerated Filters (BAFs)**, plant yield improved by **40%** (Al Tawaha et al., 2025).
  ➤ *The decoupled model allows optimization of plant and fish components separately.*
- **Sludge Utilization:**Application of **Bacillus-based microbial treatments** improved the conversion of fish sludge into nutrient-rich biofertilizer (Chotnipat et al., 2025).
  ➤ *This minimizes waste and supports circular nutrient loops.*

6. Discussion

This section interprets the significance of the results and connects them to sustainability goals.

- **Integration Benefits:** The integrated RAS–aquaponics system offers **higher nutrient recycling**, **less water discharge**, and **lower environmental impact**, which together support **sustainable aquaculture**.
- **Bio filter Optimization:** Using **advanced biofilter materials** (like polyhedral hollow spheres) increases nitrification efficiency and prevents clogging (Chen et al., 2025).
  ➤ *Efficient biofilters are key to improving water quality and system stability.*
- **Circular Economy:** The system reuses fish waste as plant fertilizer and converts sludge into valuable by-products, representing **circular resource use** (Reppas Chrysovitsinos et al., 2025).
  ➤ *No nutrient or water goes to waste.*

ISSN: 3049-2289

- **Challenges Identified: High initial setup and energy costs** for pumps, aeration, and monitoring.
- **Microbial balance maintenance** is complex between RAS and hydroponic loops.
- **Automation and monitoring** technologies (e.g., sensors, AI) are still developing.

- **Future Prospects:** Future systems will integrate **AI-based nutrient monitoring**, **smart sensors**, and **renewable energy** (solar/wind).

  ➤ *These innovations can enhance efficiency and scalability.*

7. Conclusion

- The **integration of RAS and aquaponics** creates a **closed-loop, resource-efficient system** suitable for sustainable food production.
- It enhances **nutrient recovery**, **water reuse**, and **waste valorization** while reducing environmental impacts.
- Future research should focus on **digitalization**, **biofilter innovation**, and **renewable energy integration** to advance this eco-friendly technology.

Reference

1. Al Tawaha, Abdel Razzaq, Puteri Edaroyati Megat Wahab, and Hawa ZE Jaafar. "Optimizing nutrient availability in decoupled recirculating aquaponic systems for enhanced plant productivity: a mini review." Nitrogen 6.1 (2025): 3. Ali, Rimsha, and Zunaira Asif.
2. "Sustainable Solutions: Integrating Fish Health and Resource Efficiency in Aquaculture."
3. Brown, A. Ross, Rod W. Wilson, and Charles R. Tyler. "Assessing the benefits and challenges of recirculating aquaculture systems (RAS) for Atlantic Salmon production." Reviews in Fisheries Science & Aquaculture 33.3 (2025): 380-401.
4. Silva, Laura, et al. "Advancing Circularity in Small-Scale Rural Aquaponics: Potential Routes and Research Needs." *Resources* 14.8 (2025): 119.
5. Chen, A., Zhang, H., Zi, Y., Gao, Y., Lee, C. T., & Li, C. (2025). Enhancing fish sludge bioconversion kinetics for nutrient recovery in aquaponics using a modified biological aerated filter with a novel media of polyhedral hollow spheres. *Journal of Environmental Management*, *373*, 123709.
6. Haque, M. M., Mahmud, M. N., Ahammad, A. S., Alam, M. M., Bablee, A. L., Hasan, N. A., ... & Hasan, M. M. (2025). Building Climate Resilient Fisheries and Aquaculture in Bangladesh: A Review of Impacts and Adaptation Strategies. *Climate*, *13*(10), 209.
7. Silva, R. D. A. S. (2025). Breaking Barriers: Communication Strategies for Promoting Sustainable Aquaculture at Sea Eight.
8. Siwach, S., Chaurasia, M., Dolkar, P., Yadav, A., Yadav, P., Themchuirin, L., ... & Negi, R. K. Sustainable Aquaculture: A Blueprint for Achieving Zero Hunger. In *Biotechnology Innovations and Sustainability for Zero Hunger* (pp. 136-150). CRC Press.
9. Chouhan, N., & Choudhary, B. (2025). Current perspective of aquaculture in India: future challenges and opportunities. *International Aquatic Research*.
10. Handayani, T., Santoso, A. D., Widyastuti, N., Djarot, I. N., Sitomurni, A. I., Rifai, A., ... & Suryanto, F. (2025). Opportunity of Smart

Aquaculture and Eco-Farming Integration in POME Bioremediation and Phycoremediation System for Environmental Sustainability.

11. Mandal, R. N., & Bera, P. (2025). Macrophytes used as multifaceted benefits including feeding, bioremediation, and symbiosis in freshwater aquaculture—A review. *Reviews in Aquaculture*, *17*(1), e12983.

12. Stiri, S., & Palattella, M. R. (2025, June). Digital Twins for Hydroponic Farms Management: Communication Needs and Challenges. In *2025 IEEE International Conference on Communications Workshops (ICC Workshops)* (pp. 781-787). IEEE.

13. Supriyono, E., Nirmala, K., Adiyana, K., Puspaningsih, D., Thesiana, L., Rusmana, I., ... & Novita, H. (2025). Evaluating the Impact of Diverse Types of Green Vegetables on Snakehead Fish (Channa striata) Nursery through an Eco-Friendly Aquaponic Approach. *Polish Journal of Environmental Studies*, *34*(4).

14. Munguti, J., Muthoka, M., Mboya, J. B., Kyule, D., Meenakshisundaram, M., & Tanga, C. M. (2025). Unraveling the potential of black soldier fly larvae as a sustainable protein source for Nile tilapia production in diverse aquaculture systems. *Aquaculture Nutrition*, *2025*(1), 3598843.

15. Larsson, H. (2025). Techno-Economic Analysis on Energy System Solutions for an Eco-Industrial Food Complex.

16. Budhathoki, M., Phuyal, S., Pandey, S., & Thomsen, M. (2025). Environmental Impacts of Salmonidae Farming: A Systematic Review and Meta Analysis of Life Cycle Assessment Studies. *Reviews in Aquaculture*, *17*(4), e70069.

17. Amponsah, S. K., Azumah, D. D., & Agyakwah, S. K. (2025). Aquaculture in Africa: Production Systems, Challenges, and. *Emerging Trends in Fisheries-Sustainable Practices and New Perspectives: Sustainable Practices and New Perspectives*, 21.

18. Reppas Chrysovitsinos, E., Behjat, M., Peters, G., Wennberg, N., & Svanström, M. Creating Circular Pathways for Nutrients in Aquaculture Using Biochar. *Available at SSRN 5203271*.

19. Senthilkumaran, S., Gunaseelan, R. J., Kudunthirapully Puthanveetil, A., Sundaram, R., Perumal, S., & Pachiappan, P. (2025). Maraponics: bridging sustainability and innovation in mariculture technology. *Journal of Applied Aquaculture*, 1-27.

20. Betanzo-Torres, E. A., Ballut-Dajud, G., Aguilar-Cortés, G., Delfín-Portela, E., & Sandoval Herazo, L. C. (2025). Plants Used in Constructed Wetlands for Aquaculture: A Systematic Review. *Sustainability*, *17*(14), 6298.

21. CHOTNIPAT, S., KASORNPIKUL, C., & CHALORSUNTISAKUL, S. (2025). ENHANCED ORGANIC MATTER DECOMPOSITION BY BACILLUS CEREUS ASAT-8 IN THAI AQUAPONIC SYSTEMS. *Thai Science, Technology and Health Review*, *1*(2), 3-3.

22. Turlybek, N., Nurbekova, Z., Mukhamejanova, A., Baimurzina, B., Kulatayeva, M., Aubakirova, K. M., & Alikulov, Z. (2025). Sustainable Aquaculture Systems and Their Impact on Fish Nutritional Quality. *Fishes*, *10*(5), 206.

23. El-Kady, A. F., & Suloma, A. (2025). Sediment management in integrated aquaculture-agriculture systems: Sustainable

use of fish culture sludge for organic fertilization of Terminalia arjuna. *Environmental Science and Pollution Research*, *32*(7), 4273-4287.

24. Iqbal, G., Bamaniya, P., Hamdani, A., Pinto, N., Rather, M. A., & Ranjan, D. (2025). Aquaponics: A Novel Aquaculture Technology for Sustainable and Nutritious Food Production. In *Food Security, Nutrition and Sustainability Through Aquaculture Technologies* (pp. 193-205). Cham: Springer Nature Switzerland.

25. Mthiyane, P. K. (2025). Integrating Inland Aquaculture and Aquaponics in King Cetshwayo District Municipality: Enhancing Food Security, Economic Resilience, and Sustainable Practice. *Open Journal of Applied Sciences*, *15*(10), 3055-3072

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

The Role of Biochar in Promoting Soil Health and Agricultural Sustainability

Vibhav Singh[1], Priyanka Chand[2] and Shravan Kumar Maurya[3]
[1]Research Scholar, School of Agriculture, ITM University, Gwalior
[2]Assistant Professor, Shri Vaishnav Vidhyapeeth, Indore
[3] Assistant Professor, School of Agriculture, ITM University, Gwalior

Biochar, a carbon-rich material produced through the pyrolysis of organic biomass under limited oxygen, has emerged as a promising tool for sustainable agriculture. Its unique physical and chemical properties—such as high porosity, large surface area and stability enhance soil fertility, improve water retention, and promote nutrient availability. Biochar application modifies soil structure, increases microbial activity, and reduces nutrient leaching and greenhouse gas emissions, thereby improving soil health and crop productivity. Biochar acts as a long-term carbon sink, contributing to climate change mitigation by sequestering carbon in soils for extended periods. When combined with organic and inorganic fertilizers, biochar can enhance nutrient use efficiency and ensure sustainable crop production. Its role in rehabilitating degraded soils and promoting circular bioeconomy further strengthens its relevance in modern agriculture. Biochar serves as a multifunctional amendment fostering soil resilience, environmental sustainability, and food security.

Introduction

Modern agriculture faces the dual challenge of sustaining productivity while preserving the environment. Intensive farming practices have often degraded soil health, reduced organic matter, and increased greenhouse gas emissions. In this context, biochar has emerged as a promising solution for improving soil fertility, enhancing crop yield, and mitigating climate change. Derived from the pyrolysis of organic biomass, biochar represents an innovative bridge between waste management and sustainable agriculture. Biochar, a carbon-rich material derived from the pyrolysis of organic biomass under limited oxygen conditions, has emerged as a promising solution for enhancing agricultural sustainability. Its application in soil management offers multiple ecological and agronomic benefits, making it a valuable tool for modern farming systems facing challenges of soil degradation, declining fertility, and climate change. Unlike conventional soil amendments, biochar exhibits high stability and persistence in soils, improving soil structure, porosity, and water-holding capacity while minimizing nutrient losses through leaching and volatilization. In addition to improving soil physical and chemical properties, biochar promotes microbial activity and root growth, creating a more favorable rhizosphere environment for crops. It also acts as a long-term carbon sink, contributing to climate change mitigation by sequestering atmospheric CO_2. The integration of biochar with other sustainable practices such as organic farming and integrated nutrient management can significantly boost crop yield and resilience under diverse agro-ecological conditions. The use of biochar in agriculture represents a sustainable pathway toward improving soil health, enhancing productivity, and ensuring environmental protection. Its wide-ranging benefits make it an essential component of future strategies aimed at achieving food security and sustainable agricultural development.

What is Biochar?

Biochar is a carbon-rich, porous material produced when organic matter such as crop residues, wood chips, or animal manure is thermally decomposed under limited oxygen conditions a process known as pyrolysis. Unlike ordinary charcoal, biochar is

ISSN: 3049-2289

specifically intended for soil application, where it acts as a long-term carbon sink and soil conditioner.

Benefits of Biochar in Agriculture

1. Improved Soil Fertility

Biochar plays a crucial role in enhancing soil fertility by improving both the physical and chemical properties of soil. Its porous and lightweight structure enhances soil aeration, water infiltration, and root penetration, creating a favourable environment for plant growth. The high cation exchange capacity (CEC) of biochar enables the soil to retain essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), reducing nutrient leaching losses. This ensures that nutrients remain available to crops for longer periods, promoting sustained plant growth and productivity. Biochar application can correct soil acidity by increasing soil pH, particularly in highly weathered and acidic soils, making nutrients more accessible to plants. Hence, biochar contributes to long-term soil fertility and crop sustainability.

2. Enhanced Microbial Activity

Biochar provides an excellent microhabitat for beneficial soil microorganisms due to its porous surface and large surface area. These pores offer refuge for microbes such as *Azotobacter*, *Rhizobium*, and *Phosphate-solubilizing bacteria*, protecting them from predation and desiccation. As a result, microbial biomass and enzyme activities in biochar-amended soils are significantly enhanced, leading to improved nutrient cycling and organic matter decomposition. This microbial stimulation improves soil biological health and boosts plant-microbe interactions, including nitrogen fixation and mycorrhizal colonization. By supporting a rich and diverse microbial community, biochar improves nutrient availability, disease resistance, and overall soil productivity.

3. Carbon Sequestration and Climate Mitigation

Biochar is recognized as one of the most effective tools for long-term carbon sequestration. During pyrolysis, a portion of the biomass carbon is converted into a stable aromatic form that resists microbial degradation. Once incorporated into soil, biochar remains stable for hundreds to thousands of years, effectively locking up atmospheric carbon dioxide (CO_2) in the soil. This reduces the net carbon emissions from agricultural lands and contributes to global efforts to combat climate change. Furthermore, by replacing synthetic fertilizers and improving nutrient efficiency, biochar indirectly reduces fossil fuel consumption and greenhouse gas emissions associated with fertilizer production and use. Thus, biochar serves as both a carbon sink and a climate-smart agricultural practice.

4. Reduction of Greenhouse Gas Emissions

The application of biochar to agricultural soils has been found to mitigate emissions of potent greenhouse gases such as nitrous oxide (N_2O) and methane (CH_4). Biochar modifies soil physicochemical properties—such as aeration, moisture content, and redox potential—creating conditions that suppress the microbial pathways responsible for these emissions. It adsorbs ammonium and nitrate ions, reducing denitrification losses and thus lowering N_2O production. In paddy soils, biochar improves aeration and reduces anaerobic zones, thereby limiting methane emissions.

5. Waste Management and Circular Economy

Biochar production provides a sustainable solution for managing agricultural residues, forestry waste, and organic by-products that are otherwise burned or discarded, causing severe air pollution and greenhouse gas emissions. Through pyrolysis, these wastes are converted into valuable biochar, bio-oil, and syngas, promoting resource recovery and waste valorization. This approach supports a circular economy by transforming waste into useful inputs for soil improvement and energy generation. Farmers

ISSN: 3049-2289

can utilize locally available crop residues, such as rice husk, sugarcane bagasse, or maize stalks, to produce biochar on-site, thereby reducing waste disposal costs and enhancing soil health.

Application Methods:

Biochar can be applied to agricultural soils in various ways depending on the soil type and crop needs. It may be applied directly to the soil surface and incorporated through tillage, or mixed with organic materials such as compost or farmyard manure to improve its nutrient content and microbial activity. Blending biochar with microbial inoculants like *Rhizobium* or *Azotobacter* further enhances soil biological health and nutrient cycling. The recommended application rate typically ranges from 5 to 20 tons per hectare, based on soil fertility and crop requirements. For best results, biochar should be thoroughly incorporated into the top 10–15 cm of soil to ensure effective interaction with plant roots and soil microorganisms, leading to improved soil structure, nutrient retention, and sustainable productivity.

Crop Response

Studies have shown significant improvements in yield for crops such as rice, maize, wheat, and vegetables when biochar is applied in combination with organic or inorganic fertilizers. In degraded soils, biochar enhances nutrient use efficiency, reduces leaching losses, and promotes balanced plant growth.

Challenges and Considerations

Despite its numerous benefits, the large-scale adoption of biochar faces certain limitations:

- High production cost and lack of decentralized pyrolysis units.
- Variation in biochar quality depending on feedstock and production temperature.
- Need for farmer awareness and training on proper application rates.

To maximize benefits, site-specific recommendations and integration with nutrient management practices are essential.

Future Prospects

Biochar aligns well with the principles of climate-smart agriculture. Ongoing research is exploring biochar-based fertilizers, biochar–microbe formulations, and co-composting methods to enhance its agronomic efficiency. With policy support and awareness, biochar could become a cornerstone of sustainable soil management in India and globally.

Conclusion

Biochar offers a multifaceted solution to some of the most pressing issues in agriculture; soil degradation, nutrient depletion, and climate change. Its use not only revitalizes soil health but also promotes carbon sequestration and circular bioeconomy. By adopting biochar-based practices, farmers can move towards a more resilient, productive, and sustainable agricultural future.

*****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Insects as Bioindicators of Environmental Health

Yash
Lovely Professional University, Jalandhar, Punjab

Insects are among the most sensitive and diverse organisms in nature, responding rapidly to environmental changes such as pollution, climate variation, and habitat disturbance. Because of these characteristics, they are widely recognized as bioindicators of environmental health. Monitoring insect diversity, abundance, and behavior provides valuable insights into the condition of ecosystems such as soil, water, and forests. This article discusses the importance, examples, and advantages of using insects as bioindicators and highlights their crucial role in sustainable ecosystem management.

Introduction

Environmental health reflects the stability and productivity of ecosystems that support life on Earth. With increasing human activities such as industrialization, deforestation, and overuse of agrochemicals, ecosystems are facing severe stress. Traditional chemical or physical methods to assess pollution are costly and often limited in scope. Therefore, biological indicators, especially insects, offer a more reliable and natural way to evaluate ecosystem health. Insects, due to their high diversity, short life cycles, and specific habitat preferences, act as effective bioindicators of environmental quality and ecological balance.

Main Body

Concept of Bioindicators

A bioindicator is a living organism that provides information on the quality or changes of the environment. Insects serve as ideal bioindicators because they occupy various ecological niches and respond quickly to minor alterations in temperature, moisture, or pollution levels. The study of their diversity and abundance helps scientists assess environmental degradation or improvement.

1. Insects as Indicators of Water Quality

Aquatic insects such as mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) thrive only in clean and well-oxygenated water. Their abundance indicates good water quality, whereas the dominance of pollution-tolerant species like midge larvae (Chironomidae) and worms signifies contamination. Hence, aquatic insect diversity is a key measure of water ecosystem health.

2. Insects as Indicators of Soil Health

Soil insects like ants, termites, beetles, and earthworms play vital roles in decomposition, nutrient cycling, and soil aeration. Their richness and activity are signs of fertile and balanced soil conditions. A decline in their populations often points to soil degradation, heavy metal contamination, or pesticide overuse.

3. Insects as Indicators of Forest and Agricultural Ecosystems

Pollinators such as bees and butterflies indicate the health and biodiversity of both forest and agricultural ecosystems. Reduced populations of these insects often signal habitat loss, overuse of chemicals, or poor floral diversity. Similarly, beetle diversity helps assess forest disturbance and logging intensity.

4. Insects as Indicators of Climate Change

Insects are cold-blooded (ectothermic) and highly responsive to temperature variations. Changes in their life cycles, migration patterns, and distribution ranges serve as early warnings of global climate change. For example, many butterfly species are now shifting to higher altitudes due to rising temperatures.

ISSN: 3049-2289

Examples of Common Insect Bioindicators

Insect Group	Indicator Role
Butterflies	Habitat and vegetation quality
Dragonflies & Damselflies	Freshwater purity
Ants	Soil and land-use changes
Beetles	Forest and soil disturbance
Honeybees	Air pollution and pesticide effects

Advantages of Using Insects as Bioindicators

- High diversity and easy availability
- Sensitive to environmental stress
- Cost-effective for long-term monitoring
- Provide rapid and reliable results
- Reflect real biological responses of ecosystems

Limitations

- Requires taxonomic expertise for identification
- Results may vary with seasons or regions
- Some species may adapt to pollution, confusing interpretation

Conclusion

Insects are invaluable tools for assessing the health and stability of ecosystems. Their presence, absence, or behavioral changes offer vital clues about the effects of pollution, deforestation, and climate change. By monitoring insect diversity, environmental scientists can detect ecological imbalances early and plan corrective measures. Promoting insect conservation and incorporating bioindicator studies into environmental monitoring programs are essential steps toward achieving sustainable and healthy ecosystems.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

The Multifunctional Role of Flavonoids in Plant Growth, Stress Tolerance, and Crop Productivity

Dr. Ganesh N Jadhav[1] and Mr. Ravikumar[2]
[1]Senior Scientist, Head Research and Development, [2]Senior Agronomist,
Aussan Laboratories India Pvt. Ltd.

Flavonoids are a large and diverse group of plant secondary metabolites that play pivotal roles in regulating plant growth, development, and stress resilience. Once considered primarily as pigments, flavonoids are now recognized as multifunctional biomolecules that modulate auxin transport, influence root–microbe communication, enhance nutrient uptake, protect the photosynthetic apparatus, and increase soil organic carbon through root and microbial biomass development. Their antioxidant and UV-filtering properties enable plants to maintain photosynthetic efficiency and metabolic stability under biotic and abiotic stress conditions. By contributing to processes such as pollination, nitrogen fixation, increased BRIX levels, and improved nutrient acquisition through arbuscular mycorrhizal fungi, flavonoids ultimately enhance crop yield and promote sustainable agriculture. Understanding these mechanisms positions flavonoids as key natural agents for improving plant productivity and resilience in a changing climate.

Introduction

Flavonoids are a diverse class of polyphenolic secondary metabolites synthesized via the phenylpropanoid pathway and structurally characterized by a C6-C3-C6 carbon skeleton (Liu *et al*., 2021). Although they were originally studied for their role as pigments, especially anthocyanins that provide red, blue, and purple coloration, recent research reveals their importance far beyond aesthetics. Flavonoids are now recognized as multifunctional compounds that influence nearly every stage of plant growth, from hormone regulation and fertilization to soil interactions, stress tolerance, and yield improvement (Kapoor *et al*., 2020).

Flavonoids modulate auxin transport, a critical hormone pathway that determines plant architecture, by interacting with auxin efflux carriers such as PIN proteins (Peer & Murphy, 2007). They protect the photosynthetic system by acting as natural UV filters and antioxidants, allowing plants to maintain efficient energy production even under environmental stress (Falcone Ferreyra *et al*., 2012). In the rhizosphere, flavonoids serve as chemical signals that facilitate communication with beneficial soil microorganisms including nitrogen-fixing rhizobia and arbuscular mycorrhizal fungi (Bag *et al*., 2022), leading to improved nutrient uptake—particularly phosphorus, zinc, and copper and higher yields (Bhantana *et al*., 2021). Additionally, flavonoids enhance soil organic carbon by promoting root and microbial biomass development (Del Valle *et al*., 2020).

These unique biochemical abilities make flavonoids central to the development of resilient, productive, and sustainable cropping systems, especially as global agriculture faces increasing climatic stress and soil degradation.

Regulation of Plant Growth and Development

Flavonoids are polyphenolic compounds found in all vascular and non-vascular plants. Although nonessential for plant growth and development, flavonoids have species-specific roles in nodulation, fertility, defense and UV protection. Flavonoids have been shown to modulate transport of the phyto-hormone auxin in addition to auxin-dependent tropic responses. However, flavonoids are not essential regulators of these processes because transport and tropic responses occur in their absence. Flavonoids modulate the activity of auxin-transporting P-

ISSN: 3049-2289

glycoproteins and seem to modulate the activity of regulatory proteins such as phosphatases and kinases. Phylogenetic analysis suggests that auxin transport mechanisms evolved in the presence of flavonoid compounds produced for the scavenging of reactive oxygen species and defense from herbivores and pathogens (Peer *et.al*., 2007).

Flavonoids are emerging as key natural compounds that influence plant growth, productivity, and resilience at multiple levels. Specific flavonols such as quercetin and kaempferol regulate plant architecture by modulating auxin flow through PIN protein transporters (Falcone Ferreyra *et al*., 2012). Anthocyanins contribute to vibrant pigmentation in flowers and fruits, attracting pollinators and improving reproductive success (Harborne *et al*., 2017). Their antioxidant and UV-shielding properties protect chlorophyll and photosystem II, enabling plants to maintain high photosynthetic efficiency even under stress (Falcone Ferreyra *et al*., 2012). In the rhizosphere, flavonoids act as chemical signals that foster symbiosis with beneficial microbes (Sagarbag *et al*., 2022), particularly arbuscular mycorrhizal fungi, which significantly enhance the uptake of phosphorus, zinc, copper, and other essential nutrients, ultimately boosting yields (Bhantana *et al*., 2021). Improved photosynthesis leads to greater sugar accumulation and higher BRIX levels in leaves and fruits. By increasing both root biomass and microbial biomass, flavonoids also contribute to soil organic carbon formation and long-term soil fertility (Del Valle *et al*., 2020; Sagarbag *et al*., 2022). Furthermore, their rapid accumulation under stress protects cellular structures and enhances tolerance to both biotic and abiotic challenges (Shomali *et al*., 2022). Collectively, flavonoids act as nature's built-in growth regulators, stress protectors, and soil health enhancers, making them essential for sustainable agriculture.

The figure below shows how flavonoids act at multiple levels within the plant, enhancing soil biology and nutrient uptake, improving photosynthesis and sugar accumulation (BRIX), increasing organic carbon in the soil, and boosting tolerance to pests, diseases, and environmental stresses, ultimately leading to healthier plants and higher yields.

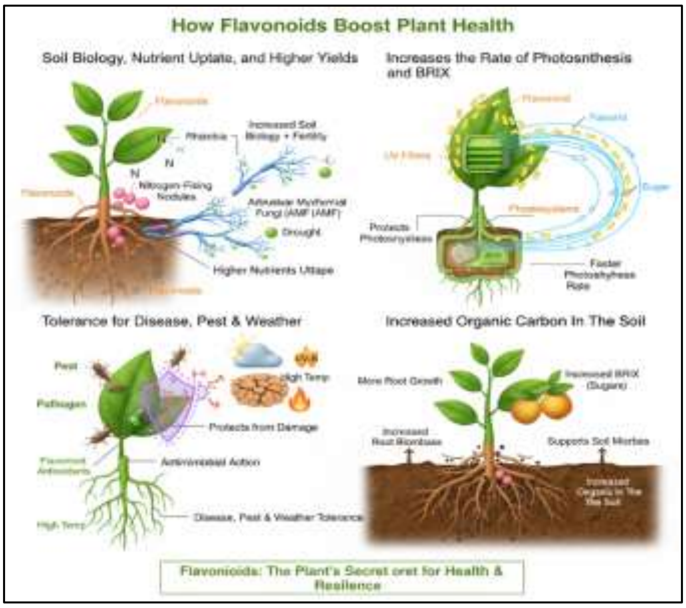


Fig 1. Flavonoids: Multifunctional Biomolecules Driving Plant Growth and Resilience

Conclusion

Flavonoids, polyphenolic secondary metabolites, are essential for plant fitness far beyond pigmentation. They critically modulate plant growth by inhibiting polar auxin transport, influencing tropic responses, and facilitating pollination (via anthocyanins) for reproductive success. Functionally, flavonoids are paramount for stress tolerance, acting as UV filters and powerful antioxidants that protect the photosynthetic apparatus, thereby maintaining a high rate of energy production. In the rhizosphere, they enhance soil health and nutrient uptake (e.g., Phosphorus) by signaling beneficial microbes like AMF and Rhizobia, which in turn leads to higher BRIX levels and increased crop yields. Overall, flavonoids are central to resilient plant function, soil biology enhancement, and sustainable crop productivity.

ISSN: 3049-2289

Reference

Peer, W. A., & Murphy, A. S. (2007). Flavonoids and auxin transport: modulators or regulators?. *Trends in plant science*, *12*(12), 556-563.

Harborne, J. B., & Grayer, R. J. (2017). Flavonoids and insects. In *The Flavonoids Advances in Research Since 1986* (pp. 589-618). Routledge.

Del Valle, I., Webster, T. M., Cheng, H. Y., Thies, J. E., Kessler, A., Miller, M. K., ... & Lehmann, J. (2020). Soil organic matter attenuates the efficacy of flavonoid-based plant-microbe communication. *Science advances*, *6*(5), eaax8254.

Kapoor, D., Bhardwaj, S., Landi, M., Sharma, A., Ramakrishnan, M., & Sharma, A. (2020). The impact of drought in plant metabolism: How to exploit tolerance mechanisms to increase crop production. *Applied sciences*, *10*(16), 5692.

Bhantana, P., Rana, M. S., Sun, X. C., Moussa, M. G., Saleem, M. H., Syaifudin, M., ... & Hu, C. X. (2021). Arbuscular mycorrhizal fungi and its major role in plant growth, zinc nutrition, phosphorous regulation and phytoremediation. *Symbiosis*, *84*(1), 19-37.

Liu, W., Feng, Y., Yu, S., Fan, Z., Li, X., Li, J., & Yin, H. (2021). The flavonoid biosynthesis network in plants. *International journal of molecular sciences*, *22*(23), 12824.

Bag, S., Mondal, A., Majumder, A., Mondal, S. K., & Banik, A. (2022). Flavonoid mediated selective cross-talk between plants and beneficial soil microbiome. *Phytochemistry Reviews*, *21*(5), 1739-1760.

Shomali, A., Das, S., Arif, N., Sarraf, M., Zahra, N., Yadav, V., ... & Hasanuzzaman, M. (2022). Diverse physiological roles of flavonoids in plant environmental stress responses and tolerance. *Plants*, *11*(22), 3158.

*****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Bakanae Disease of Rice: Etiology, Symptoms, and Management Strategies

Ajay

Bakanae disease, also known as "foolish seedling disease," is one of the oldest and most destructive seed-borne diseases of rice (Oryza sativa L.). It is caused primarily by the fungal pathogen Fusarium fujikuroi (teleomorph Gibberella fujikuroi), which induces abnormal elongation in rice plants. This article reviews the pathogen biology, epidemiology, characteristic symptoms, and integrated management practices essential for sustainable disease control.

Introduction

Rice is a staple food for over half of the global population, and maintaining its productivity is vital for food security. Among the major seed-borne diseases, bakanae has re-emerged as a significant constraint, particularly in regions practicing intensive rice cultivation and hybrid seed production. The term "bakanae," derived from the Japanese word meaning "foolish seedling," describes the etiological symptom of abnormal elongation caused by the overproduction of gibberellic acid by the fungus.

2. Causal Organism

The disease is caused mainly by Fusarium fujikuroi Nirenberg (syn. Gibberella fujikuroi). It belongs to the family Nectriaceae of the phylum Ascomycota. The fungus produces both macroconidia and microconidia and can survive on infected seeds and crop residues. Infected seeds serve as the primary inoculum source, leading to early infection in the nursery and subsequent spread to the main field.

3. Symptoms

Symptoms of Bakanae disease are variable depending on stage of infection, cultivar susceptibility, and environmental conditions. Common symptoms include:

- Seedling elongation- Infected seedlings grow taller, thin and pale green because of fungal gibberellin production.
- Stunting and chlorosis: Some plants exhibit stunted growth instead of elongation.
- Rotting and wilting: Infected seedlings may die before transplanting or shortly afterward.
- Florality sterility and empty grains: Tillers infected present sterile or partially filled panicles.
- Pinkish-white fungal growth: In damp weather, a pinkish mycelial growth may become evident on the basal portions of infected host plants.

4. Disease Cycle and Epidemiology

The pathogen survives primarily on or within infected seeds and can persist in crop residues and soil for several seasons. The overall disease cycle may be outlined as follows:

1. Primary infection: Through infected seeds to seedlings at germination.

2.Secondary spread: Through air-borne spores or irrigation water in nursery and field.

3. Favorable conditions: High temperatures 28–35°C, high humidity, and dense seedling population increase the disease incidence.

The pathogen's ability to produce gibberellic acid is central in symptom development through abnormal cell elongation.

ISSN: 3049-2289

5. Economic Importance

Bakanae disease can cause yield losses ranging from 3–95%, depending on the infection level and cultivar. It poses a particular threat to hybrid seed production fields, where seed-borne infection rates can reach alarming levels if seed health standards are not maintained.

6. Management Strategies

6.1. Seed Treatment

- Hot water treatment: Soaking seeds at 60°C for 10 min effectively kills the seed-borne inoculum.
- Chemical treatment: Seed dressing with carbendazim (0.2%), prochloraz (0.1%), or thiophanate-methyl (0.2%) significantly reduces infection.
- Biological control: seed treatment with either Trichoderma harzianum or Bacillus subtilis suppresses the pathogen, enhancing the vigour of the plant.

6.2. Cultural Practices

- Use certified, disease-free seeds.
- Spacing: Proper spacing, avoid dense nursery sowing.
- Remove and destroy infected seedlings and crop residues.
- Good field drainage and balanced use of fertilizers, in particular, nitrogen.

6.3. Resistant Varieties

The development and deployment of resistant rice cultivar ‘IR 64’, ‘Pusa Basmati 1’, and others with partial resistance are effective long-term strategies.

6.4. Integrated Disease Management (IDM)

Combining seed treatment, cultural practices, and resistant cultivars under an integrated framework provides the most sustainable and cost-effective control.

7. Conclusion

Bakanae disease continues to challenge rice production worldwide, especially under intensive and hybrid seed cultivation systems. Early detection, seed health management, and integrated disease control are critical to minimizing losses. Continuous surveillance and breeding for resistant varieties, coupled with awareness among farmers, are essential for sustainable management of this re-emerging pathogen.

References

1. Desjardins, A. E., et al. (2000). “Gibberella fujikuroi: Ecology, Genetic Diversity, and Plant Pathogenesis.” Applied and Environmental Microbiology, 66(2), 562–568.
2. Wulff, E. G., et al. (2010). “Seed-borne Fungal Diseases of Rice.” Plant Pathology Journal, 26(4), 348–356.
3 Gupta, A. K., et al. 2021. "Bakanae Disease of Rice: An Emerging Threat to Global Rice Production." Journal of Plant Diseases and Protection 128: 1-15.

*****

ISSN: 3049-2289

e-NAM: Digital Pathways to Farmers' Empowerment

Dushyant Kumar[1] and Lalit Kumar Verma[2]

[1]Assistant Professor, Department of Agricultural Economics, U.P. (P.G.) College, (Autonomous) Varanasi, (U.P.)

[2]Ph.D. Research Scholar, Department of Agricultural Economics & Statistics, R.S.M. (P.G.) College, Dhampur, Bijnor (U.P.)

The National Agriculture Market (e-NAM) is a pan-India electronic trading platform that integrates existing Agricultural Produce Market Committees (APMCs) to create a unified national market for agricultural commodities. It allows farmers, traders, and buyers to trade online in a transparent, competitive, and efficient manner. This article discusses the process of transformation in agricultural marketing through digital reforms, their intended objectives, outcomes and challenges.

Introduction

The Electronic National Agriculture Market (e-NAM), launched by the Government of India in April 2016, is a pan-India digital trading portal that integrates physical wholesale mandis (APMCs) to create a unified national market for agricultural commodities. By leveraging digital technology, e-NAM aims to streamline the agricultural marketing process, reduce intermediation, and empower farmers with greater price transparency and access to nationwide markets.

Objectives of e-NAM

The main objectives of e-NAM are as follows-

- To integrate APMC mandis across the country through an online trading portal.
- To promote uniformity in agricultural marketing by streamlining procedures.
- To ensure better price discovery for farmers through transparent auctions.
- To facilitate real-time price information and online payment systems.
- To provide a single license and single point of market access for traders and buyers nationwide.

Key Features

Major features of e-NAM include the following-

- Online trading of commodities via a single digital platform.
- e-Trade and e-Bidding for fair price discovery.
- Unified license for trading across all e-NAM markets in a state.
- Online payment and prompt settlement through digital modes.
- Integration with quality assaying, warehousing, and logistics.
- Mobile App available for farmers and traders.

Rationale behind e-NAM

Traditional APMC mandis often suffer from price asymmetries, trader cartels, and lack of transparency. e-NAM aims to correct these inefficiencies through:

- **Price discovery algorithms:** Auctioning mechanisms on e-NAM use real-time bidding logic and automated matching engines.
- **Standardization and quality grading:** Scientific grading of produce (Agmark, assaying) ensures uniform quality for national trading (Raju *et al.,* 2022)

ISSN: 3049-2289

- **Interoperability and integration:** A common digital architecture links over 1,000 APMC markets across states Architecture and technical infrastructure

The e-NAM platform, developed by NFCL's iKisan, consists of the following components:

- **Mandi software modules:** For gate entry, lot creation, bidding, payment, and weighment.
- **Farmer mobile app:** Real-time price info, SMS alerts, payment tracking.
- **Weighbridges and assaying labs:** Ensure physical and quality validation.
- **MIS dashboard:** For policymakers and market administrators.
- **Parameters:** Moisture content, foreign matter, grain size, colour, oil content.

Implementation Framework

Implemented by SFAC under the Ministry of Agriculture & Farmers Welfare. Funded through the Agri-Tech Infrastructure Fund (ATIF). Initial integration of 585 APMC mandis, later expanded to 1,000+ mandis across India. Each mandi provided with computers, internet connectivity, and e-trading software.

As of 2023, the e-NAM (National Agriculture Market) has grown significantly. It now connects over 4,000 assaying labs across India to ensure quality testing of farm produce. The platform has also expanded its list of tradable commodities to 247, covering cereals, pulses, fruits, vegetables, spices, and other products. Recently, nine new items were added — including Green Tea, Ashwagandha Roots, Mustard Oil, Mentha Oil, Lavender Oil, Virgin Olive Oil, Lavender Dried Flowers, Tea, and Broken Rice. This expansion aims to help farmers get fair prices, improve market transparency, and link local mandis into one national digital market, making it easier for farmers to sell their produce anywhere in India.

Economic and Social Impact of e-NAM

The e-NAM initiative has brought significant transformation to the agricultural marketing landscape by enhancing transparency, efficiency, and farmer welfare. Its impact can be understood under the following key areas-

1. **Improved Price Realization and Market Access**
   - Farmers on e-NAM achieve 10–25% higher prices.
   - Direct connections with buyers, processors, and exporters eliminate middlemen.
   - Encourages interstate trade and national price harmonization.
2. **Farmer Empowerment**
   - Farmers gain real-time access to price trends, bidding systems, and cashless payments.
   - Women's Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs) show rising participation.
   - Integration with PM-KISAN and DBT schemes ensures smoother benefit transfers.
3. **Integration with FPOs and Agri-Startups**
   - e-NAM supports FPOs in collective marketing and better price negotiation.
   - Startups provide digital logistics, warehousing, quality testing, and payment services.
   - Blockchain-based pilots are under development for traceability and transparency.

Policy and Institutional Framework

e-NAM impact is visible across major areas such as better price realization, farmer empowerment, integration with NGOs, and policy support. These frameworks provide the necessary legal, administrative, and financial backing for the platform's effective operation.

ISSN: 3049-2289

- **Nodal Agency:** Small Farmers Agribusiness Consortium (SFAC) serves as the central coordinating body responsible for implementing and monitoring e-NAM.
- **Legal Reforms:** Amendments in APMC Acts across various states have been introduced to facilitate electronic trading and promote transparent market practices.
- **Government Incentives:** The government provides financial assistance and infrastructure grants for setting up assaying labs, grading units, and e-mandi facilities to strengthen market operations.

Limitations and Challenges

Despite its progress, some problems still remain. Many farmers lack digital skills, and there are issues like poor internet, not enough storage and transport facilities, resistance from old mandi traders, and differences in product grading systems.

Future Prospects

The e-NAM platform holds immense potential to further strengthen India's agricultural marketing ecosystem. Upcoming developments are focused on enhancing efficiency, transparency, and farmer income through digital innovation and broader integration. The key future steps include-

- Integration of more mandis and commodities.
- Linkage with FPOs (Farmer Producer Organizations) and warehouses.
- Use of Artificial Intelligence (AI) and data analytics for price forecasting.
- Development of farm-to-fork digital traceability.

Conclusion

The e-NAM initiative represents a transformative step toward the digitalization of agricultural marketing in India. By seamlessly connecting farmers, traders, and consumers across regions, it promotes fair pricing, transparency, and efficiency in agricultural trade—realizing the vision of **"One Nation, One Market."** Its robust design, integrated digital ecosystem, and nationwide reach have the potential to break traditional mandi monopolies and establish a more equitable agribusiness environment. With sustained efforts in infrastructure development, capacity building, and policy support, e-NAM can truly evolve into the foundation of India's Agri-marketing landscape, empowering farmers of every scale and ensuring inclusive growth in the agricultural sector.

References:

Bisen, J. and Kumar, R. (2018). Agricultural marketing reforms and e-national agricultural market (e-NAM) in India: a review. *Agricultural Economics Research Review*, 31: 167-176.

Gohain, N. (2024). An Introspection of Agricultural Marketing Reforms in India. *Journal of Agricultural Development and Policy*. 34.

Manjula, M. (2021). The Smallholder in the Agriculture Market Reforms in India. *Economics and Political Weekly*, 56(15): 23.

Ministry of Agriculture and Farmers Welfare. (2023). Various annual reports 2021–22 and 2022–23. Government of India.

Namdeo, S. (2023). *e-NAM (National Agriculture Market): "One Nation – One Market for Agricultural Produce."* Agriculture Forum for Technical Education of Farming Society; Department of Agricultural Extension Education, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya.

Raju, M. S., Devy, M. R. and Gopal, P. V. S. (2022). Farmers perceived effectiveness of e-NAM. *Indian Research Journal of Extension Education*, 22(3): 43-48

Roy, D. (2022). Agriculture Marketing in India: Perspectives on Reforms and Doubling Farmers' Income. *Journal of Marketing Development & Competitiveness*, 16(3).

AGRICULTURE BULLETIN
ISSN: 3049-2289

Agricultural Education in India — If Graduates Don't Work in Agriculture, the Curriculum Is the First Suspect

Pradeep Unnikrishnan

In medicine or law, most graduates practise what they study. In agriculture, too many don't. The core issue isn't "students lack interest" — it's that much of the coursework is outdated, spread thin across too many subjects, and weakly tied to real jobs or real revenue streams.

Scale isn't the issue. Relevance is.

India runs one of the world's largest ag-education systems: 113 ICAR institutes and 74 agricultural universities (plus affiliated/private colleges). Even the ICAR national quota alone offered 5,842 UG seats in 2024–25 across 12 programmes; states and private colleges add thousands more.

Has this moved the needle? Yes and no.

Yes: India hit a record ~332.3 MT foodgrain harvest in 2023–24—a huge leap from the 1960s.

No (enough): 10,786 people in the farming sector died by suicide in 2023; production gains ≠ livelihood security. India still imports massive edible oil volumes despite policy pushes.

It's not the **size** of the system—it's **what and how** we teach.

Where the Curriculum Lags

1. Too broad, too shallow

Seventy-plus checkbox courses across soils, agronomy, entomology, pathology, PHT, AE, and horticulture produce **"jack of all trades, master of none"** graduates. Few tracks force specialisation in a **value chain** or **toolset** (data science, supply chain, sustainability, ag finance).

2. Weak linkage to markets and jobs

Pipelines still funnel to input sales, bank exams, or insurance roles—while structured routes into **FPO management, cold-chain logistics, ag-fintech, commodity trading, or ESG roles** are missing. The gap isn't academic—it's **commercial**.

Students graduate with a degree in agriculture, but without any grasp of how **commodities are priced**, how **futures or options** can hedge risk, or how **collateral warehouse receipts** can unlock credit. Most curricula never cover:

- How mandi and e-NAM price discovery works.
- How **MSP vs open-market** spreads shape planting decisions.
- Why **farm-gate prices** haven't kept up with inflation or with land-value appreciation.
- How **cost–benefit analysis** at the farm level determines profit or loss.
- How **commodity finance** and **warehouse receipt funding** can improve cash flows.
- The impact of **logistics costs, export parity, and policy distortion** on farmer margins.

Without this commercial layer, students know how to grow a crop but not how to make it pay.

3. Slow update cycle

Even ICAR's own NAHEP review flagged that agricultural higher education has lagged industry evolution by years. Reforms exist—but unevenly adopted, and rarely include **pricing analytics, trading, or ag-finance modules.**

ISSN: 3049-2289

"Is there any AI in agriculture?" — Yes, but make it count

At TNAU, B.Tech (Agricultural Information Technology) includes AI & ML, Python, IoT, Big Data Analytics, Digital Image Processing, Automation & Sensors—**real, examinable coursework**. ICAR also runs AI-linked trainings and data schools.

But sprinkling "AI/ML" into a syllabus doesn't fix employability. Without **applied projects tied to commercial KPIs** (e.g., a disease detector that reduces packhouse rejects, or a model that improves water budgeting to save cost per acre), "AI in Ag" is just a line on a marksheet.

A Candid Addition: The "Civil Services" Detour

A growing number of ag colleges pitch the degree as a UPSC or State PCS pathway—"**you can prepare for civil services.**" Ask yourself: does any other professional stream market itself that way? You don't see MBBS promoted as "great for UPSC prep," or LLB as Plan-B for bureaucracy. This messaging quietly **admits weak labour-market linkage** and diverts talent from the very sector that needs it.

Stop the Excuses. Start Building.

Small holdings, limited resources, and patchy irrigation are **design constraints**, not excuses. The curriculum must teach students to design **around** them—with viable service models, clusters, and low-capex kits that students can deploy with FPOs, cooperatives, or startups.

Add these now:

1. Blockchain tech in agri (traceability & faster payments)

- **Teach:** permissioned vs public chains; QR/GS1 tagging; on-chain weighment and quality anchoring.
- **Pilot:** one FPO chain (banana/turmeric/tea); QR-tracked farm→buyer traceability; conditional escrow.
- **KPI:** payment lag cut from T+7 to T+1, rejects ↓, price premium ↑.

2. Vertical farming & hydroponics (urban/peri-urban micro-units)

- **Teach:** NFT/DWC design, EC/pH control, unit economics, lighting math.
- **Pilot:** a 2–4 rack hydroponic micro-unit with B2B offtake (retail/cloud kitchen).
- **KPI:** kg/m²/month yield, cost vs mandi, payback period.

3. AI-powered precision agriculture (satellite + low-cost sensors)

- **Teach:** NDVI, ETc via GEE, Python, weather APIs, field-validation probes.
- **Pilot:** NDVI-based irrigation calendars; low-cost sensors for verification.
- **KPI:** water saved (m³/acre), yield ↑, input cost ↓.

4. AI-powered crop disease diagnosis

- **Teach:** dataset collection, CNNs, Android deployment, expert loop.
- **Pilot:** disease-detection app for turmeric/banana/paddy.
- **KPI:** diagnosis accuracy, chemical use optimization, reject reduction.

5. Mechanization as a Service (pay-per-use)

- **Teach:** drone and implement unit economics, routing, pricing.
- **Pilot:** partner with drone operators; run service P&L.
- **KPI:** acres serviced/month, cost per acre vs manual labour.

ISSN: 3049-2289

Embed the Missing Commercial DNA

Every project should also include **financial and pricing modules**:

- **Commodity pricing analytics:** Understand daily/weekly price trends from Agmarknet, NCDEX, and e-NAM; teach price forecasting using regression or ML.
- **Farmgate profitability:** Cost of cultivation (input, labour, transport) vs market price, adjusted for inflation; understand why the price–cost gap hasn't improved despite record outputs.
- **Ag-finance & collateral funding:** Teach warehouse receipt financing, trade credit, factoring, and insurance-linked lending.
- **Price hedging:** Introduce NCDEX futures and basic options strategies; show how smallholders can aggregate to hedge price risk.
- **Cost–benefit analysis:** Real-life calculations—irrigation cost vs yield gain; fertigation ROI; greenhouse vs open-field economics.
- **Inflation & land price disconnect:** Examine why ag land inflation outpaced produce prices and how policy/subsidy distortions play in.

Without these, agricultural education remains production-centric but **not profit-centric**—and the disconnect between **output growth** and **farmer income** will persist.

Make Assessment Outcome-Based

Every semester should measure outcomes, not just viva marks:

- KPI-linked studio credits (yield gain %, water saved, price improvement).
- Mandatory 20–24 week paid immersions with **FPOs, exporters, fintechs, cold chains, and ag-tech startups**.
- Annual publication of hard metrics: placement by role/sector, median salary, and impact KPIs (yield, cost/acre, income stability).
  If impact is invisible, people assume it doesn't exist.

Research Gaps That Need Closing

Technology is only half the story; adoption decides success.
We still lack robust data on:

- What drives or blocks smallholder adoption of digital tools (cost, trust, usability).
- Risk perception and financial readiness by segment (tenant, woman, elderly farmer).
- Effectiveness of digital literacy programs by demographic.

Embed these as **mixed-methods capstones** (field experiments + surveys) and publish open dashboards for policymaking.

The Bottom Line

We're not lagging because agriculture is "unattractive." We're lagging because **curriculum and assessment** haven't caught up with **markets, finance, or technology**. TNAU teaches AI; ICAR trains on digital tools; but **value appears only when tied to farm economics and commercial KPIs**.

Until agri education stops producing students who can quote rainfall averages but can't calculate break-even prices, the sector will remain underpaid and underpowered.

At the end of the day, **agriculture is a business**—and the study of it must reflect that.

****

AGRICULTURE BULLETIN

ISSN: 3049-2289

Infrared Drying: A Scientific Approach to Premium Mushroom products

Neethu, K.C., Aniesrani Delfiya, D.S., Murali, S.

ICAR-Central Institute of Fisheries Technology, Cochin-682029, Kerala

Mushrooms are edible fungi of commercial importance, and because of their distinct flavour, nutritional value, and status as a delicacy, their production and consumption have increased dramatically. With over 40% of the world's production, the button mushroom (*Agaricus bisporus*) is the market front-runner (Giri et al., 2007). Because of its typical flavour, nutritional content, and therapeutic potentials, *Pleurotus ostreatus* is one of them that is consumed extensively throughout the world. *P. ostreatus*, which is rich in nutrients and bioactive compounds, has antiviral, anticholesterolemic, antioxidant, antiarthritic, anticancer, antibacterial, and antidiabetic properties (Deepalakshmi et al., 2014). However, mushrooms only last for a few hours at room temperature, making them highly perishable. They must be consumed or processed right away since post-harvest. Biochemical changes make them unfit for human consumption. The majority of mushrooms are therefore marketed in processed form all over the world (Giri et al., 2007). The high protein content makes mushrooms a useful addition to a variety of recipes, such as soups, meat and vegetable dishes, and even some medical applications. Drying is one of the simplest methods to preserve mushrooms. Drying remove moisture, and preserves their nutritional value and flavour. Furthermore, dehydrated mushrooms take up less volume (Celen et al., 2010). Infrared (IR) radiation is a key energy source in the food industry, facilitating multiple applications including drying, roasting, pasteurization, blanching, peeling, and reducing antinutrients in legumes (Sakare et al., 2020). The infrared dryer was used as the best technique for drying food materials as a result of quicker drying and yielding best quality product (Prashob et al., 2022).

Food items can be dried under hygienic and controlled conditions using a solar-electric hybrid dryer (SEHD) also. The supplementary electric heating coil provides backup heat energy in dryer during low sunshine hours. Using solar energy and keeping the drying conditions under control, SEHD made better products than traditional open sun drying methods and drying cost less than electric dryers (Cisni et al., 2024).

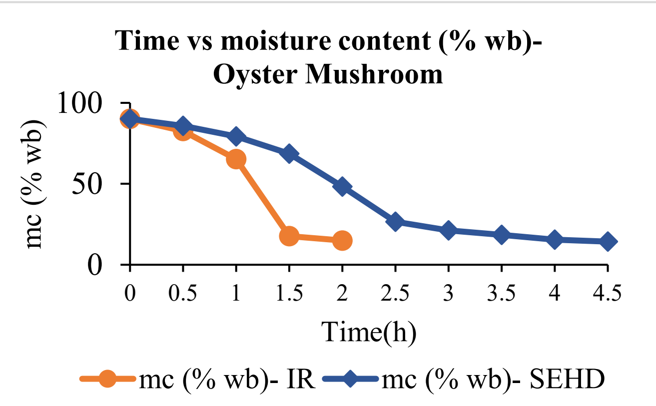
For comparing the drying techniques, fresh mushrooms were cleaned thoroughly, cut into uniform sizes, and dried in a batch-type hot air assisted IR dryer and SEHD developed at ICAR-CIFT, Kochi. Thin layer drying is followed in both dryers, by evenly spreading on the trays inside the drying chamber. The chamber was heated directly by infrared lamps in case of IR dryer. The mushrooms were dried at a set temperature, usually between 50 and 60°C, until their moisture content goes below 20%. Similarly, the drying temperature in SEHD was set at 60°C, the drying chamber was connected to solar thermal air collector for harvesting solar energy and supported by an electric heating for low sunshine hours. During drying, the weight loss was of the mushroom samples was measured at regular intervals. The dried mushrooms were tested for quality parameters such as colour, rehydration ratio, and sensory attributes like odour.

a b c d

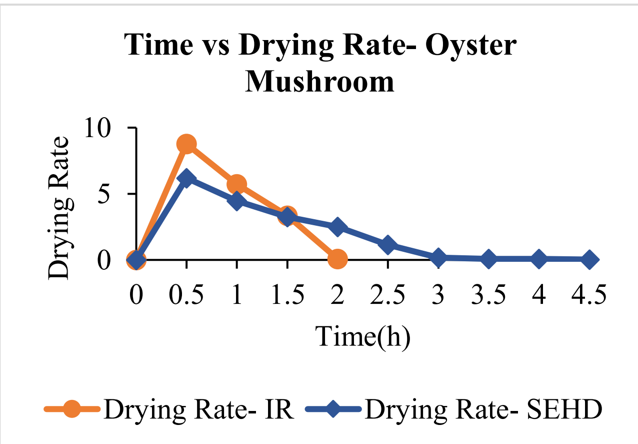
Fig. 1. Dried oyster mushroom using (a) Batch type IR dryer and (b) solar-electrical hybrid dryer and dried button mushroom using (c) Batch type IR dryer and (d) solar-electrical hybrid dryer

The differences between the two drying techniques are depicted in Figures 2 and 3. Mushrooms dried using IR dryer had better drying rates and a faster moisture loss than mushrooms dried with SEHD. It is understood that the solar–electrical hybrid dryer offered advanced drying offered by by solar energy and additional electrical heating. However, infrared drying was superior, because, it not only accelerated moisture removal but also maintained superior quality.

Drying curves were plotted in both cases. It was understood that moisture loss faster in IR drying compared to solar hybrid drying. Overall, the findings of the experiment showed that IR drying was an effective technology for batch processing mushrooms as this method provided faster drying rates, better colour and odour retention, consistent moisture removal, and enhanced overall quality.

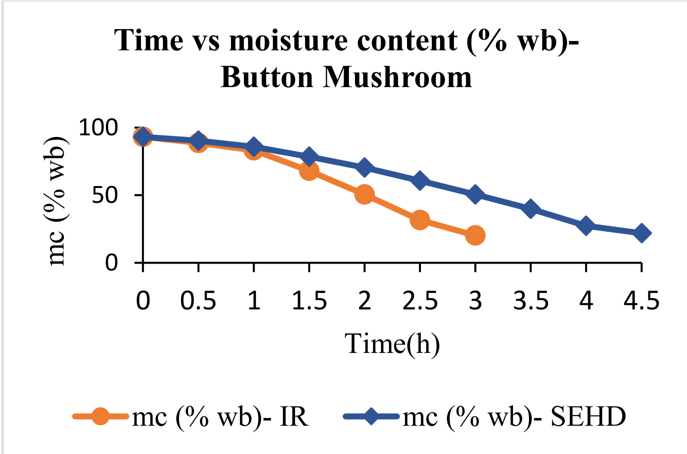


a

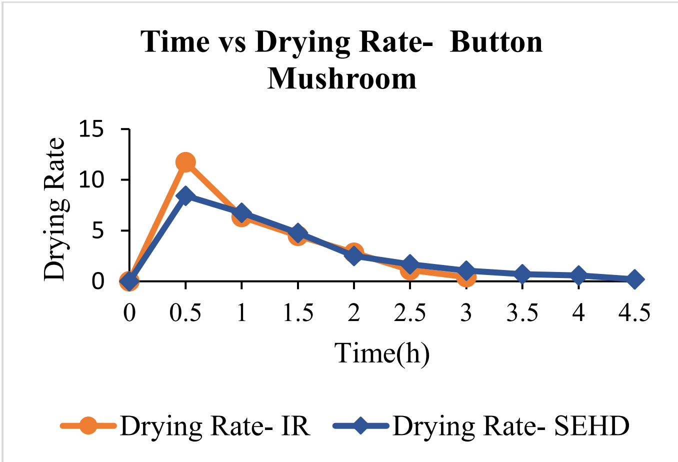


b

Fig. 2. Change in moisture content (a) and drying rate (b) oyster mushroom against time in different drying methods



a



b

Fig. 3. Change in moisture content (a) and drying rate (b) button mushroom against time in different drying methods

With an average drying rate of 3.58 g/g solids/h, a shrinkage of 28.81%, and a rehydration ratio of 3.73, oyster mushrooms undergo IR drying for two hours in order to achieve a final moisture content of 13.63% (w.b.). Using the same infrared drier, button mushrooms reached a final moisture content of 20.79% after 3 hours, with an average drying rate of 3.85 g/g solids/h, a shrinkage of 41.44%, and a rehydration ratio of 1.90. With an average drying rate of 1.79 g/g solids/h, shrinkage of 44.64%, and a rehydration ratio of 1.85, oyster mushrooms took 4.5

ISSN: 3049-2289

hours to reach 14.20% moisture, while button mushrooms took 4.5 hours to reach 21.74% moisture, shrinkage of 47.66%, and a rehydration ratio of 1.85. In contrast, the solar–electrical hybrid dryer took longer to dry both mushrooms. All things considered, the IR dryer outperformed the solar–electrical hybrid system in terms of drying speed, shrinkage, and rehydration ratios.

Table 1. Drying and quality characteristics of mushroom

Drying method	Type of mushroom	Drying time (h)	Final moisture content (%w.b.)	Average Drying rate (g/g solids/h)	Shrinkage (%)	Rehydration ratio
Batch type hot-air assisted IR dryer	oyster	2	13.63	3.58	28.81	3.73
	button	3	20.79	3.85	41.44	1.90
solar-electrical hybrid dryer	oyster	4.5	14.20	1.79	44.64	3.19
	button	4.5	21.74	2.67	47.66	1.85

Infrared (IR) drying found to have a number of benefits over the solar-electric hybrid drying method. First, because direct radiant heating penetrates the mushroom tissue and accelerates moisture removal, and thus, infrared drying drastically cuts down the drying time. A higher rehydration ratio of IR dried mushroom, indicated improved cellular structure retention and less collapse, which could be maintained by this quick drying. Additionally, IR drying reduced shrinkage, maintaining the mushrooms' overall appearance, texture, and shape, which is very critical for processing and consumer acceptance. Additionally, quicker drying increased product quality and shelf life by limiting the processing time of mushrooms and thus chances exposed to microbial attack. While, solar-electric hybrid drying was slower, infrared drying guaranteed more uniform heat distribution, resulting in consistent quality product across batches. Considering all, IR drying is an excellent technique for creating premium dried mushrooms since it blends quality preservation, and energy efficiency. Other researchers too support our findings that IR-assisted drying of mushrooms resulted in quicker drying, less energy use, and retention of functional and nutritious elements in mushrooms (Nurmawati et al., 2023; Malçok et al., 2023).

Reference

Celen, S., Kahveci, K., Akyol, U., & Haksever, A. (2010). Drying behavior of cultured mushrooms. *Journal of Food Processing and Preservation*, *34*(1), 27-42. https://doi.org/10.1111/j.1745-4549.2008.00300.x

Cisni, F. M., Neethu, K. C., Murali, S., Delfiya, D. A., & Ninan, G. (2024). Design and development of solar-electrical hybrid dryer and its performance evaluation using shrimps. *Biomass Conversion and Biorefinery*, *14*(20), 25343-25356.

Deepalakshmi, K., & Sankaran, M. (2014). Pleurotus ostreatus: an oyster mushroom with nutritional and medicinal properties. *Journal of Biochemical Technology*, *5*(2), 718-726.

Giri, S. K., & Prasad, S. (2007). Drying kinetics and rehydration characteristics of microwave-vacuum and convective hot-air dried mushrooms. *Journal of*

ISSN: 3049-2289

food engineering, *78*(2), 512-521. https://doi.org/10.1016/j.jfoodeng.2005.10.021

Malçok, S. D., Karabacak, A. Ö., Bekar, E., Tunçkal, C., & Tamer, C. E. (2023). Influence of a hybrid drying combined with infrared and heat pump dryer on drying characteristics, colour, thermal imaging and bioaccessibility of phenolics and antioxidant capacity of mushroom slices. Journal of Agricultural Engineering, 54(3).

Nurmawati, T., Hadiyanto, H., Cahyadi, C., Fachrizal, N., & Sutopo, S. (2023). Efficiency and Energy Consumption Analysis of Infrared-Assisted Drying of Oyster Mushrooms. International Journal of Heat & Technology, 41(4).

Prashob, K., Aniesrani Delfiya, D. S., Murali, S., Alfiya, P. V., & Samuel, M. P. (2022). Drying of shrimp using hot air-assisted continuous infrared drying system. *Journal of Food Processing and Preservation*, *46*(9), e16364.

Sakare, P., Prasad, N., Thombare, N., Singh, R., & Sharma, S. C. (2020). Infrared drying of food materials: Recent advances. *Food Engineering Reviews*, *12*(3), 381-398.

*****

ISSN: 3049-2289

Technologies Behind Vertical Farming

Thingom Beeny
B.Sc (Hons.) Agriculture, School of Agriculture,
Lovely Professional University, Phagwara, Punjab

Vertical farming is a modern agricultural practice that involves growing crops in vertically stacked layers inside controlled indoor environments using soilless method. Instead of spreading out over large fields like traditional farming, vertical farming stacks plants upwards, using towers or shelves making it ideal for urban areas with limited land availability.

Vertical farming is important because it helps us grow food in smarter, more efficient ways especially as cities keep getting bigger and farmland gets harder to find. Instead of needing lots of space, vertical farms use stacked layers, so they can grow tons of fresh veggies right where people live. It saves a lot of water. With regular farming, a lot of water just gets lost, it either soaks into the soil without helping the plants or evaporates into the air. Since plants are kept indoors, there is hardly any water wasted or sometimes even usage of soil which helps plants grow packed in a small area with all the nutrients they need. It helps plants grow faster and cleaner since everything is tightly controlled. It's a smarter, more efficient way to grow food that fits perfectly with the vertical farming idea.

Core Technologies

a) **Hydroponics** - In this method, plants are kept in nutrient-rich water without the need of soil. This way the roots get everything directly-water, food, and oxygen and so plants often grow faster and healthier. Since crops are grown in controlled environment, there are fewer pests which reduces the need for chemical pesticides. This method ensures space saving and also results in higher yield compared to traditional farming. It enables farmers to grow anytime regardless of season or climate by controlling indoor conditions. One of the greatest advantages is that it saves water up to 90% less than traditional farming by recycling and reusing it within the system. These benefits make hydroponics a highly efficient and sustainable method of farming, especially in areas with limited land and water resources.

b) **Aeroponics** – In this method, plants are grown without soil with their roots hanging freely in the air and the roots are sprayed with nutrient-rich mist. Because the roots are exposed, they get plenty of oxygen which helps plants to grow faster and stronger. It is an extremely water efficient method because it uses lesser water than hydroponics since only fine mist is needed. There are fewer problems with pests and weeds. Aeroponics has also been used in scientific research and space programs as NASA has tested it as a way for astronauts to grow fresh food in space.

c) **Aquaponics** – This method is a combination of aquaculture (fish farming) and hydroponics in a single system. Chemical fertilizers are not needed as fish wastes naturally fertilizes the plants. It provides sustainable food production – both fish and vegetables, providing protein and fresh produce. It is space saving and eco-friendly. We can grow vegetables and raise fish all year round, even in small spaces. It is good for environment and also grows quicker, thanks to the nutrient-rich water and fish and it takes up little space making it ideal for urban areas or rooftops.

d) **LED lighting** - In this method, artificial light sources are used in vertical farming to provide essential light for plant growth. These LED lights give plants the exact colours of light that they need to grow which is red and blue spectrum. They use much less electricity than regular lights reducing energy cost. The LEDs produce minimal heat which prevents plant damage and farmers can adjust how bright the lights are and how long they stay on which helps different plants grow better. Ther LEDs are small and can be fitted anywhere and be placed on multiple layers, so every plant can get enough lights and they also work for many years and with the right light, plants grow faster, healthier, and give better yield.

e) **Automation and Sensors** – This method uses technology and machines to perform tasks like watering, lighting, temperature, soil moisture, nutrient level, etc automatically. It creates a smart farming system reducing manual labour and improving efficiency. It also saves water and energy as it uses just the right amount of water, nutrients and electricity, reducing waste and so plants get equal care every time, resulting in healthier and more reliable crops. It helps farmers fix problems quickly and plan better for the future and the technologies make it simple to grow the farm bigger without the need of lots of labour.

f) **Artificial Intelligence and Data Analytics** – AI helps farmers understand exactly what plants need- like water, nutrients and light so crops can be grown faster and healthier. By analyzing real time data, AI ensures resources like water, energy and fertilizers to be used efficiently, cutting down on waste and costs. It detects problems early such as pests, diseases or nutrient deficiencies and so are fixed before they affect the harvest and it makes sure each plants get proper and right care producing uniform and high-quality crops. Farmers can better plan harvests, predict yields and manage resources making the farmers more organized and less stressful. Using AI and analytics, scaling up becomes easier and more efficient and automated monitoring saves time, allowing farmers to focus on innovation and improving productivity.

Enhanced Productivity

It optimizes crop growth, which can be tuned and controlled environment agriculture uses specialized technologies like LED lights, intensity to maximize the photosynthesis and this can be tuned to specific spectrum lights. In year-round production, this ensures a consistent of food supply, and control the lighting, humidity and temperature which enables continuous, year-round production. The automate operation improves the efficiency and it also allows to optimize the predictive modelling and crop yields.

Key technologies for optimization of resources

Artificial intelligence empowers algorithm with data to monitor the development of plants and it also predicts the potential issues and resource a location such as adjustment of the nutrient solutions and the intensities of light.

In soilless cultivation systems (Aeroponics, Hydroponics, Aquaponics), these systems and the sensors significantly uses less amount of water than in the traditional farming which delivers nutrients directly to the plants root and this leads to faster growth and higher yields with fewer resources.

Objectives

Vertical farming shows how modern technologies can come together to grow food more efficiently and sustainably. Techniques like hydroponics and aquaponics allow crops to grow soilless, water and nutrient efficient systems while LED lighting provides plants the exact wavelength of lights they need to grow for photosynthesis which results to higher yield. Automation and sensors continuously monitor environmental conditions such as temperature, humidity and nutrient levels so as for the plants to get right amount of care without the

ISSN: 3049-2289

farmers having to do everything by hand. On top of that AI and data analytics can predict growth patterns, detect problems early, optimizes resource use and helps farmers make precise decision.

By combining all these technologies, vertical farm can produce more food with less waste, grow crops year-round and even operate in cities or areas with little farmland. In essence, vertical farming is not just about growing crops indoor, it is about integrating science and technology to create a resilient food system. As these technologies become more advance, vertical farming could play a major role in feeding more people in the future sustainably.

*****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Digital Agriculture Policies: Governance, Data Privacy, and Ethical Use of AI in Farming

Thoufic khan D
B.Sc. (Hons) Agriculture

Digital agriculture, which uses AI, IoT, drones, and big data, has great potential to transform farming systems worldwide. It can improve productivity, sustainability, and resilience (Wolfert et al., 2017). However, issues in governance, data privacy, and the ethical use of AI could harm trust and fair benefits (Bronson & Knezevic, 2016). This review brings together current policy frameworks, regulatory challenges, and new governance models. It points out key gaps and suggests future research directions to promote inclusive, secure, and ethical digital agriculture.

Introduction

Digital agriculture brings together technologies like AI, IoT, drones, satellite imaging, and big data analysis to improve farm decisions across the value chain (Rose & Chilvers, 2018). While it shows promise for efficiency and sustainability, concerns about data ownership, privacy, and the ethical use of AI are becoming key issues in adoption discussions (Carbonell, 2016). This review looks at current policies, governance efforts, and research gaps, and outlines paths for future policy-focused and inclusive innovation.

Digital Agriculture: Benefits and Risks

Digital agriculture enables precision interventions such as smart irrigation, pest forecasting, and resource optimization through real-time data capture and analytics (Liakos et al., 2018). However, it also carries risks like data misuse, lack of transparency in AI models, technology inequality, and weak legal frameworks (Eastwood et al., 2019).

Policy & Regulatory Landscape

a) International & Multilateral Frameworks

Initiatives like the Global Open Data for Agriculture and Nutrition (GODAN) promote open, anonymized agricultural data to improve collaboration and reduce data siloing (Davies, 2016). The OECD notes that poor governance decreases trust in technology adoption (OECD, 2021).

b) Regional & National Examples

The EU's General Data Protection Regulation (GDPR) indirectly impacts discussions about farm data ownership and privacy (Harrison et al., 2022). India's Digital Agriculture Mission (DAM) uses AI for personalized advice and market connections (Government of India, 2021). Maharashtra's MahaAgri-AI Policy 2025–2029 allocates significant funds for AI-based agricultural infrastructure and blockchain traceability (Times of India, 2025a). Odisha's AI Policy-2025 establishes ethical data governance in agriculture (Times of India, 2025b).

When considering AI governance in agriculture, trust is crucial. Transparency and explainability are essential. The field faces major challenges such as algorithmic bias, black-box decision-making, and unclear accountability when issues arise. With biosurveillance technology for pest control being introduced, there is a real risk of undermining farmers' autonomy and privacy, especially if ethical guidelines are not firmly established.

Gaps in Current Policies

Many farmers are still wary of technology providers. They have ongoing concerns about how fairly their data is handled (Eastwood et al., 2019). Current regulations often do not meet their needs. They fail to address the complex realities of managing agricultural data (Wiseman et al., 2019). There is also a significant lack of ethical oversight. Few reliable

ISSN: 3049-2289

ways exist to monitor AI fairness or prevent the misuse of surveillance technologies in agriculture (Bronson, 2019). Additionally, digital inequality remains a serious problem. Smallholder farmers risk being left out if they cannot access or use digital tools fairly (Rose & Chilvers, 2018).

a. Farmer-Centric Data Governance

It is important to create cooperative data ownership frameworks and farmer-led data trusts in agriculture. When farmers control their data, they can make informed choices, negotiate better terms with agritech companies, and possibly earn money by sharing their data. These structures can also improve transparency and trust among farmers, policymakers, and technology providers (Carbonell, 2016).

b. Ethical AI Standards

The quick rise of artificial intelligence in agriculture brings significant ethical problems. To tackle these, we need clear frameworks that require transparency, accountability, and fairness in agri-AI systems (Floridi et al., 2018). This includes guidelines for how algorithms work, strong auditing processes, and ways to address harm or bias. More studies should explore how to adapt these frameworks to local agricultural contexts and the specific needs of smallholder farmers.

c. Privacy-Preserving Technologies

Research into privacy-preserving technologies like federated learning, differential privacy, and blockchain is crucial for secure data sharing in agriculture. These technologies can help reduce the risks of data breaches and unauthorized access while still providing valuable insights from combined data (Nguyen et al., 2021). There is plenty of opportunity for future work on scalable and cost-effective uses of these tools, especially in resource-limited rural areas.

d. Cybersecurity & Surveillance Ethics

The rising use of biosurveillance and digital monitoring tools in agriculture requires strong cybersecurity measures and ethical supervision (Kamilaris et al., 2017). Ethical frameworks must look into the potential misuse of surveillance data, ensure informed consent for data collection, and protect against cyber threats to essential agricultural infrastructure. Future research should consider the balance between the benefits of biosurveillance and the potential harm to privacy and personal freedom.

e. Capacity Building for Inclusivity

Investing in training farmers about digital rights and improving rural digital infrastructure are key steps for inclusive digital agriculture (Rose & Chilvers, 2018). Training programs should focus on technical skills and raise awareness about data rights, privacy, and ethical technology use. Additionally, making reliable internet access and digital tools available in rural areas is still a major challenge that needs ongoing policy focus.

f. Harmonizing Governance

Encouraging global cooperation on agricultural data sharing and AI ethics is crucial for addressing international challenges and ensuring fair access to technology benefits (OECD, 2021). Setting international standards and promoting collaborative governance can help prevent data splitting, enhance interoperability, and build trust among stakeholders. More research is necessary to find effective ways to harmonize regulations and create consensus across various agricultural systems.

Conclusion

Digital agriculture can significantly change food systems, but making this change depends on more than just technology. It requires a thoughtful policy approach that puts people's basic rights and ethical concerns first, not just flashy solutions. If policies overlook the needs and experiences of farmers—those who actually work the land—the entire effort could fail or mainly benefit a few. Inclusivity needs to be more than a formality; for digital agriculture to fulfill its promise, access and benefits must reach those who lack resources and connectivity. Policymakers should work to ensure broad, fair access to these technologies. This may involve improving infrastructure in rural areas or creating opportunities for smallholder farmers to take part fully. In the end, the future of digital agriculture relies on finding a balance between pushing for innovation and maintaining a strong commitment to rights, ethics, and trust. Only then can it provide fair and lasting benefits for everyone involved in the food system.

References

Bronson, K. (2019). Looking through a responsible innovation lens at uneven engagements with digital farming. NJAS - Wageningen Journal of Life Sciences, 90–91, 100294. https://doi.org/10.1016/j.njas.2019.04.001

Bronson, K., & Knezevic, I. (2016). Big Data in food and agriculture. Big Data & Society, 3(1), 1–5. https://doi.org/10.1177/2053951716648174

Carbonell, I. M. (2016). The ethics of big data in big agriculture. Internet Policy Review, 5(1). https://doi.org/10.14763/2016.1.405

Davies, T. (2016). Open data in developing countries: Lessons from the Open Data Research Network. African Minds.

Eastwood, C., Klerkx, L., Ayre, M., & Dela Rue, B. (2019). Managing socio-ethical challenges in the development of smart farming: From a fragmented to a comprehensive approach for responsible research and innovation. Journal of Agricultural and Environmental Ethics, 32(5–6), 741–768. https://doi.org/10.1007/s10806-017-9704-5

Floridi, L., Cowls, J., Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V., … Vayena, E. (2018). AI4People—An ethical framework for a good AI society: Opportunities, risks, principles, and recommendations. Minds and Machines, 28(4), 689–707. https://doi.org/10.1007/s11023-018-9482-5

Government of India. (2021). Digital Agriculture Mission 2021–2025. Ministry of Agriculture & Farmers Welfare.

Harrison, J., Wiseman, L., & Beeby, R. (2022). Farm data ownership: Balancing legal frameworks and farmer rights. Agricultural Law Journal, 27(3), 145–165.

Kamilaris, A., Kartakoullis, A., & Prenafeta-Boldú, F. X. (2017). A review on the practice of big data analysis in agriculture. Computers and Electronics in Agriculture, 143, 23–37. https://doi.org/10.1016/j.compag.2017.09.037

Liakos, K. G., Busato, P., Moshou, D., Pearson, S., & Bochtis, D. (2018). Machine learning in agriculture: A review. Sensors, 18(8), 2674. https://doi.org/10.3390/s18082674

Nguyen, T. T., Nguyen, N. D., & Nguyen, D. T. (2021). Privacy-preserving machine learning for smart agriculture. IEEE Access, 9, 111347–111361. https://doi.org/10.1109/ACCESS.2021.3102643

OECD. (2021). Issues around data governance in the digital transformation of agriculture. OECD Publishing. https://doi.org/10.1787/53ecf2ab-en

Rose, D. C., & Chilvers, J. (2018). Agriculture 4.0: Broadening responsible innovation in an era of smart farming. Frontiers in Sustainable Food Systems, 2, 87. https://doi.org/10.3389/fsufs.2018.00087

Wiseman, L., Sanderson, J., Zhang, A., & Jakku, E. (2019). Farmers and their data: An examination of farmers' reluctance to share their data through the lens of the laws impacting data sharing in Australia. NJAS - Wageningen Journal of Life Sciences, 90–91, 100301. https://doi.org/10.1016/j.njas.2019.04.007

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big Data in smart farming – A review. Agricultural Systems, 153, 69–80. https://doi.org/10.1016/j.agsy.2017.01.023

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Empowering Farmers Through Digital Advisory Platforms: Lessons from Kisan Call Centres and e-Choupal in Rural India

Ayushi Jogi[1] & Amit Singh Kshatri[1]
[1]College of Fisheries Science,
Chaudhary Charan Singh Haryana Agricultural University, Hisar (125004), Haryana

Introduction

The agriculture industry in India is undergoing a digital revolution, moving away from local market rumours and conventional in-person extension to an ecosystem driven by knowledge and enabled by information and communication technology (ICTs). Nowadays, farmers use helplines, SMS, apps and websites to obtain weather-based warnings, pest alerts, subsidy information and prices at the market. Research indicates that well-designed digital advisory systems reduce weather shocks, boost agricultural profitability and facilitate the adoption of better practices. Despite the fact that digital technologies cannot address every limitation when tailored to local languages and cropping methods they allow for quicker and more economical outreach. The information divide between farmers and technology has narrowed through complementary public and private ICT models such as Kisan Call Centres (KCC) and e-Choupal. KCCs provide farmers with a free language-friendly phone line to specialists for urgent issues; e-Choupal and comparable kiosks (as well as their contemporary counterparts) integrate internet access, market connections, locally relevant content and trusted local mediators. Together, they address trust (local language, local intermediaries) and reach (Naika & Km, 2024).

Kisan Call Centres (KCC): Voice-based Agricultural Advisory

One of the most user-friendly and accessible digital advising models in India is Kisan Call Centers (KCC) which provide voice-based agricultural advice in a number of regional languages via a toll-free number (1800-180-1551). KCC is a multi-tiered system that was started by the Ministry of Agriculture to provide expert support to even older, less literate and female farmers without the need for smartphones or internet access. Farm Tele-Advisors answer simple questions and refer more complicated ones to national and state subject-matter experts. The system which is backed by ICAR institutes, KVKs and agricultural universities is increasingly using AI and natural language processing to increase accuracy and speed up responses. KCC has developed into a multi-modal advisory service that not only responds to millions of farmer inquiries annually but also produces data that aids policymakers in identifying pest outbreaks, weather stress zones and training requirements by combining voice calls with SMS follow-ups, IVR alerts and connections to field demonstrations. A crucial link between technology, research and grassroots agriculture KCC's prompt guidance has been shown to enhance input use, lower crop losses and boost farmers trust in scientific recommendations.

e-Choupal: A Model of Digital Empowerment

ITC Ltd. introduced e-Choupal in 2000 and since then it has become a trailblazing example of digital empowerment in rural India through the use of internet-enabled village kiosks run by Sanchalaks or trained local farmers. What started off as a platform to facilitate direct crop purchases from farmers has developed into a multipurpose rural service center that provides weather forecasts, agronomic advises, input services, real-time mandi prices and market connections. While the Sanchalak connects technology with local social networks by analyzing data, organizing group purchases and upholding credibility the kiosk serves as a trusted community space where farmers can access information collectively, lessen reliance on middlemen and make better informed decisions about production and sale. According to studies, e-Choupal has improved farmers price realization, decreased transaction costs and raised awareness of better farming practices. Nevertheless e-Choupal is a potent illustration of how with the support of community trust and private-public cooperation, decentralized digital access points may democratize knowledge and improve rural lives (Jha & Shah, 2025).

Complementarity between KCC and e-Choupal

The public-private partnership between e-Choupal and Kisan Call Centers (KCC) shows how two different ICT models one community driven and kiosk-based the other voice-based and nationwide can work together to improve India's digital extension ecosystem. e-Choupal offers a reliable local interface run by Sanchalaks that combines information access with market connections and on-the-ground support while KCC provides affordable language-friendly expert guidance through a toll-free helpline. Both systems enhance one another's capabilities when they are carefully connected such as when kiosks send sophisticated farmer inquiries to KCC or when KCC shares disease hotspot information with kiosk owners striking a balance between local credibility and size. There are three useful strategies to increase synergy: (1) Information sharing where Sanchalaks relay field issues to experts and KCC call analytics direct kiosk-based demonstrations (2) Multi method delivery (voice → demonstration → sale or input procurement) where voice advisories, printed materials, visual aids and on-site support reinforce behavior change and (3) Data-driven planning where aggregated helpline trends help prioritize crops, villages and extension campaigns. Three policy-oriented steps are essential to operationalizing this complementarity: establishing cooperative capacity through recurring training of Farm Tele-Advisors, Sanchalaks and KVK scientists enabling two-way escalation between kiosks and KCC experts and developing shared anonymized dashboards for real-time issue tracking. When combined these actions have the potential to turn disparate digital projects into a well-organized, farmer-focused advising network that offers accessibility and significance (Agarwal *at el.,* 2023).

Impact on Farmers Knowledge, Income and Decision-making

Digital advisory platforms like Kisan Call Centres (KCC) and e-Choupal have greatly enhanced farmers knowledge, income and decision-making abilities by providing quicker and more dependable access to essential information. Farmers can now compare market prices, receive real-time weather updates and determine the best times and places to sell their products, thus minimizing distress sales and increasing profit margins, rather than relying on middlemen, hearsay or making long trips to the mandi. Additionally, the effect on crop planning and productivity is significant: timely guidance delivered through phone helplines, SMS/IVR messages or kiosk-based assistance enables farmers to make more informed choices regarding seed selection, fertilizer application, pest control and harvesting timelines resulting in tangible yield improvements especially for those with limited access to conventional extension services. In addition to their economic advantages, consistent interaction with these platforms fosters digital skills and self-assurance, motivating farmers to utilize a wider array of digital tools such as online payments, crop insurance and purchasing portals. Research conducted in India indicates that farmers who are digitally connected often become information leaders within their villages offering guidance to fellow farmers and amplifying the distribution of extension services. Collectively these platforms illustrate how thoughtfully crafted digital ecosystems can make information more accessible, bolster resilience and empower rural communities on a large scale.

ISSN: 3049-2289

Challenges and Limitations

Digital advice platforms like e-Choupal and Kisan Call Centers despite their extensive reach nonetheless suffer a number of operational and structural obstacles that limit their full potential in rural India. For many farmers digital services are unstable due to poor internet and energy infrastructure which frequently interferes with timely advice particularly in isolated settlements. The adoption and impact of these platforms are further limited because a significant part of smallholders are either ignorant of them or have not been exposed to contemporary agricultural technologies. Information flow is made much more difficult by language barriers since cautions given in non-local languages are frequently misinterpreted or disregarded. In order for services to adapt to changing technology and farmers changing demands, ongoing farmer training, digital handholding and routine system monitoring are necessary to guarantee long-term efficacy.

Conclusion

The future of digital advising platforms like Kisan Call Centers and e-Choupal depends on developing a more resilient and inclusive digital ecosystem for agriculture that incorporates infrastructure, innovation and policy support. To ensure farmers receive real-time market and weather information without interruption it is imperative to increase the availability of smart devices provide inexpensive internet access and guarantee dependable electricity. Even first-generation digital users can benefit from more personalized, predictive and locally relevant advisories that use artificial intelligence, mobile apps and multilingual support. In addition the future need greater cooperation with the government supplying enabling laws businesses spearheading technology advancements and non-governmental organizations filling in last-mile trust and capacity gaps at the local level. In addition to strong monitoring systems to continuously improve services based on farmer feedback strong legislative support for digital literacy, region-specific content and equitable access will be essential. By combining these actions digital advice platforms can be turned from pilot projects to national hubs for resilience and agricultural empowerment.

Reference

Agarwal, V., Malhotra, S., & Dagar, V. (2023). Coping with public-private partnership issues: A path forward to sustainable agriculture. *Socio-Economic Planning Sciences*, *89*, 101703.

Jha, A., & Shah, S. (2025). Value creation in AgriTech ecosystems through ITCMAARS. *Journal of Information Technology Teaching Cases*, 20438869251325242.

Naika, K. V., & Km, S. (2024). Satisfaction level of the farmers regarding Kisan Call Centre (KCC) advisories. *Asian Journal of Agricultural Extension, Economics & Sociology*, *42*(4), 162-167.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Importance of Pollinators in Horticulture and Ways to Attract Them to Get Qualitative Fruit Production

Maneesh Sonkar [1*], Veena Dhruw[1] and Nidhi Taram[1]
[1]Research scholar, Department of Processing and Food engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur

Introduction

Pollinators are animals (insects) that play an important role, in the pollination of various plants, including those in horticulture and agriculture. They transfer pollen from the part of a flower to the part of another flower enabling pollination and seed production. Approximately three quarters of the crops cultivated worldwide depends on pollinators to produce fruits, seeds, and veggies.

More than 80% of the pollination activities are performed by the insects and the yields of some of the fruits can decrease by more than 90% without these pollinators. Many fruit crops require an insect pollinator to help insure pollination.

There is a range of pollinators, such as bees, butterflies, moths, flies, beetles, birds, and bats. Each type possesses characteristics that make them effective at pollinating types of plants.

Different types of pollinators

In horticulture pollinators are essential for the production of fruits, vegetables, and other crops. A well pollinated flower will contain more seeds, with better germination quality, leading to better and bigger shaped fruit. Without their assistance many crops would struggle to yield fruit or produce seeds resulting in decreased productivity and quality.

To support populations of pollinators in scale horticultural operations several strategies can be implemented. These include planting flowers that attract pollinators minimizing pesticide usage, when possible, to avoid harming them or their habitats. Additionally providing sites and implementing conservation programs have proven effective measures. Adopting pollinator practices can also yield economic b enefits for large scale horticultural operations. By supporting the health and abundance of pollinators in this way through increased yield and better crop quality which translate s into profits.

Importance of Pollinators in horticulture:

Pollinators play a crucial role in horticulture as they are responsible for pollinating many crops that are grown for food, fiber, and other products. Without pollinators, many of these crops would not produce fruit or seeds, resulting in significant economic losses and food shortages. Some examples of crops that rely on pollinators include fruits such as apples, peaches, and strawberries, nuts such as almonds and cashews, and vegetables such as tomatoes, peppers, and cucumbers. Pollinators also play a role in the production of honey and other bee products.

In addition to their economic importance, pollinators also contribute to the biodiversity and health of ecosystems. They help to maintain the genetic diversity of plant populations, which is important for their ability to adapt to changing environmental conditions.

However, the decline in pollinator populations due to factors such as habitat loss, pesticide use, and climate change is a major concern for horticulture. This has led to increased efforts to protect and promote

ISSN: 3049-2289

pollinator populations through practices such as planting pollinator-friendly habitats and reducing pesticide use.

Effect of climate change on pollinators:

Climate change poses a significant threat to pollination and pollinators. It is important to take action to mitigate the effects of climate change and protect these essential species. Here are some ways in which climate change can affect them:

1. **Changes in flowering times**: As temperatures warm, plants may shift their flowering times, which can affect the timing of when pollinators emerge and their ability to find food.
2. **Habitat loss:** Climate change can cause changes in precipitation patterns, leading to droughts or flooding. This can cause habitat loss for pollinators and the plants they rely on.
3. **Range shifts:** As temperatures warm, some pollinators may shift their ranges to cooler areas, while others may not be able to adapt and could face extinction.
4. **Changes in plant-pollinator interactions**: Climate change can alter the relationship between plants and their pollinators, potentially leading to declines in both.
5. **Pesticide use:** With climate change, pests and diseases may become more prevalent, leading to increased pesticide use. This can harm pollinators directly or indirectly by reducing their food sources or nesting habitats.

Most effective methods to attract in Pollinators to Your vegetable nursery/fruit orchard:

1. **Pollinator-friendly plants**: Choose plants that are native to your area and have flowers that provide nectar and pollen for pollinators. Some examples include milkweed, lavender, sunflowers, and wildflowers. Numerous pollinators are drawn to local species for their food. Discover likewise some extraordinary local flowers to Take care of the pollinators. Draw in pollinators to your nursery with different brilliant plants.

Plants that attract hummingbird

Hummingbirds are attracted to red and orange plants, although odor is not important. Their long beaks allow them to feed on funnel-shaped flowers. They also prefer a strong perch when feeding. Cardinal

1. Flower (Lobelia)
2. Columbine (Aquilegia)
3. Penstemon
4. Bee Balm (Monarda)
5. Hibiscus (Tropical and Hardy)
6. Peony
7. Coral Bells (Heuchera)
8. Catmint (Nepeta)
9. Agastache
10. Salvia (Annual and Perennial)

ISSN: 3049-2289

Plants That Attract Butterflies

Butterflies are drawn to brightly colored plants, including reds and purples. They prefer fresh scents that are faint, not overwhelming. They feed best on plants with narrow, tube-like flowers with a wide landing pad.

1. Butterfly Weed (Asclepias)
2. Coneflower (Echinacea)
3. Aster
4. Verbena Black Eyed Susan (Rudbeckia)
5. Daisy (Leucanthemum)
6. Ironweed (Veronia)
7. Agastache Bee Balm (Monarda)

Plants That Attract Bees

Bees prefer bright white, yellow, or blue plants with a fresh, mild odor. They can feed easily on plants with shallow, tubular flowers and a landing platform

1. Butterfly Weed (Asclepias)
2. Coneflower (Echinacea)
3. Aster
4. Salvia (annual and perennial)
5. Black Eyed Susan (Rudbeckia)

6. Daisy (Leucanthemum)
7. Bee Balm (Monarda)
8. Ironweed (Veronia)
9. Agastache

2. **Selecting Plants That Offer Vivid Blossoms in Your Nursery Beds and Pots** Pollinators are better ready to track down these beautiful blossoms. Splendid varieties resemble a signal to attract the pollinators. Many blossoms incorporate spots, stripes, and different markings to draw in the different pollinators.

3. **Add Flowers with Aroma:** Numerous pollinators are drawn to the smell of the blossoms and plants. Incorporate fragrant spices like sage, thyme, rosemary, dill, fennel, oregano, and basil in your flowerbeds to energize more pollinators. To additionally draw in pollinators, permit a portion of your spices to bloom.

4. **Develop Flowers for pollinators:** That Give Various Shapes and Sizes to Draw in a More prominent Assortment of Pollinators have their shapes and sizes of blossoms they look for. Hummingbirds love long, cylindrical blossoms while honey bees appreciate round shapes. Butterflies incline toward level beat blossoms.

5. **Provide nesting habitats**: Many pollinators, such as bees, need a place to nest. providing nesting habitats by leaving dead wood or installing bee houses. Set up regions around your yard and garden that give spots to pollinators to make housing habitats. Making honey bee houses or buy an instant honey bee house. These honey bee houses give a spot to local honey bees to lay their eggs. Pass on little areas of open ground to give ground-inhabitants a spot to live. Covering the bed extensively can create difficulties to the

ISSN: 3049-2289

pollinators that make their homes underground.

6. **Reduce pesticide use**: Pesticides can harm pollinators directly or indirectly by reducing their food sources or nesting habitats. Consider using natural pest control methods, such as companion planting or introducing beneficial insects.
7. **Provide water sources and food**: Pollinators need water to drink, so consider providing a shallow dish of water with rocks for them to perch on. Pollinators need a standard stockpile of water that is effectively open. Water basins, lakes, and little water bowls can all supply water routinely. Keep these water sources accessible all through the developing season. These pollinators will be glad to return over and over as long as the food and water sources will be available for them.
8. **Manage your garden sustainably:** Avoid tilling soil excessively, as this can disrupt the habitat of ground-nesting bees. Instead, use mulch to conserve moisture and suppress weeds.

Role of pollinators in qualitative fruit production

- **Papaya:** Papaya plants might be self-pollinating (sexually unbiased plants) or cross pollinated by bugs or wind. Pollinators incorporate bumble bees, wasps, midges, thrips, syrphid flies, and butterflies. The papaya is wind pollinated, additionally pollinated by honey bees and moths. Bumble bees are the essential pollinating specialists of papaya. The hummingbird moths *(Macroglossum stellatarum)* and different types of Trigona and Xylocopa were additionally the guests of papaya blossoms.
- **Banana:** Among the pollinators visiting banana inflorescence, the bumble bees are the predominant pollinator (77.50%) followed by the wasps (*Polistes haebraceous and Vespa orientalis)* with 15.53% pollination. The other pollinators of banana are hymenoptran bugs including the sting less honey bees.
- **Pomegranate:** Honey bee pollination can improve the fruit setting rate and physical qualities of pomegranate. With resulting cross-fertilization, natural fruit set can increase to around 68%. There is minimal quantitative information available concerning the role of bumble bees in the pollination of pomegranate.
- **Strawberry:** Impact of bug pollination can increase natural product yield and quantity. Honey bee pollination improve the weight and shape of strawberries.
- **Custard apple:** In the case of custard apple, the nitidulid beetles are the main pollinators. The 10% of yield can be credited to fertilization by honeybees.
- **Melons:** insect pollination in melons play a major role because sticky pollens of melons flowers cannot be moved by wind. Which makes insect pollination crucial for commercial fruit setting in melons, but some melons (seedless and parthenocarpy) do not need pollinators.
- **Aonla:** Aonla is fundamentally a cross pollinated plant. Wind, honeybees, and gravity assume a significant part in compelling pollination. The utilization of pollinators (honey bees) and pollinizers in Aonla plantations is vital for expanding the organic product yield.
- **Passionfruit**: honey bee and carpenter honey bees, both are main pollinator insect of passionfruit. the Carpenter honey bee is the best pollinator as it has enormous body and its body brushes along the anther and stigma while acquiring nectar.

ISSN: 3049-2289

- **Ber:** The blossoms are protandrous. Thus, natural fruit set relies upon cross-pollination by bugs pulled in by the scent and nectar. pollen of the Indian jujube is thick and weighty. It is not airborne however is moved from one bloom to another by bumble bees.
- **Cashew:** Cashew production can be expanded by installing settlement of honey bee. Honey bees are the proficient pollinators of cashew. *Trigona spinipes* honey bee visits to cashew blossoms were straightforwardly related to nut yield.
- **Cherries and plums:** Wind is not a figure pollinating Prunus spp. (Cherries and plums) and bumble bees are by a long shot the larger part of the bug guests to plum bloom. Bumble bees gather nectar and dust from blooms also, find this gathering of plants extremely appealing. Sugar focuses as high as 55% in sweet cherry nectar have been recorded which makes the bloom extremely alluring to honey bees.
- **Apple:** pollination of apple though honey bees play an important role in apple fruit production. The effect of expanded honey bee visits and arrangement of honey bee settlements can improve natural fruit set and lower natural fruit drop in apple.
- **Litchi:** pollen movement in litchi might be by help of autogamous self-fertilization, wind, or bugs, nonetheless, for business crops pollination by insects (specifically by the honey bee) play efficient role to get decent fruit yield and quality.
- **Sapota:** The thrips (*Thrips hawaiiensis* and *Haplothrips tenuipennis*) live on nectar, dust grains and stigmatic exudations and take cover in the return they do the help of fertilization
- **Fig:** The female fig wasp's part in pollinating certain edible figs, particularly Smyrna fig *(Ficus carica)*, is important to the fig cultivators, as most valuable figs necessary to fertilization to mature.
- **Guava:** honey bees are the best pollinators and also affect the yield of guava fruit. Honey bees can increase Twenty to forty percent pollination in guava. Natural yield quality can also be improved by honey bees.

References:

1. Hummingbirds, butterflies, and bees: attracting pollinators to your garden (https://www.skh.com/thedirt/attracting-pollinators-to-your-garden/)
2. Pashte, V.V., and Kulkarni, S. R. (2015). Role of pollination in qualitative fruit crop production: a review, *Trend in Bioscience, 8* (15), 3743-3749.
3. https://www.carolinafarmstewards.org/25-ways-to-attract-pollinators-to-your-farms-gardens/
4. https://www.peanc.org/7-ways-attract-pollinators
5. Crane, J. H. (2013). Papaya growing in the florida home landscape- fact sheet HS 11. A series of the Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, pp. 1-6.

6. Kaushik, H. D., Yadav, S. and Nadaf, H. A. (2012). Role of insect pollinators in tropical/ sub-tropical/arid fruit crops. In: Advances in bio-ecology and management of insect pollinators of crops. Centre of advanced faculty training, Department of Entomology, CCS, Haryana Agricultural University, Hisar, pp. 113.

7. Allemullah, M. and Ram, S. 1990. Causes of low fruit set and heavy fruit drop in Indian gooseberry (Emblica officinalis Gaertn). Indian J. Hort. 47(3): 270-277.

8. Tao De-shuang, Dong Xia, Dong Kun, Zhang Xue-wen and Yu Yu-sheng 2010. Study on the effects of pollination by honey-bees on pomegranate (Punica granatum L.). J Bee 3: 10-11.

9. Kishore, K., Pathak, K. A., Shukla, R. and Bharali, A. (2010). Studies on floral biology of passion fruit (Passiflora spp.). Pak. J. Bot. 42(1): 21-29.\

10. Sharma, H. K., Uma Partap, Bisht, K., Tewari, P. and Phartiyal, P. 2012. Impact of honeybee pollination in enhancing the apple production in Nainttal district of Uttarakhand. Adv. Pollen Spore Res. 30: 99-102

*****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Farming in Harmony with Nature

Dr. Prabhu Nayaka
Principal & Dean and I/c Registrar,
Gujarat Natural Farming Science University, Halol, Gujarat

The escalating global population has intensified the demand for food production, leading to an increased reliance on chemical inputs including fertilizers, pesticides, insecticides, and growth regulators. While these inputs have become integral to modern agriculture, their indiscriminate and excessive use has raised concerns regarding their long-term effects on soil and crop health. Therefore, it is imperative to assess soil health prior to the application of such synthetic agents to avoid unforeseen negative consequences.

Understanding Aboveground Habitat Management

There are several strategies available to enhance the quality and functionality of the aboveground habitat in agricultural systems. One fundamental approach involves the selection of crop species and cultivars that exhibit resistance to locally prevalent pests, in addition to possessing other desirable agronomic traits such as high yield potential, favourable taste, and adaptability to environmental conditions.

Optimizing planting density and incorporating companion crops are additional practices that can promote vigorous crop growth, suppress weed populations, and offer partial protection against pest infestations. In some cases, utilizing mixtures of two or more cultivars of the same crop species has proven beneficial. For instance, combining a high-yielding variety that may be susceptible to pests or drought with another that is more resilient or pest-resistant has demonstrated potential in enhancing total yields, particularly in staple crops such as wheat and rice. Although monoculture is still practiced in such cases, the introduction of genetic diversity through cultivar mixing appears to confer increased resilience to biotic and abiotic stresses. Intercropping, such as alternating rows of distinct crop species—e.g., sunflowers with soybeans or peas—may further contribute to pest management and ecological stability.

Another effective technique involves the use of perimeter or trap crops, which are more attractive to specific pests than the main economic crop and thus serve to intercept or divert pest populations. A practical example of this strategy includes the planting of Blue Hubbard squash around fields of summer squash to attract and trap striped cucumber beetles. A more integrated method, known as the "push-pull" system and widely practiced in East Africa, enhances this concept by incorporating repellent and attractive plants within and around the crop field. In this system, Desmodium, a low-growing legume, is intercropped with maize to repel stem borers ("push"), while attractant grasses are planted along the field margins to lure adult moths ("pull"). This approach not only contributes to pest control but also provides additional agronomic benefits such as nitrogen fixation and weed suppression.

Finally, the establishment of field borders and internal zones that attract beneficial insects can support natural pest regulation. This is typically achieved by planting diverse mixes of flowering species either around the field perimeters or in strips within the field. These floral resources offer shelter and sustenance for pollinators and predatory insects, thereby enhancing ecological balance and contributing to integrated pest management.

Growing cover crops regularly helps in many ways. They can give helpful insects a place to live, add nutrients like nitrogen to the soil, keep the soil

ISSN: 3049-2289

from washing away, help water soak into the ground better, and keep nutrients from being lost. In fact, in some areas, like the southern U.S., a strong winter legume like crimson clover can give all the nitrogen needed for the next crop. In the north, hairy vetch can do the same.

It's also smart to rotate crops, especially using different plant families and including grass/clover hay or other sod crops that stay in the ground for years without being tilled.

Cutting back on tillage is a key part of eco-friendly farming. Tilling the soil removes plant residue and leaves the soil uncovered, making it easier for rain to wash it away. It also breaks up the natural structure of the soil. Reducing erosion is important to keep soil healthy for the future.

Belowground Habitat Management

Improving soil conditions to support crop root systems and beneficial soil organisms relies on a consistent set of management principles applicable across all fields. The key considerations are which practices to choose and how best to apply them in a specific context. The general practices for improving the soil as a place for crop roots and beneficial organisms are the same for all fields. The real question is: which ones are best implemented, and how are they implemented in a specific situation.

Conclusion

To address these challenges, a holistic approach to soil management is essential. Enhancing soil health must be prioritized to sustain productivity and ensure the ecological compatibility of agricultural practices. Achieving optimal crop yield and quality requires a synergistic relationship between soil fertility and microbial activity. Accordingly, the conservation of native soil microbial populations within their natural niches is critical to maintaining soil health.

******

ISSN: 3049-2289

Modern Digital Tools in Precision Management of Subtropical Fruit Farms

[1*]Shreesty Pal, [2]Sumit Raj Khare, [3]Sakshi Blagan, [4]Vishal Johar

[1]Indian Council of Agricultural Research-Agricultural Technology Application Research Institute, Zone IX, Jabalpur, Madhya Pradesh, India

[2,3,4]Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara (Punjab) India

Introduction

Subtropical fruit crops, including mango, citrus, guava, litchi and pomegranate are vital to global horticultural production due to their high nutritional value, export potential and economic importance. However, their cultivation faces several challenges such as irregular rainfall, soil heterogeneity, pest infestations, and labour scarcity. Traditional management approaches, which rely heavily on uniform input application, often result in low resource efficiency and environmental degradation.

To overcome these challenges, precision horticulture has emerged as an advanced approach that integrates digital tools, data analytics and automation to manage fruit orchards efficiently. It focuses on site-specific management applying the right input, at the right time, and in the right quantity based on real-time field data. Modern digital tools such as Internet of Things (IoT) sensors, drones, Geographic Information Systems (GIS), Artificial Intelligence (AI), and satellite imaging are revolutionizing subtropical fruit farming by improving productivity, reducing input use and enhancing fruit quality.

2. Concept of Precision Horticulture

Precision horticulture is the application of precision agriculture principles to perennial fruit crops. Unlike annual crops, fruit orchards exhibit high spatial and temporal variability in soil, canopy structure and yield potential. Precision horticulture aims to measure and manage this variability by using digital technologies to optimize resource use and orchard performance.

In subtropical fruit systems, precision management involves monitoring tree vigour, soil moisture and microclimate conditions and adjusting irrigation, fertilization and pest control accordingly. This approach enhances resource efficiency, reduces input costs and ensures sustainability while maintaining consistent fruit yield and quality

3. Digital Tools for Precision Management

Modern digital technologies are at the core of precision horticulture. The following tools are increasingly being adopted in subtropical fruit production systems:

3.1 Internet of Things (IoT) and Smart Sensors

IoT-based smart sensors monitor real-time parameters such as soil moisture, temperature, humidity and nutrient status. These sensors transmit continuous data to centralized systems or mobile applications for informed decision-making. For example, soil moisture sensors in citrus orchards enable automated irrigation scheduling based on actual water needs, preventing over-irrigation and improving water use efficiency.

3.2 Remote Sensing and GIS

Remote sensing technologies, through drones or satellites, generate high-resolution images to assess canopy health, leaf chlorophyll content and disease incidence. GIS integrates these spatial data layers to map variability in orchards. This information helps identify problem zones, allowing site-specific management of irrigation, fertilizers and pest control. For instance, NDVI (Normalized Difference Vegetation Index) maps can detect nutrient deficiencies or stress areas within mango and guava orchards.

3.3 Unmanned Aerial Vehicles (UAVs) or Drones

Drones equipped with multispectral or thermal cameras provide real-time aerial imagery for monitoring crop vigour, flowering intensity and fruit load estimation. In dense canopies like mango or litchi, drone-based monitoring helps detect early pest attacks, canopy gaps, and sunburned fruit. It also assists in planning pruning and targeted pesticide applications, thereby reducing chemical use and labour costs.

3.4 Artificial Intelligence (AI) and Machine Learning (ML)

AI and ML algorithms process large datasets from sensors, weather stations, and imagery to predict irrigation requirements, disease outbreaks and yield potential. For instance, AI-based models can correlate environmental factors with fruit cracking in pomegranate or spongy tissue formation in mango, helping growers take preventive actions. Decision Support Systems (DSS) powered by AI are increasingly being used for irrigation and nutrient scheduling in precision orchards.

3.5 Mobile Applications and Decision Platforms

User-friendly mobile apps now integrate multiple data sources, enabling farmers to monitor orchards remotely and receive actionable alerts. These platforms connect IoT data with weather forecasts, providing recommendations for irrigation, fertigation and pest management. Such systems bridge the gap between advanced digital technologies and on-farm decision-making.

4. Application of Precision Tools in Subtropical Fruit Crops

Mango (*Mangifera indica* L.)

In mango, UAV imaging and thermal sensors are used to assess canopy temperature, vigour, and flowering patterns. Remote sensing aids in identifying alternate-bearing trees and managing them with differential nutrient application or pruning. Soil moisture sensors and automated irrigation systems help prevent water stress during flowering and fruit development stages.

Citrus (*Citrus spp*.)

Citrus orchards benefit greatly from IoT-based irrigation systems that regulate water supply according to soil moisture data. Drones and spectral imaging help monitor leaf greenness and detect nutrient deficiencies early. Precision fertigation based on real-time data improves fruit size and juice quality while minimizing fertilizer losses.

Guava (*Psidium guajava* L.)

In high-density guava orchards, canopy mapping and spectral analysis help maintain uniform growth and identify overcrowded zones. Digital pruning maps generated from drone imagery enhance light penetration, improving fruit color and sugar content. Smart irrigation and fertigation systems reduce fruit cracking and increase yield uniformity.

Pomegranate (*Punica granatum* L.)

Thermal imaging detects heat stress and early signs of fruit cracking, allowing timely irrigation adjustments. AI-based disease detection models identify bacterial blight and fungal infections before visible symptoms appear. Precision spraying and soil nutrient mapping improve productivity and minimize chemical use.

Litchi (*Litchi chinensis* Sonn.)

Litchi orchards in subtropical regions face water and heat stress during fruit development. IoT-based irrigation combined with thermal cameras ensures timely water delivery and uniform fruit growth. Remote sensing helps forecast yield and optimize harvest timing to maintain export quality.

5. Benefits of Digital Precision Management

The use of digital tools in subtropical fruit farms offers several advantages:

a. **Resource Efficiency:** Reduces wastage of water, fertilizers and chemicals through data-driven input application.

b. **Yield Optimization:** Maintains uniform crop health, enhances fruit size, and reduces physiological disorders.

c. **Cost Reduction:** Minimizes labour dependence and input costs through automation and predictive management.

d. **Environmental Sustainability:** Prevents overuse of agrochemicals and reduces greenhouse gas emissions.

e. **Improved Decision-Making:** Real-time monitoring and predictive analytics enhance accuracy in management decisions.

6. Challenges in Adoption

Despite its potential, precision horticulture faces several limitations:

a. **High Initial Cost:** Setting up IoT networks, drones, and AI platforms can be expensive for smallholders.

b. **Lack of Technical Knowledge:** Farmers need training to interpret digital data and use advanced tools effectively.

c. **Data Integration Issues:** Multiple devices and platforms often lack compatibility, complicating data analysis.

d. **Limited Connectivity:** Poor internet and power supply in rural areas restrict real-time data transmission.

e. **Policy and Infrastructure Gaps:** Standardization of data formats and subsidies for digital tools are still lacking in many subtropical regions.

7. Future Prospects

The future of subtropical fruit farming lies in integrating automation, robotics and artificial intelligence for complete digital orchard ecosystems. The development of low-cost sensors, solar-powered devices and cloud-based analytics platforms will make these technologies accessible to small and marginal farmers. Additionally, AI-driven predictive models can help forecast pest infestations and weather extremes, allowing proactive management. Collaborative initiatives between researchers, agri-tech start-ups and farmers will accelerate the digital transformation of subtropical horticulture toward greater sustainability and profitability.

8. Conclusion

The integration of modern digital tools into subtropical fruit farming marks a significant step toward sustainable, efficient and climate-resilient horticulture. Technologies such as IoT sensors, drones, GIS and AI enable real-time, site-specific management that enhances productivity, optimizes resource use and minimizes environmental impact. While challenges related to cost, data handling and technical skills remain, ongoing advancements and policy support are expected to make precision horticulture more inclusive and farmer-friendly. By embracing these innovations, subtropical fruit growers can achieve higher yields, better quality and improved profitability paving the way for a data-driven, sustainable future in horticultural production.

*****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Integration of Mulching and Drip Fertigation Practices for Climate-Resilient Fruit Orchards

[1*]Shreesty Pal, [2]Sumit Raj Khare, [3]Sakshi Blagan, [4]Vishal Johar
[1]Indian Council of Agricultural Research-Agricultural Technology Application Research Institute, Zone IX, Jabalpur, Madhya Pradesh, India
[2,3,4]Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara (Punjab) India

Introduction

Fruit crops are among the most valuable and resource-intensive components of horticulture, particularly in tropical and subtropical regions where climate variability poses a serious threat to productivity. Erratic rainfall, rising temperatures, and increasing frequency of droughts have intensified the need for climate-resilient orchard management practices. Among the various approaches developed for sustainable water and nutrient use, the integration of mulching and drip fertigation has proven to be one of the most effective technologies for mitigating the impacts of climate stress in fruit production.

Mulching and drip fertigation not only improve water and nutrient-use efficiency but also help maintain soil temperature, enhance microbial activity, suppress weeds, and reduce evapotranspiration losses. Together, these techniques create a favourable rhizosphere environment that supports steady growth, flowering, and fruiting even under fluctuating climatic conditions.

2. Concept of Climate-Resilient Orchard Management

Climate resilience in fruit production refers to the ability of orchard systems to sustain productivity despite adverse environmental conditions. It involves practices that conserve water, enhance soil health, and stabilize yields under heat and drought stress. The integration of precision irrigation through drip systems and soil microclimate regulation through mulching enables fruit crops to cope with climatic extremes more effectively than conventional methods such as flood irrigation or manual nutrient application.

In climate-smart horticulture, the goal is not only to increase yield but also to improve input efficiency, reduce greenhouse gas emissions, and ensure long-term sustainability of fruit production systems

3. Role of Mulching in Climate Adaptation

Mulching involves covering the soil surface around the plant base with organic or inorganic materials to conserve soil moisture and regulate temperature. It plays a crucial role in reducing evaporation losses, preventing soil erosion, and suppressing weed growth.

3.1 Types of Mulching Materials

- **Organic mulches**: Crop residues, dry leaves, straw, sugarcane trash, compost, and farmyard manure.
- **Inorganic mulches**: Plastic films (black, silver, or biodegradable), gravel, and geo-textiles.

3.2 Benefits of Mulching in Fruit Orchards

- **Moisture Conservation**: Mulching reduces direct soil evaporation by up to 70%, thereby maintaining consistent soil moisture levels even under limited irrigation.
- **Temperature Regulation**: It insulates roots from extreme temperatures cooling soil in summer and warming it in winter.

ISSN: 3049-2289

- **Weed Suppression**: By blocking sunlight, mulch restricts weed germination, reducing competition for water and nutrients.
- **Improved Soil Health**: Organic mulches decompose gradually, enriching the soil with carbon and enhancing microbial activity.

In mango, citrus, and guava orchards, mulching has been found to significantly improve fruit yield and quality by stabilizing the rhizosphere microclimate and reducing water stress during dry spells.

4. Drip Fertigation: Precision Irrigation and Nutrient Management

Drip fertigation combines drip irrigation and fertilizer application in a single system, allowing precise delivery of water and nutrients directly to the plant root zone. This method ensures uniform distribution and minimizes losses due to leaching or runoff.

4.1 Advantages of Drip Fertigation

- **High Water-Use Efficiency:** Water is applied directly to the root zone, reducing evaporation and deep percolation losses by up to 50%.
- **Nutrient-Use Efficiency:** Fertilizers are applied in soluble form through irrigation water, ensuring immediate availability to plants and minimizing wastage.
- **Reduced Labor and Input Cost:** Automation reduces dependence on manual labor and optimizes fertilizer dosage.
- **Enhanced Yield and Quality:** Consistent water and nutrient availability improves fruit size, color, and taste.
- **Environmental Protection:** Less nutrient leaching minimizes groundwater contamination.

Drip fertigation has been successfully adopted in fruit crops such as banana, citrus, pomegranate, papaya, and mango, where it has increased productivity by 20–40% compared to conventional irrigation methods.

5. Integration of Mulching and Drip Fertigation

The combination of mulching and drip fertigation forms a synergistic system that enhances orchard resilience to climatic stresses. While drip fertigation delivers precise amounts of water and nutrients, mulching reduces evaporation and maintains favorable soil temperature, ensuring optimal root activity.

5.1 Complementary Benefits

- **Reduced Evaporation and Nutrient Losses:** Mulching limits soil surface exposure, ensuring water and nutrients delivered via drip lines remain available to roots longer.
- **Enhanced Root Growth:** The uniform soil moisture from drip irrigation, combined with cooler soil temperatures under mulch, promotes healthy root development.
- **Improved Fertilizer Efficiency:** Studies show that combining mulching with fertigation can increase nitrogen-use efficiency by up to 25–30%.
- **Stabilized Yield Under Stress:** During heat waves or drought periods, integrated systems sustain higher yields compared to conventional orchards.

5.2 Field Evidence

In mango and pomegranate orchards, the integration of plastic mulching with drip fertigation has resulted in 20–35% water savings and yield increases of 15–25%. Similarly, in citrus, soil temperature fluctuations were reduced by 3–5°C, improving root health and nutrient uptake efficiency.

Such combined systems are particularly beneficial for semi-arid subtropical regions like parts of India, where uneven rainfall and high evapotranspiration rates severely affect fruit production.

6. Challenges and Limitations

- **High Initial Investment:** Installation costs for drip lines, filters, and plastic mulch sheets can be high for small and marginal farmers.
- **Maintenance and Clogging Issues:** Drip emitters may clog if water quality is poor or filtration systems are inadequate.
- **Disposal of Plastic Mulch:** Non-biodegradable mulches pose environmental challenges if not disposed of properly.
- **Knowledge Gap:** Many farmers lack technical knowledge on fertilizer scheduling, system calibration, and mulch selection.

Addressing these challenges requires capacity building, financial incentives, and policy support for small-scale growers.

7. Climate Resilience and Sustainability Aspects

The integrated approach supports climate resilience through:

- **Water Conservation:** Up to 50% reduction in water use through precise irrigation and evaporation control.
- **Reduced Carbon Footprint:** Lower fertilizer and energy use results in reduced greenhouse gas emissions.
- **Soil Health Maintenance:** Organic mulches improve organic matter content and microbial biomass.
- **Enhanced Productivity:** Higher fruit yield and quality ensure better income stability for farmers.

8. Future Perspectives

Future research should focus on:

- **Use of biodegradable and reflective mulches** to improve environmental sustainability.
- **Automation and sensor-based fertigation systems** integrated with soil moisture and nutrient sensors.
- **Integration with renewable energy sources**, such as solar-powered drip systems, for energy-efficient orchard management.
- **Decision Support Systems (DSS)** and AI-based tools to optimize water and nutrient delivery schedules.

The combination of smart irrigation, data-driven fertigation, and sustainable mulching materials will further enhance resilience to climate variability in fruit orchards.

9. Conclusion

Integrating mulching with drip fertigation represents a climate-smart, resource-efficient, and sustainable orchard management strategy for fruit crops. This approach optimizes soil moisture, nutrient uptake, and energy use while reducing environmental impacts. It ensures stable yields under climate stress conditions, making it an essential component of modern horticulture.

Promoting this technology through farmer training, demonstration projects, and government support can accelerate its adoption, particularly among small and marginal fruit growers. As climate change continues to challenge global horticultural productivity, the synergy between mulching and drip fertigation offers a scientifically proven pathway toward resilient and sustainable fruit production systems.

****

ISSN: 3049-2289

Mackerel Fishing Using Gill Nets with Double 9.9 HP Outboard Engines in Sindhudurg, Maharashtra

Shravan Kumar Sharma[1], Rujuta R. Donadkar[1], Sumi S. Panikar[1], Baiju M.V[2], Paras Nath Jha[2], Shalaka R. Salunkhe[1]

[1]Mumbai Research Centre, ICAR-Central Institute of Fisheries Technology

[2]ICAR-Central Institute of Fisheries Technology, Cochin

Mackerel fishing along the Southern coast of Maharashtra supports small-scale fisheries using 25-foot FRP vessels powered by double 9.9 HP outboard engines. The twin-engine configuration improves maneuverability and stability especially during monsoon operations while sustaining optimal fuel efficiency. Polyamide (PA) monofilament gill nets with 25 mm mesh ensure selectivity and effective deployment. Despite higher fuel use, dual engines enhance operational reliability and productivity, reducing risk in rough seas. Challenges include rising fuel costs, adverse weather, and juvenile catch during peak seasons. Strengthening mesh-size regulation, optimizing engine performance, and adopting adaptive fishing practices can enhance both ecological sustainability and fisher resilience mackerel fishery in Maharashtra

Introduction

Indian mackerel (*Rastrelliger kanagurta*), locally known as "*Bangda*" forms an important fishery along the southern coast of Maharashtra. The present study was carried out from 10 to 12 August 2024. Providing a crucial source of livelihood for small-scale fishers engaged in short-duration trips using fibre-reinforced plastic (FRP) boats (Roul et al., 2023). These 25 foot FRP vessels, powered by 9.9 hp outboard engines operated through two to three fishers per trip (Kazi et al., 2010). In Sindhudurg, twin 9.9 hp engines are often installed to enhance maneuverability, speed, and reliability, especially during adverse monsoon conditions when mechanical redundancy ensures crew safety and reduces downtime (Waghmare et al., 2018).

Fishing operations generally begin in the evening and conclude by early morning, coinciding with the nocturnal surface migration of mackerel from 20 to 40 m depth (Godø et al., 2004; David et al., 2021). The combination of efficient vessel configuration, selective gear design, and experiential knowledge underscores a balanced approach in achieving economic viability and ecological sustainability.

Description of Gill Net Components

Netting Material and Design

Gill nets used for mackerel fishing are fabricated from polyamide (PA) monofilament with a 25 mm mesh size, ensuring the selective capture of adult fish while allowing smaller species to escape. The material provides high tensile strength, durability, and minimal water resistance, enhancing efficiency and supporting sustainable fishing practices. Each extends almost 2 km and is fitted with thermocol floats of approximately 10 cm diameter and 1 cm thickness attached along the upper headrope and cylindrical cement sinkers weighing about 170-200 gms are fixed along the lower footrope to maintain a stable vertical orientation in the water column. The balanced distribution of these sinkers with floats keeps the net upright and fully extended in the desired fishing depth (Yu et al., 2023).

Engine Specifications

The 9.9 HP outboard engines used in small FRP fishing vessels along the Southern coast are engineered for lightweight performance, reliability, and energy efficiency. Weighing between 36 to 42 kg, these engines provide a favorable power to weight ratio that enhances vessel stability and reduces

ISSN: 3049-2289

operational costs (Shinde 2016). The configuration suits short duration coastal fishing operations that demand agility and quick response.

Operational Features

Functioning within a throttle range of 5000–6000 rpm the twin cylinder single overhead camshaft system ensures smooth propulsion with minimal vibration, improving handling during net setting and retrieval (Tran & Kim 2023). Compact structure and vertical crankshaft orientation of engine enhance hydrodynamic performance in shallow and turbulent waters (Sebastian 2022).

Fuel System and Efficiency

The carburetor based fuel induction system remains preferred in artisanal fisheries for its simplicity and maintenance ease, despite lower efficiency compared with modern fuel-injection engines (Koričan et al., 2023).

Engine Performance & Fuel Efficiency

Paired 9.9 HP outboard engines in single day fishing enhance maneuverability, reliability, and speed. Fuel costs form 50–80% of trip expenses, making economy vital (Pahlevi et al., 2024; Koričan et al., 2023). Each engine consumes about 7 l/h, allowing 4 hour operations with a 30 l/ petrol tank. Dual setups raise speed from 13 to 16 knots and ensure propulsion continuity during engine failure (Altosole et al., 2014). Proper engine propeller matching improves efficiency (Tran & Kim, 2023). Though fuel use increases, dual engines offer better safety, control, and productivity for artisanal fishers in variable sea conditions.

Fig 1. Double engine installed for gill net fishing

Fig 2. Fuel tank

Fig 3. Gill netter

Challenges and Strategies in Mackerel Fishing during Monsoon Season

Mackerel fishing in Sindhudurg is constrained during the monsoon by rough seas, strong winds, and unpredictable weather, increasing risks for small-scale fishers (Malakar et al., 2018). Climate extremes reduce fishing days and catches by limiting access and altering fish behavior (Rahim et al., 2024; Sreya et al., 2021). Intense effort also increases juvenile capture, weakening stock resilience (Ranaivomanana et al., 2023). While traditional management discourages juvenile fishing, balanced harvesting across size classes is now recommended to sustain yield and ecosystem health (Filar et al., 2023).

ISSN: 3049-2289

Through these modifications, fishers have achieved greater economic returns from mackerel fishing, as the improved gear design enables efficient capture of fast-moving shoaling fish.

Mesh Size and Selectivity

Mackerel gill nets in Sindhudurg generally use mesh sizes of 25 mm with a hanging coefficient of 0.40–0.55 which determines species selectivity and helps minimize juvenile capture. Appropriate mesh selection is vital to maintain catch quality and resource sustainability. However, small scale fisheries may still retain undersized fish when multiple mesh sizes are combined (Chaves, 2021).

Economic Considerations

The dual engine system enhances safety but increases operational costs through higher fuel consumption. As fuel represents a major expense, efficient fuel management and durable gear investments support long-term sustainability for Mackerel fishery.

Conclusion

Gill net operations powered by double 9.9 HP engines in Southern Maharashtra present a practical and sustainable model for small-scale mackerel fisheries. The configuration ensures operational safety, enhances fuel efficiency, and supports selective harvesting practices. While these modifications have improved catch per unit effort, they may also contribute to increased fuel consumption, pollution, and potential depletion of fish stocks. Therefore, adopting dual-mode LPG-retrofitted petrol engines is recommended, as this technology can mitigate long-term environmental impacts while reducing operational costs and supporting the economic sustainability of fishers.

Acknowledgement

The authors express their sincere gratitude to the Director, ICAR–Central Institute of Fisheries Technology, Cochin for their continuous support and guidance. The contributions of all Young Professionals (YPs) of the Fishing Technology Division, Mumbai, are gratefully acknowledged for their assistance during fieldwork and data collection. The authors also extend thanks to the Department of fisheries for financial support that enabled the successful execution.

*****

References

1. Altosole, M., Buglioni, G., & Figari, M. (2014). Alternative propulsion technologies for fishing vessels: a case study. *International Review of Mechanical Engineering*, *8*(2), 296-301.
2. Chaves, P. de T. da C. (2021). Juveniles and undersized fish in small-scale fisheries: gillnets are not less implied than trawling. *Marine and Fishery Sciences (MAFIS)*, *35*(2). https://doi.org/10.47193/mafis.3522022010501
3. David, V., Mouget, A., Perrot, Y., Goff, L. L., Thiriet, P., Diogoul, N., Feunteun, É., Acou, A., & Brehmer, P. (2021). Insights from a multibeam echosounder to survey pelagic fish shoals and their spatio-temporal distribution in ultra-shallow waters. *Estuarine Coastal and Shelf Science*, *264*, 107705. https://doi.org/10.1016/j.ecss.2021.107705
4. Filar, J. A., Holden, M., Mendiolar, M., & Streipert, S. (2023). Overcoming the impossibility of age-balanced harvest. *Mathematical Biosciences*, *367*, 109111. https://doi.org/10.1016/j.mbs.2023.109111
5. Godø, O. R., Hjellvik, V., Iversen, S. A., Slotte, A., Tenningen, E., & Torkelsen, T. (2004). Behaviour of mackerel schools during summer feeding migration in the Norwegian Sea, as observed from fishing vessel sonars. *ICES Journal of Marine Science*, *61*(7), 1093. https://doi.org/10.1016/j.icesjms.2004.06.009
6. Shinde, K. S., & Mohite, A. S. (2016). Design, technical aspects and construction of FRP gillnetters of Ratnagiri, Maharashtra.
7. Kazi, T. G., Mohite, A. S., & Jadhav, R. R. (2010). *Design characteristics of mackerel encircling gill nets of Ratnagiri, Maharashtra*.
8. Kim, S., Kim, H., & Kim, P. (2023). The application of tie-down gillnet to improve the capture of blackfin flounder (Glyptocephalus stelleri) in a sustainable way. *Frontiers in Marine Science*, *10*. https://doi.org/10.3389/fmars.2023.1034999
9. Koričan, M., Vladimir, N., & Fan, A. (2023). Investigation of the energy efficiency of fishing vessels: Case study of the fishing fleet in the Adriatic Sea. *Ocean engineering*, *286*, 115734.
10. Malakar, K., Mishra, T., & Patwardhan, A. (2018). Drivers of response to extreme weather warnings among marine fishermen. *Climatic Change*, *150*, 417. https://doi.org/10.1007/s10584-018-2284-1
11. Muhammad, A. H., Syarifuddin, S., Paroka, D., Rahman, S., Wisyono, & Pratama, A. A. (2018). MANEUVERING PERFORMANCE OF A 30 GT FISHING VESSEL WITH ASYMMERICAL PROPELLER CONFIGURATION. *Jurnal Ilmu Dan Teknologi Kelautan Tropis*, *9*(2), 491. https://doi.org/10.29244/jitkt.v9i2.19314
12. Nguyen, L. T., Nguyen, K. Q., & Nguyen, T. P. (2023). Experimental Mixed Gillnets Improve Catches of Narrow-Barred Spanish Mackerel (Scomberomorus commerson). *Fishes*, *8*(4), 210. https://doi.org/10.3390/fishes8040210
13. Pahlevi, M. F., Kurniawati, V. R., & Novita, Y. (2024). Suitability of engine power for small-sized fishing boats at the Palabuhanratu Fishing Port. In *BIO Web of Conferences* (Vol. 112, p. 03003). EDP Sciences.
14. Putra, G. L., Rizqillah, F., Yatim, A., & Liu, Y. (2023). Design optimization of small fishing vessel structures: A case study. *IOP Conference Series Materials Science and Engineering*, *1294*(1), 12023. https://doi.org/10.1088/1757-899x/1294/1/012023
15. Rahim, Abd., Hastuti, D. R. D., Ahmadin, A., Sari, D. A. P., & Afandi, M. (2024). Survival Decisions

and Adaptation Strategies of Small-scale Fishers in the Face of Extreme Weather Impacts in Coastal Areas. *Journal of Marine and Island Cultures*, *13*(3). https://doi.org/10.21463/jmic.2024.13.3.05

16. Ranaivomanana, H. S., Jaquemet, S., Ponton, D., Behivoke, F., Randriatsara, R. M., Mahafina, J., & Léopold, M. (2023). Intense pressure on small and juvenile coral reef fishes threatens fishery production in Madagascar. *Fisheries Management and Ecology*, *30*(5), 494. https://doi.org/10.1111/fme.12637

17. Roul, S. K., Raju, S. S., Ghosh, S., Jeeva, C. J., Narayanakumar, R., & Pattnaik, P. (2023). Economic evaluation of marine fishing operations in Purba Medinipur district of West Bengal, India. *Journal of the Marine Biological Association of India*, *65*(2), 46. https://doi.org/10.6024/jmbai.2023.65.2.2396-07

18. Saldanha, M. C. W., Carvalho, R. J. M. de, Arcuri, R., Amorim, A. G., Vidal, M. C., & Carvalho, P. V. R. de. (2019). Understanding and improving safety in artisanal fishing: A safety-II approach in raft fishing. *Safety Science*, *122*, 104522. https://doi.org/10.1016/j.ssci.2019.104522

19. Sebastian, M. (2022). Designs of typical small-scale fishing vessels and gears in Nagapattinam-Kanyakumari coast of Tamil Nadu, India. *Fishery Technology*, *59*, 154-164.

20. Sreya, P. S., Parayil, C., Aswathy, N., Bonny, B. P., Aiswarya, T. P., & Nameer, P. O. (2021). Economic vulnerability of small-scale coastal households to extreme weather events in Southern India. *Marine Policy*, *131*, 104608. https://doi.org/10.1016/j.marpol.2021.104608

21. Tran, T. G., & Kim, H. C. (2023). A study on the matching problem of engine, propeller, and ship hull under actual service conditions. *International Journal of Naval Architecture and Ocean Engineering*, *15*, 100538.

22. Waghmare, K. V., Sadawarte, R. K., Mohite, A., Mulye, V. B., & Koli, J. (2018). Comparative analysis of marine gillnets of Sindhudurg district, Maharashtra. *JOURNAL OF EXPERIMENTAL ZOOLOGY INDIA*, *21*(1), 171. https://www.cabdirect.org/cabdirect/abstract/20183127210

23. Yu, M., Tang, Y., Min, M., Herrmann, B., Cerbule, K., Liu, C., Dou, Y., & Zhang, L. (2023). Comparison of physical properties and fishing performance between biodegradable PLA and conventional PA trammel nets in grey mullet (Mugil cephalus) and red-lip mullet (Liza haematocheila) fishery. *Marine Pollution Bulletin*, *195*, 115545. https://doi.org/10.1016/j.marpolbul.2023.115545

******

ISSN: 3049-2289

Carbon Farming: Potential, Practices, Challenges and Policy Pathways

Sameer Shrivastava, Mohammad Vaheed, Sharda Saran
Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005, Uttar Pradesh

Agriculture contributes significantly to global greenhouse gas (GHG) emissions, accounting for nearly 1/3 of the global anthropogenic emissions when combined with land-use change and agricultural supply chains (FAO, 2023). India's Third Biennial Update Report to the UNFCCC (MoEFCC, 2021) estimates that the agriculture sector alone contributes 14% of India's total emissions, with livestock and nitrogen fertilizers being the dominant sources.

Against this background, carbon farming—the strategic adoption of agricultural practices aimed at enhancing soil organic carbon (SOC) sequestration and reducing emissions—has emerged as a multifunctional solution to climate change, soil degradation and rural economic challenges. A growing body of scientific evidence shows that sustainable land management holds substantial potential for storing carbon while improving agricultural productivity, ecosystem resilience and farmer incomes (Paustian *et al*., 2019; IPCC, 2022).

2. Concept and Definition of Carbon Farming

Carbon farming refers to a suite of agricultural practices designed to (a) increase carbon storage in soils and vegetation (b) reduce net GHG emissions. Paustian *et al.* (2019) define carbon farming as a biological negative emission strategy emphasizing that land-based carbon sequestration, if properly implemented and monitored, can contribute meaningfully to climate change mitigation.

Key practices include:

- Conservation agriculture (minimal/no tillage)
- Cover cropping and intercropping
- Agroforestry, silvopasture and tree-based systems
- Application of compost and organic amendments
- Improved grazing and pasture management
- Integrated nutrient management (INM)
- Biochar application in certain conditions

These practices support sequestration through enhanced root biomass, reduced soil disturbance, increased soil microbial activity and long-term stabilization of SOC.

3. Global Estimates of Soil Carbon Sequestration Potential

3.1 Croplands

One of the most frequently cited global assessments by Zomer *et al.* (2017) estimates that improved management practices have the potential to sequester 0.90–1.85 Pg C yr^{-1} across global croplands. This corresponds to 3.3–6.8 billion tonnes CO_2-equivalent annually that highlighting croplands as major potential carbon sinks.

3.2 Natural Climate Solutions

Griscom *et al.* (2017) show that Natural Climate Solutions (NCS), including soil carbon sequestration and agroforestry, could deliver up to 37% of the cost-effective CO_2 mitigation needed by 2030 to keep warming below 2 °C.

3.3 The "4 per 1000" Initiative

The "4 per 1000 Initiative" (Minasny *et al.,* 2017) validate that increasing global soil carbon stocks by 0.4% per year could offset the annual increase in atmospheric CO_2 from human activities. Although ambitious, it underscores the vast global carbon storage potential in soils.

3.4 Soil Carbon Dynamics and Constraints

Recent analysis by Don *et al.* (2024) indicates that:

- SOC sequestration rates vary widely by soil type, climate and management.
- Gains saturate over time (20–40 years).
- SOC is vulnerable to reversal (e.g., tillage, erosion, land-use change).

Together, these findings justify the need for robust measurement and long-term safeguards.

4. Benefits of Carbon Farming

4.1 Soil Health and Productivity

Increasing SOC improves:

- Soil structure
- Water-holding capacity
- Nutrient cycling
- Microbial diversity

Improved soil health reduces vulnerability to drought and increases yield stability (Lal, 2004).

4.2 Biodiversity Enhancement

Restoration of plant diversity accelerates SOC accumulation (Yang *et al.*, 2019) and improves ecosystem resilience.

4.3 Reduction in Input Use

Organic amendments and conservation agriculture lead to reduced reliance on chemical fertilizers and pesticides.

4.4 Economic Co-Benefits

Carbon credits offer an additional income stream. With global carbon market turnover exceeding €760 billion in 2021 (Refinitiv, 2022), land-based carbon credits are becoming increasingly valuable. Long-term corporate commitments—such as the $925 million Frontier carbon removal commitment (Stripe, Alphabet, Meta, Shopify)—are accelerating investment in land-based carbon pathways.

5. Challenges and Limitations

5.1 Water Constraints

Dryland areas face limitations in establishing cover crops or agroforestry due to water scarcity. This challenge is especially pronounced in India's arid and semi-arid regions.

5.2 Species Selection

Not all plant species sequester carbon equally. Fast-growing trees and deep-rooted grasses sequester more carbon but may not thrive in all agroecological zones.

5.3 Permanence and Reversibility

Soil carbon gains can be reversed by:

- Tillage
- Land degradation
- Extreme heat or drought
- Land-use change

Amundson and Biardeau (2018) emphasizes that SOC sequestration should be seen as a *temporary* but valuable mitigation tool.

5.4 Measurement, Reporting and Verification (MRV)

IPCC (2022) notes that MRV is the most significant bottleneck. Accurate assessment requires:

- Repeated soil sampling
- Remote sensing
- Digital soil modeling
- Standardized protocols

High MRV costs often prevent smallholders from accessing carbon markets.

ISSN: 3049-2289

6. Carbon Farming in India: Opportunities and Potential

6.1 Spatial Potential

India has an estimated **170 million hectares** of cultivable land (MoA&FW, 2022). Estimates suggest:

- Indian agricultural soils could sequester 3–8 billion tonnes CO_2-equivalent annually for 20–30 years (Lal, 2004; IPCC, 2022).
- Indo–Gangetic Plains and Deccan Plateau have the highest potential due to existing cropping intensity and soil depth.

6.2 Policy Alignment

India's policies supportive of carbon farming include:

- National Mission on Natural Farming (NMNF)
- Green Credit Programme (MoEFCC, 2023)
- Soil Health Card Scheme
- National Agroforestry Policy (2014)

Several states, such as Meghalaya, are drafting Carbon Farming Acts, reflecting a global trend toward legislating soil carbon enhancement.

6.3 Economic Potential

Agroecological transitions could generate USD 63 billion annually (Council on Energy, Environment and Water – CEEW, 2022), with per-acre payments of ₹5,000–6,000 possible under carbon credit schemes.

7. International Models and Lessons

7.1 Kenya Agricultural Carbon Project (World Bank)

Demonstrates effective community-based carbon farming, generating verified credits and improving food security.

7.2 Australia's Carbon Farming Initiative (CFI)

One of the world's most established compliance-grade agricultural carbon credit schemes.

7.3 Chicago Climate Exchange (U.S.)

Laid groundwork for soil carbon trading and aggregator-based models.

8. Policy and Research Recommendations

1. **Establish a National Carbon Farming Framework** aligned with India's NDC under the Paris Agreement.
2. **Develop Low-Cost MRV Tools** (remote sensing + modelling + periodic soil sampling).
3. **Set Up Carbon Banks** for farmer aggregation and transparent credit issuance.
4. **Strengthen Extension Services** to support practice adoption.
5. **Prioritize Region-Specific Practice Bundles**, considering soil type, rainfall and socio-economic profiles.
6. **Promote Public–Private Partnerships** for carbon finance, restoration projects, and MRV solutions.

Conclusion

Promoting carbon farming in India requires capacity-building, policy support, awareness campaigns, and financial assistance. Carbon farming presents a promising multipurpose tool for climate mitigation, adaptation and improved rural livelihoods. Scientific estimates indicate substantial but not unlimited potential for cropland soil sequestration and recent growth in carbon markets and private commitments is creating economic opportunities. However, realizing this potential requires robust MRV, equitable finance and regionally tailored policies that account for water constraints, permanence and smallholder realities.

ISSN: 3049-2289

References

Amundson, R., & Biardeau, L. (2018). Soil carbon sequestration is an elusive climate mitigation tool. Proceedings of the National Academy of Sciences, 115(46), 11652-11656.

Don, A., Seidel, F., Leifeld, J., Kätterer, T., Martin, M., Pellerin, S., ... & Chenu, C. (2024). Carbon sequestration in soils and climate change mitigation—Definitions and pitfalls. *Global Change Biology*, *30*(1), e16983..

FAO. (2023). *Greenhouse Gas Emissions from Agrifood Systems*.

Griscom, B. W., Adams, J. A., & Ellis, P. W. (2017). Natural climate solutions PNAS 114 (44), 11645-11650..

IPCC. (2022). *AR6 WGIII Chapter 7: Agriculture, Forestry and Other Land Use*.

Lal, R. (2004). Soil carbon sequestration to mitigate climate change. *Geoderma*, *123*(1-2), 1-22.

Minasny, B., Malone, B. P., McBratney, A. B., Angers, D. A., Arrouays, D., Chambers, A., ... & Winowiecki, L. (2017). Soil carbon 4 per mille. *Geoderma*, *292*, 59-86..

MoEFCC. (2021). *India's Third Biennial Update Report to the UNFCCC*.

Padarian, J., Minasny, B., McBratney, A., & Smith, P. (2022). Soil carbon sequestration potential in global croplands. *PeerJ*, *10*, e13740.

Paustian, K., Larson, E., Kent, J., Marx, E., & Swan, A. (2019). Soil C sequestration as a biological negative emission strategy. *Frontiers in Climate*, *1*, 482133.

Yang, Y., Tilman, D., Furey, G., & Lehman, C. (2019). Soil carbon sequestration accelerated by restoration of grassland biodiversity. *Nature communications*, *10*(1), 718.

Zomer, R. J., Bossio, D. A., Sommer, R., & Verchot, L. V. (2017). Global sequestration potential of increased organic carbon in cropland soils. *Scientific reports*, *7*(1), 15554.

******

ISSN: 3049-2289

Climate Resilient Practices-A Guide for Farmers of Dhubri District, Assam

Subashi Baruah[1], Dibyarishi Bhattacharjya[2], F.U.A Ahmed[3]

[1]Senior Research Fellow (NICRA), [2]Subject Matter Specialist (Agronomy) and [3]Sr. Scientist & Head

Krishi Vigyan Kendra, Dhubri, Assam Agricultural University, Jorhat

Climate change in Dhubri district, Assam has led to frequent floods, erratic rainfall, and reduced crop productivity. This guide provides farmers with simple, location-specific climate-resilient practices including stress-tolerant varieties, improved soil and water management, crop diversification, and integrated pest management. The aim is to enhance farm sustainability, reduce climate risks, and improve long-term livelihood security.

The NICRA (National Innovation in Climate Resilient Agriculture) Village of Dhubri district of Assam is highly vulnerable to annual floods, affecting agricultural productivity and farmers livelihood every year. The villages include Udmari which is situated under Bilasipara sub-division in the district 'Dhubri' of Assam, India on 26° 15. 425´ to 26° 16.570´ N latitude and 90° 14.034´ to 90° 18.040´ E longitude at an elevation of 128 ft from mean sea level and Sreegram (26^{o} 5.250 to 26.^{o}15'00 N latitude and 90^{o}333' to 90^{o}20'00 E longitude). The increasing frequency and intensity of climate induced stress such as floods have posed serious challenges to agriculture especially in the vulnerable regions of the NICRA villages. These climatic hazards severely affect agricultural productivity, damage crops and reduce the resilience of small and marginal farmers who depend heavily on traditional practices. Moreover, in the recent years the annual mean temperature has risen by 0.59 ^{o}C between 2010 and 2024. By 2050, the temperature is projected to rise by 1.7-2.2 ^{o}C. Extreme rainfall events are expected to increase by 38 %, intensifying flood related damages. About 32% of Assam's population lives below the poverty line, with high dependence on agriculture for livelihoods. Climate sensitive agriculture is repeatedly affected by floods drought and eratic weather reducing yields and pushing up prices. This creates a cycle of low income and high prices, worsening rural poverty. Assam has low adaptive capacity, making it more susceptible to climatic shocks. Recurrent droughts are going to rise as well by more than 75 % with respect to the baseline (1971-2000) in districts like Dhubri, Barpeta, Baksa, Kokrajhar and Bongaigaon which led to decreased productivity and economic losses further staining state development. In Dhubri district the annual rainfall during the normal year was recorded to be 2765.60 mm but in 2024 the annual rainfall was found to be deficit by 27 % and dry spell of more than 10 days was recorded in the recent year.

Recognizing the need for climate resilient solutions the Indian Council of Agricultural Research (ICAR) launched the National Innovations in Climate Resilient Agriculture (NICRA) project in February 2011. In Dhubri of Assam, CRIDA, ICAR sponsored project on "National Innovations on Climate Resilient Agriculture (NICRA) Project has been implementing in KVK, Dhubri, since 2011.The mega project has three major objectives of strategic research, technology demonstrations and capacity building. The main objective of the Project is to enhance the resilience of Indian agriculture covering crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies.

ISSN: 3049-2289

Key interventions under NICRA module:

1. Crop Production:

- **Demonstration on submergence tolerant rice variety "Ranjit Sub-1" in flash flood affected area** –Ranjit Sub1 is a submergence tolerant rice variety (10-15 days submergence with a duration of 145-150 days and yield was recorded to be 5.5-6.0 t/ha. This variety is suitable for all agroclimatic zones of Assam.

- **Demonstration on submergence tolerant rice variety "Bahadur Sub-1" in flash flood affected area-** Bahadur Sub1 is a submergence tolerant rice variety (10-15 days submergence with a duration of 140-145 days and yield was recorded to be 5.5-6.0 t/ha. This variety is suitable for all agroclimatic zones of Assam.

- **Demonstration on staggered planting rice variety "Gitesh" under aberrant weather condition** –Staggered planting rice variety "Gitesh' (30-60 days old seedlings) for Rice-Rice sequence and Rice monocropped areas (June –July Transplanting). This variety yield about 5.0-5.5 t/ha and duration of 150-160 days. Suitable for all agroclimatic zones of Assam.

- **Demonstration on direct seeding of rice variety "Disang" in post flood situation-** Direct seeded late Sali variety with a short duration of 90-95 days**,** average plant height of 110-115 cm, yield-5.0-5.5 t/ha and direct seeding up to last part of August in post flood situation which can be grown as a contingency crop.

- **Demonstration on combined stress tolerant rice var. CR Dhan 802 (Subhas: IET 25673)** – The climate smart variety was developed from the breeding materials of cross Swarna-Sub1*4 /IR81896-BB-195 which is suitable for both the drought and flood situation to address the challenges for making rice farming sustainable. This has been christened 'Subhas' after Cuttack-born freedom fighter and illustrious son of India Netaji Subhas Chandra Bose. It has short bold grain with a test weight of 19.0 g. It produces an average yield of 6.5 t/ha under normal condition and 4.3 t/ha under submergence while 2.3 t /ha under drought conditions.

- **Crop diversification by introducing high yielding variety of Toria 'TS-38' to compensate losses during *kharif* crop** – Toria variety for normal sowing "TS-38" with a duration of 90-95 days and yield about 10-12 q/ha to compensate the kharif losses caused to the kharif crop.

- **Demonstration on Double cropping by cultivation of high yielding variety of Toria 'TS-67' in Rice-Toria cropping sequence-** Toria variety "TS-67" for late sown conditions due to extended rainy period (up to mid October) in a double cropping system (Rice-Toria) with a duration of 90-95 days and yield (10-12 q/ha).

2. Natural Resource Management:

- **Popularization of low cost raised base vermicomposting Unit :**

  Raised bed Vermicomposting unit measuring about 7 X 3 X 3 and 3 feet raised above the ground to overcome the flood damage and helps in the enhancement of soil organic carbon build up.

- **Demonstration on summer paddy with AWD irrigation technology:**

  A Practical way to measure irrigation water precisely is by ('pani pipe') to monitor the water depth on the paddy field. The field water tube can be made of 30 cm long plastic pipe and should have a diameter of about 10-15 cm so that the water table is easily visible. When the water level has dropped to about 15 cm below the surface of the soil, irrigation should be applied to re-flood the field to a depth of 5cm over the surface. It saves 30-35% irrigation water & associated cost. Alternate wetting and drying lower the green house gas emission (methane) by draining and re-flooding the field that destroy the anerobic condition that helps in methane production.

ISSN: 3049-2289

- **Zero till Maize (fodder):** To ensure continuous fodder supply for livestock during flood periods by cultivating maize under zero tillage and preparing silage before the onset of floods. Zero tillage enables quick sowing after rabi harvest. So silage can be stored and used during flood when fresh fodder is unavailable which can enhance the resilience of livestock-based livelihoods.

- **Demonstration on recycling of crop residue through vermicomposting and application in chilli:** A demonstration on recycling of crop residue through vermicomposting and its application in chilli cultivation to promote sustainable nutrient management. Farmers were trained on the scientific method of preparing vermicompost using locally available crop residues such as paddy straw, chilli stalks, vegetable waste, along with cowdung and earthworms (*Eisenia fetida*). This process involved layering of organic minerals, maintaining adequate moisture and periodic turning to facilitate decomposition. After 45-60 days nutrient rich vermicompost was harvested and applied in chilli field as basal dose.

3. Livestocks & Fisheries

- **Popularisation of improved breed of poultry Kamrupa:** Kamrupa developed by Assam Agricultural University is a dual-purpose poultry breed known for its adaptability, egg production and meat quality under backyard farming. Kamrupa hens can lay between 100-148 eggs/year, the average egg weight is around 40-55 grams, male body weight of 1950 g and female about 1315 g at 4 months of age.This initiative aimed to create an alternative source of income, particularly for small and mariginal farmers whose livelihoods are vulnerable to frequent flood.

- **Introduction of improved breed of Duck (Khaki Campbell):** Rearing of Dual purpose duck breed "Khaki Campbell" for income diversification through duck farming to compensate crop loss. Khaki Campbell duck weight about 2 to 2.2 kg and drakes 2.2 to 2.4 kg. It lays about 300 eggs/duck/year which weighs about 65-70 gm.

- **Demonstration on Livestock Horticulture based Integrated Farming System:**Livestock-Horticulture based Integrated Farming System to showcase the benefits of resource recycling, income diversification and sustainability in small holder farms. Under this system components like duckery were integrated with the fishery, horticultural crops and fruits trees. Duck droppings serve as natural fertilizer, enriching pond water with nutrients that promote plankton growth which is essential for fish. The horticultural component was managed using compost and organic matter derived from livestock and pond residues thereby reducing dependency on chemical inputs.

- **Low cost improved *Mechang* type Goat house and poultry house for flood affected areas:** Low cost mechang type Goat House and poultry house with a dimension of 8m X 6m X 7m and and 3 m above the ground for rearing of Goat and poultry birds with scientific management practices to prevent the livestock from coming in contact with stagnant flood waters which often leads to disease incidence like diarrhea that are common in wet, unhygienic environments and also to prevent from flood damage.

4. Institutional Interventions:

- **Rice Seed Bank:** A community managed system that stores and preserve seeds of improved rice varieties (Ranjit Sub1, Bahadur Sub1, Gitesh, Disang, CR Dhan 802) to ensure timely availability of quality seeds, especially in flood prones or drought prone areas.

- **Seed Production of Submergence tolerant rice variety "Ranjit Sub1 in flood prone areas**: Ranjit Sub1 is a high yielding submergence tolerant rice variety developed by incorporating the Sub1 gene into the popular Ranjit variety. It can withstand complete submergence for upto 14 days. For seed production, a well-leveled and bunded field is selected with an isolation distance of 3-5 m from other rice varieties to maintain genetic purity. Certified seeds are used to raised a healthy nursery with seedlings transplanted at 20 X 15 cm spacing.

Conclusion:

Climate-resilient practices are essential for sustaining agricultural productivity and ensuring livelihood security in the flood-prone regions of Dhubri district, Assam. The district's unique agro-ecological challenges, including recurrent floods, soil degradation, and climate variability, demand scientific interventions and adaptive strategies. By adopting improved cultivation practices, submergence-tolerant rice varieties, timely agronomic management, resource conservation techniques, and diversified livelihood options, farmers can minimize climate risks and enhance long-term resilience. Empowering farmers through training, demonstrations, and continuous technical support will further strengthen their capacity to cope with climate-induced stress. Sustainable adoption of these climate-resilient practices will not only boost agricultural output but also contribute to greater food security, income stability, and overall socio-economic development in Dhubri district.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Blooming with Technology: The Role of Robotics in Modern Floriculture

Rajeshwari.E* and Padma.P
*Assistant professor, B.Tech Agricultural Engineering,
Asian college of engineering and technology, kondayampalayam,
Coimbatore, Tamilnadu

The production and maintenance of flowers and attractive plants, or floriculture, is an essential component of horticulture that has both economic and beauty values. Although this business has always trusted a lot of manual labour, it is surrounded by many issues today, such as labour prices, uneven quality and lack of skilled workers. Robotics provides innovative solutions by automating important processes such as planting, harvesting, sorting, packing and even the disease detection. This analysis examines the latest progression of robotics, applications and potential futures in floriculture, as well as those issues that must be resolved for comprehensive implementation.

1. Introduction

Floriculture is a prominent player in the agricultural economy of many countries that contribute to exports, increase local markets and produce jobs. However, floriculture-like planting, sorting, harvesting, and subsequent handling of harvesting are complicated and required efficient hands. As the availability of labour decreases and the demand for flowers at the top increases, the industry is rapidly embracing automation. Recent successes in robotics, Artificial Intelligence (AI), and machine visions are revolutionized, helping to reduce dependence on manual labour, helping to reduce dependence on manual labour.

2. Robotics application in floriculture

Robotics are creating waves in the world of floriculture, which we grow and manage flowers. One of the standout applications is in robot planting and transplantation. These advanced systems are designed to be delicately handled by transferring transplanting to their new homes, whether it is in beds or vessels, with all impressive accuracy. Thanks to vision technology, they can assess vacancy and orientation, ensuring that each plant is kept correct. Companies such as ISO Group and Visar Hortic Systems have transplanted robots for especially young decorative plants, which have actually increased planting efficiency. Another major area where robotics shine, is in the cutting of flowers. This task can be quite difficult due to the fragility and variability of flowers. However, robotic weapons and machine vision systems equipped with soft grippers are now able to harvest selected flowers based on their maturity and quality. For example, take a sweeper robot; It was originally designed for sweet chili, but the flower is cleverly adapted for use in the greenhouse. It easily appoints RGB-D cameras and AI algorithms to identify and take flowers. When it comes to post -harvesting operations, automated systems are taking steps to sort and grade flowers. These systems use computer vision and AI to assess various characteristics such as colour, size, stem length and any defects. Technologies such as high-resolution cameras, conversion neural networks (CNNs), and spectral analysis are commonly used to ensure frequent quality and reduce waste. Additionally, robot packaging systems are streamlined to bundling, trimming, and packing procedures, increasing operational speeds and cuts in labour costs, especially in high-virtue production settings. In addition, robotics are important for monitoring insect and disease. Robots equipped with multisactral and hyperpactral cameras can navigate through the greenhouse, spotting the initial signs of the disease or insect issues. This technique supports real -time data collection and analysis, allowing producers to work quickly and keep their plants healthy.

3. Technologies enable robotics in floriculture.

A handful of groundbreaking technologies are paving the way for robotics in the world of floriculture. For the beginning, the machine vision robots to identify plants, evaluate their health and grade the quality of flowers correctly. With the help of artificial intelligence, these robots can take smart decisions, selective harvesting and easily timing complex tasks. The sensor plays an important role in monitoring the environment from integration-integration-integration-temperature and humidity to light and soil moisture and allows quick adjustments in changing conditions. Soft robotics, characteristic of gentle and flexible actuators, ensures that delicate flowers are treated with care during various automated processes.

4. **Benefits of robotics in floriculture**

Bringing robotics into floriculture comes with a host of advantages. To begin, it dramatically increases productivity as robots can work around the clock without tired. It also increases efficiency in time-sensitive functions such as non-stop operation harvesting. At its top, robotic systems provide a level of stability and quality that reduces the variability seen with human labour frequently. Additionally, automation helps in cutting labour costs and dealing with increasing issues of labour shortage in agriculture. Finally, robotics support data-powered farming, where accurate agricultural technology leads to better resource management, high yields and healthy plants.

5. Challenges and limitations

Despite its advantages, the introduction of robotics to floriculture has been not problem-free. The main barrier is the considerable amount of money which is needed for the purchase and installation of robotic systems. Also, these improved systems are so technical that a user will need a certain degree of mechanical knowledge to operate and maintain them. Such difficulty in technical aspects will thus impede its quick acceptance by the producers. In addition, robots often need to correspond to specific crops and varieties, as the characteristics of the flowers can vary greatly. The fragile nature and the variety of flowers offer unique challenges to robotic systems, which need to be incredibly sensitive and adaptable to effectively handle.

6. Future prospects

Given the future, the role of robotics in floriculture seems bright. With ongoing technological progress and decreasing costs, we can expect robot systems will be more accessible to a wide range of producers. The Internet of Things (IOT), Cloud Computing, and Integration of Autonomous Mobile Robot will greatly promote the capabilities of these systems, making them smarter and more responsible. In the long run, we can see a fully automated greenhouse environment, where interconnected robotic systems manage most flower functions, possibly replaced by increasing the entire supply chain in delivery.

7. Conclusion

Robotics has the ability to enhance efficiency, ensure quality and bring revolution in floriculture by reducing dependence on manual labour. Although there are still challenges related to cost, technical complexity, and crop-specific adaptation, constant innovation and collaboration in subjects, which are cleaning the path for wide adoption. By integrating robotics into floriculture, we not only improve operational performance, but also move towards the more durable and scalable future for decorative plant production.

*****

ISSN: 3049-2289

Regenerative Organic Agriculture for Sustainable Development

Nivedita, Mahammadrafeek N Nadaf, Puneeth P
M.Sc. (Agri.) in Microbiology, Department of Microbiology UAS, Dharwad, karanataka

Regenerative agriculture represents a transformative approach to food production that aims not only to sustain but to actively restore and enhance the health of ecosystems. Rooted in ecological principles, it integrates practices such as cover cropping, crop diversification, reduced tillage, organic amendments, and managed grazing to rebuild soil fertility, increase biodiversity, and sequester atmospheric carbon. The adoption of regenerative practices helps to improve soil organic matter, water retention capacity, and crop productivity while reducing dependency on chemical inputs. It offers socio-economic benefits by improving rural livelihoods and long-term farm profitability. By integrating ecological principles with sustainable management, regenerative agriculture offers a holistic pathway toward resilient and environmentally sound ecosystem.

Introduction

In the past 50 years, farming around the world has become more dependent on resources that cannot be renewed, such as fossil fuels, mined minerals, and large amounts of water for irrigation. Fossil fuels are used to make nitrogen fertilizers and pesticides, while minerals like phosphorus (P) and potassium (K) are mined for use as fertilizers (Rempelos *et al.*, 2021). However, the prices of these inputs have been rising faster than the prices farmers receive for their crops, which has reduced farm profits and created risks for food production and food security.

At the same time, the heavy use of chemical fertilizers and pesticides has caused many problems, including damage to soil health, lower crop quality, loss of biodiversity, and higher greenhouse gas emissions. Because of these growing challenges, there is increasing interest in regenerative agriculture a farming approach that focuses on restoring soil health, improving ecosystems, and producing food in a more sustainable and natural way. It emphasizes working with nature rather than against it, using ecological principles to restore degraded lands and create resilient agricultural systems (Newton *et al.*, 2020)

Principles of Regenerative Agriculture

Regenerative agriculture is guided by several key principles that support ecosystem regeneration and rebuilding natural processes rather than relying solely on external chemical inputs.

1. **Minimize soil disturbance:** Intensive tillage disrupts soil aggregates, increases erosion, and destroys beneficial microorganisms. Minimizing soil disturbance helps preserve soil structure, enhances water infiltration, and maintains carbon stored in the soil (Lal, 2020).
2. **Maintain continuous soil cover:** The use of cover crops such as legumes, grasses, and brassicas helps protect soil surfaces, reduce compaction, and improve moisture retention (Kaye & Quemada, 2017).
3. **Encourage biodiversity:** Growing multiple species of plants, support beneficial insects, enhance pollination, and reduce pest outbreaks and strengthens ecological functions and enhances long-term productivity (Jose, 2009).
4. **Integrate livestock:** Managed grazing helps distribute manure, stimulate plant regrowth, and recycle nutrients efficiently (Teague et al., 2013).

ISSN: 3049-2289

5. **Build soil organic matter:** Composting and adding organic amendments improve fertility, water retention, and microbial activity (Lal, 2016).

Environmental and Economic Benefits

Regenerative farming systems offer multiple environmental and economic advantages:

- **Soil Health Improvement:** Increased organic matter and microbial life enhance nutrient cycling and soil fertility.
- **Carbon Sequestration:** Healthy soils capture and store atmospheric carbon, reducing greenhouse gas concentrations.
- **Water Conservation:** Improved soil structure enhances water infiltration and reduces runoff, making farms more resilient to droughts.
- **Biodiversity Restoration:** Mixed cropping, agroforestry, and reduced chemical use support pollinators, birds, and beneficial insects
- **Economic Viability:** Reduced input costs and improved productivity enhance farmers' long-term profitability.

4. Challenges in Adoption

Despite its promise, the transition to regenerative agriculture faces several barriers:

- **Initial Transition Costs and Economic Barrier:** Farmers may need new equipment, training, or time to see benefits.
- **Knowledge Gap and Technical support:** Many farmers lack access to technical guidance and local demonstrations.
- **Policy and Market Limitations:** Agricultural subsidies and market structures often favor industrial, high-input systems.
- **Measurement, monitoring and Verification:** Quantifying soil carbon and biodiversity benefits can be complex and time-consuming.
- **Social and Cultural Barriers:** Social norms, risk aversion, and a lack of trust in new techniques can slow transitions.

Overcoming the Barriers

To accelerate the transition toward regenerative agriculture, a combination of **policy reform, education, and financial support** is essential. Governments, Research institutions, NGOs, and international organizations can play a crucial role by:

- Redirecting subsidies toward soil health and ecosystem restoration practices.
- Supporting participatory research and farmer-to-farmer knowledge exchange.
- Developing carbon credit and ecosystem service payment schemes.
- Investing in affordable monitoring technologies and certification systems.
- Field-based demonstrations and capacity-building initiatives

Global and Indian Context

Globally, countries like the United States, Australia, and Brazil are promoting regenerative practices through national initiatives and certification programs. The **Regenerative Organic Certified (ROC)** standard developed by the Rodale Institute integrates soil health, animal welfare, and social fairness Schreefel et al.2020

In **India**, regenerative farming aligns closely with traditional practices such as **Zero Budget Natural Farming (ZBNF)** and **organic mixed cropping**. These systems emphasize local inputs, composting, and soil biology principles consistent with the regenerative approach. With its large population of smallholder farmers, India has immense potential to benefit from regenerative models that enhance both ecological and economic sustainability.

ISSN: 3049-2289

Conclusion

Regenerative agriculture represents a powerful shift in how humanity interacts with the natural environment. It restores soil fertility, enhances biodiversity, mitigates climate change, and creates more resilient farming systems. By reducing dependency on synthetic inputs and emphasizing ecological harmony, regenerative practices can ensure long-term food security and environmental health. For successful implementation, collaborative efforts among farmers, researchers, and policymakers are essential. Scaling up regenerative agriculture is not merely an environmental necessity it is a pathway toward a sustainable and equitable future for global food systems.

References

Rempelos L, Baranski M, Wang J, Adams T N, Adebusuyi K, Beckman J J Brockbank C J, Douglas B S, Feng T and Greenway J D, 2021, Integrated soil and crop management in organic agriculture: A logical framework to ensure food quality and human health. *Agronomy* 2021, 11:2494-2538.

Newton P, Civita N, Frankel-Goldwater L, Bartel K and Johns C, 2020, What is regenerative agriculture? A review of scholar and practitioner definitions based on processes and outcomes. *Frontiers in Sustainable Food Systems*, 4:1-11.

Lal R, 2020, Regenerative Agriculture for Food and Climate. *Journal of Soil and Water Conservation*, 75(6):123–124.

Jose S, 2009, Agroforestry for ecosystem services and environmental benefits. *Agroforestry Systems*, 76(1), 1–10.

Kaye J P and Quemada M, 2017, Using cover crops to mitigate and adapt to climate change. *Agronomy for Sustainable Development*, 37(1), 4-21.

Teague W R, Apfelbaum S, Lal R, Kreuter U P, Rowntree J, Davies C A and Conser R, 2013, The role of ruminants in reducing agriculture's carbon footprint in North America. *Journal of Soil and Water Conservation*, 68(6): 162-170.

Schreefel L, Schulte R P, De Boer I J M, Schrijver A P and Van Zanten H H E, 2020, Regenerative agriculture – the soil is the base. *Global Food Security*, 26: 1-8.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Carbon Farming: A pathway to Sustainable Agriculture

V. Jawahar, S. Suchiitasree, R. Jayasoorya and T. Pradeesh Kumar*
VIT School of Agricultural Innovations and Advanced Learning (VAIAL),
Vellore Institute of Technology, Vellore - 632 014, Tamil Nadu

Over the past 20 years, greenhouse gas emissions from transportation, industry, and agriculture have increased, intensifying climate change. Intensive agriculture methods greatly contribute to these emissions and soil deterioration. By storing atmospheric carbon in soil and vegetation and enhancing soil productivity and soil health, carbon farming provides a sustainable alternative. Soil carbon and biodiversity can be improved by sustainable agriculture practices. However, adoption is hampered by several issues, including high costs, lack of awareness, and inadequate policymaking. Carbon farming can become a crucial instrument for climate-smart agriculture by strengthening farmers' education and enacting supportive legislation.

Introduction

Over the last two decades, climate change has increased rapidly owing to human activities, increasing global warming to temperatures of approximately 1.2- 1.4°C. This is due to the rise of greenhouse gas emissions from several sectors, such as transportation, industrial processes, agricultural practices, and electricity. Among several factors, agriculture is the major contributor to greenhouse gas emissions, which increases the probability of a changing climate. Agriculture practices not only increase greenhouse gases and reduce the soil organic carbon, organic matter, microbial biomass, and organic matter stock, but also favour the higher application of mineral fertilisers, which leads to a decline in soil fertility status. To overcome this issue, carbon farming is a sustainable approach that allows farmers to focus on not only sustainable productivity and improve the climate change mitigation strategies.

Carbon farming

Carbon farming is a key agricultural practice for storing atmospheric carbon dioxide in soil and vegetation. Carbon dioxide is released from agricultural machinery, crops, human activities, etc. It is efficiently stored in crops such as wheat and tree species such as teak and bamboo, and more carbon dioxide is used for their metabolism and growth. As crop grow, plants absorb carbon dioxide from the atmosphere, which is transported to the shoots and roots. After growing, reaching maturity, and harvesting, the root portion remains in the soil and decomposes as organic matter, and soil organic carbon and soil remains are stored as a carbon sink instead of being released.

Major carbon farming practices in sustainable agriculture

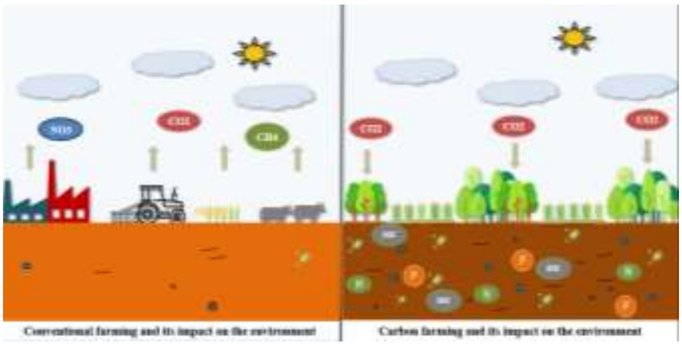
Conservation tillage: Avoiding or minimising tillage operations to protect and preserve the soil structure and enhance the soil organic cover, which protects the soil organic carbon present in the topmost layer of the soil. This is primarily achieved through zero or minimal tillage practices.

Cover cropping: Cover cropping is a crop grown in agricultural land that is used to cover the soil rather than being harvested. It protects the soil from erosion, recycles the nutrients, enhances soil structure, minimises the release of CO2 into the atmosphere, and provides organic matter to the soil.

Agroforestry: Agroforestry is the term for growing forest trees along with crops agroforestry system, such as alley cropping, agrisilvipastoral, and Agri silviculture. It captures and stores the atmospheric carbon into the larger tree canopy on tree biomass, and the wider tree canopy provides wider shade to reduce the escapes of CO_2 and minimise the release of greenhouse gases.

Organic amendments: Organic amendments are rich in both macro and micro nutrients such as nitrogen, phosphorus, potassium, iron, zinc, and manganese, etc. It is not only rich in macro and micronutrients, but it also contains carbon content, especially in organic carbon form during decomposition. It provides organic matter, improves oil organic carbon, and humus and improves soil health. Examples of organic amendments, such as farm yard manure compost, manure, biochar, oilcakes, etc.

Pasture management: Pasture management entails scheduling the movement of cattle between several paddocks and giving the pasture enough time for rest and recuperation. This encourages strong plant development and deeper root systems, which store more carbon below the ground level, while preventing overgrazing, which can deteriorate soil and result in greenhouse gas emissions.



Benefits of carbon farming

- Through minimal and zero tillage, the soil organic ground cover was increased by nearly 50% and the water infiltration rate has been increased compared to conventional tillage operations.
- Reduction in cost, time, power, energy consumption and avoiding the release of CO_2.
- During the fallow period, cover cropping helps and sustain the soil health, reduces soil compaction and acts as a mulch, which increases water retention and improves the soil organic matter and reduces weed infestations.
- It provides a symbiotic association between tree and crop, which favours and supports insects, birds, and soil biota, leading to ecological stability and reducing the emission of greenhouse gases
- Organic amendments improve the soil structure, nutrient retention, water holding capacity, and provide resilience to drought situations. It reduces the dependency on synthetic fertilisers.
- In socio-economic aspects, improved carbon credits to soil, improved infrastructure, indigenous land management, and increased farm income.

Challenges in adopting carbon farming

Institution and policy challenges: There is a complex design in implementation of carbon farming initiatives schemes for farmers. Lack of standardized and approved methods for carbon measurement, reporting, and adoption rate.

Economic barrier: High initial investment, financial risk, difficulty in selling products from agroforestry, and uncertainty in market prices.

Technical barrier: limited availability of tools and instruments, lack of practical skills for implementing carbon farming, and uncertainty of long-term soil health.

Social barrier: Personal interest towards conventional to traditional and conservation practises, fear of reduced crop yields under carbon farming and lack of extension to gather information, training, and schemes.

Circular carbon economy

The carbon circular economy focuses on closed-loop, regenerative systems that use the principles of reduce, reuse, and recycle to reduce greenhouse gas emissions. It creates a circular system in which trash turns into a resource, replacing the linear concept of "resources- products- waste". Together, these technologies-biomass carbon removal and storage (BiCRS), bioenergy with carbon capture and storage (BECCS), biochar, afforestation, increased weathering, and soil carbon sequestration can remove 24 Gt of CO_2/year, meeting the IPCC targets.

Adopting Carbon-based economy principles could increase GDP, generate employment, and lower greenhouse gas emissions globally. To achieve net-zero emission targets, both developed and developing countries must adopt carbon-negative technologies with active stakeholder participation and support policies.

Conclusion

Carbon farming is a sustainable land use strategy that enhances soil organic carbon and soil organic matter, reduces greenhouse gas emissions, and improves environmental health. Practices such as conservation tillage, agroforestry, and cover cropping boost soil productivity while maintaining soil and plant ecosystem. However, there is limited farmer awareness and involvement in adopting carbon farming, and there should be strong advisory services and policy support towards its implementation for sustainable agriculture and climate-smart agriculture.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Eco-Genetic Breeding: Integrating ecological networks into crop improvement (Pollinators, Soil biota and Natural enemies of pests)

Yashaswini R[1*], Sridhara M R[2], Raghavendra V C[1], Prem Sagar S P[1], Nazreenbanu Tahasildar[3] and Rakshitha H[4]
[1]Ph.D. Scholar, Department of Genetics and Plant Breeding,
[2]Ph.D, Department of Agronomy,
[3]Ph.D. Scholar, Department of Agricultural Extension Education,
[4]Ph.D. Scholar, Department of Entomology,
University of Agricultural Sciences, Raichur, Karnataka

Traditional crop breeding has primarily focused on maximizing yield, often at the expense of other important traits such as pest resistance, nutrient uptake efficiency and interactions with beneficial organisms. This has led to a reliance on synthetic fertilizers, pesticides and other external inputs, which can have negative impacts on the environment and human health. Eco-genetic breeding offers a more holistic approach by considering the ecological context in which crops are grown. It recognizes that crops are not isolated entities but rather integral components of complex ecological networks.

Introduction

Eco-genetic breeding means developing crop varieties that work together with nature instead of fighting against it. Rather than chasing single “magic” genes, it focuses on whole agro-ecosystems where plants, soil life, pollinators and natural enemies of pests form a resilient network. In this approach, a healthy environment is seen as the real foundation of crop performance, because soil organisms, insects, birds and plant diversity all help regulate pests, recycle nutrients and stabilize yields. Crops are bred and selected under low-input, organic or agro-ecological conditions so that only plants that can naturally cooperate with soil microbes, tolerate stress and still yield well in real fields are advanced. For example, projects like LIVESEED explicitly target improved symbiosis between roots, microbes and soil, treating the plant as one partner in a living community rather than an isolated object (IFOAM, 2023).

Eco-genetic breeding also moves away from the idea that resistance to one pest or one stress is enough to make agriculture sustainable. Single-gene resistances often break down quickly because pests and pathogens evolve, leading to “treadmill” cycles of new genes, new chemicals and new outbreaks. Instead, breeders aim for horizontal, multi-factor tolerance where plants can live with a range of pests and diseases at manageable levels, supported by beneficial insects, diverse rotations and mixed cropping. Cases like *Bt* maize, where engineered resistance led to non-target impacts and pest adaptation underline the limits of narrow genetic fixes.

Diversity is central to eco-genetic breeding, both within and between crops. Using old, local and underutilized varieties alongside modern material broadens the genetic base and creates populations better able to cope with new pests, shifting climates and changing soils. Apple breeding initiatives in Germany, for instance cross many old scab-tolerant varieties with modern types and select seedlings under zero-spray organic conditions, looking for overall vitality rather than just a single resistance gene. Such work not only reduces dependence on pesticides but also supports local food cultures and shorter, more resilient supply chains.

Understanding the genetic and molecular bases of plant-plant interactions is essential for advancing sustainable agro-ecosystems. Plants engage in diverse interactions ranging from competitive to facilitative, influencing community structure, productivity and stability in cropping systems. Recent advances in transcriptomics, metabolomics and high-throughput phenotyping have uncovered key genes, biochemical pathways and phenotypic traits involved in plant neighbor recognition and response. Such traits include root architecture modifications, allelochemical production and microbial community shifts in the rhizosphere that collectively mediate resource use efficiency and stress resilience. Moreover, genotype-by-genotype (GxG) interactions among neighboring plants reveal a complex genetic architecture underlying performance in mixed stands, going beyond single-plant genetics. Integrating this ecological genetics knowledge into breeding programs supports the development of crop varieties optimized for cooperative interactions, leading to more productive and stable mixed-species or varietal cropping systems. This approach aligns with eco-genetic breeding principles by fostering plant communities that leverage natural genetic diversity and biological networks for improved agro-ecosystem functioning under varying environments.

Because ecological networks are farm- and region-specific, eco-genetic breeding is usually participatory and decentralized. Farmers, breeders, researchers and sometimes processors or retailers all contribute to defining traits, testing new lines and sharing knowledge, so that varieties are better matched to local soils, climates, markets and management. Networks and platforms for organic plant breeding exchange practical experiences on how varieties interact with pollinators, natural enemies and soil life, speeding up learning across regions.

This breeding philosophy also treats seeds and genetic diversity as a common good that must circulate widely to keep ecosystems and innovation alive. Heavy use of patents and narrow commercial lines tends to shrink the genetic base, concentrate control and make it harder to adapt crops to local ecologies. In contrast, open and collaborative models keep more options available for shaping crops that fit into living landscapes rich in pollinators, soil biota and natural enemies of pests. In simple terms, eco-genetic breeding is about growing plants that are good team players in nature's web, so that resilience comes from the whole system, not from a single engineered trait.

Pollinators

Pollinators, such as bees, butterflies and other insects, play a crucial role in the reproduction of many crops. However, pollinator populations are declining in many parts of the world due to habitat loss, pesticide use and other factors. Eco-genetic breeding can help to support pollinator populations by selecting for crop varieties that are more attractive to pollinators. This can be achieved by:

- **Enhancing floral traits:** Breeding for larger, more colorful flowers with increased nectar and pollen production.
- **Extending flowering periods:** Selecting for varieties that flower for a longer period of time, providing a more consistent food source for pollinators.
- **Improving nectar and pollen quality:** Breeding for nectar and pollen with higher nutritional value for pollinators.
- **Reducing pesticide susceptibility:** Selecting for varieties that are less susceptible to pesticides, reducing the risk of harm to pollinators.

Soil Biota

The soil is a complex ecosystem teeming with microorganisms, including bacteria, fungi and other organisms. These organisms play a vital role in nutrient cycling, disease suppression and soil structure. Eco-genetic breeding can enhance the interactions between crops and soil biota by:

- **Improving root exudation:** Breeding for varieties that release more beneficial compounds from their roots, attracting and supporting beneficial soil microbes.
- **Enhancing mycorrhizal associations:** Selecting for varieties that form stronger associations with mycorrhizal fungi, which can improve nutrient uptake and drought tolerance.

- **Promoting nitrogen fixation:** Breeding for varieties that are more efficient at fixing nitrogen from the atmosphere, reducing the need for synthetic nitrogen fertilizers.
- **Increasing disease resistance:** Selecting for varieties that are more resistant to soil borne diseases, reducing the need for chemical controls.

Natural enemies of pests

Natural enemies of pests, such as predatory insects, parasitoids and pathogens can help to control pest populations and reduce the need for pesticides. Eco-genetic breeding can enhance the effectiveness of natural enemies by:

- **Providing habitat and food sources:** Breeding for varieties that provide habitat and food sources for natural enemies, such as nectar, pollen and shelter.
- **Reducing pesticide susceptibility:** Selecting for varieties that are less susceptible to pesticides, reducing the risk of harm to natural enemies.
- **Enhancing plant defense mechanisms:** Breeding for varieties that have stronger natural defenses against pests, such as increased production of defensive compounds.
- **Improving plant architecture:** Selecting for plant architectures that facilitate access for natural enemies to pests.

Breeding strategies for eco-genetic improvement

Several breeding strategies can be employed to achieve eco-genetic improvement:

1. **Marker-assisted selection (MAS):** Using DNA markers to identify genes associated with desirable ecological traits such as pollinator attractiveness or mycorrhizal associations.
2. **Genomic selection (GS):** Using genome-wide data to predict the breeding value of individuals for ecological traits.
3. **Participatory breeding:** Involving farmers and other stakeholders in the breeding process to ensure that the resulting varieties are well-adapted to local conditions and meet their needs.
4. **Multi-environment trials:** Evaluating crop performance across a range of environments to identify varieties that are resilient and adaptable.
5. **Intercropping and mixed cropping systems:** Breeding for varieties that perform well in intercropping and mixed cropping systems, which can enhance biodiversity and ecosystem services.

Benefits of eco-genetic breeding

Plant-insect interactions in agro-ecosystems are driven by complex chemical, molecular and ecological mechanisms that influence crop health, pest management and ecosystem sustainability. Plants emit volatile organic compounds (VOCs) and herbivore-induced plant volatiles (HIPVs) that serve as signals to attract natural enemies of pests, thereby supporting biological control within cropping systems. Additionally, plants use molecular pattern recognition systems to detect herbivore attacks and activate immune responses, influencing pest resistance and plant defense dynamics. Insect herbivory can significantly affect crop growth, yield and quality by reducing photosynthesis, causing physical damage and altering nutrient allocation. Furthermore, interactions between plants and insects impact soil health and nutrient cycling by modifying the soil microbiome and organic matter dynamics. Pollination by diverse insect species is also critical for sustaining high crop yields and quality, with declines in pollinator populations posing risks to food security. Integrating the understanding of these multitrophic interactions into eco-genetic breeding programs can enhance crop resilience, promote beneficial insect populations and foster sustainable agro-ecosystems that reduce chemical inputs and support ecosystem services.

1. **Reduced reliance on external inputs:** By enhancing interactions with pollinators, soil biota and natural enemies, eco-genetic breeding

can reduce the need for synthetic fertilizers, pesticides and other external inputs.

2. **Increased biodiversity:** Eco-genetic breeding can promote biodiversity by supporting pollinator populations, enhancing soil microbial communities and providing habitat for natural enemies.
3. **Improved ecosystem services:** Eco-genetic breeding can enhance ecosystem services such as pollination, nutrient cycling, pest control and soil health.
4. **Enhanced resilience:** Eco-genetic breeding can improve the resilience of crops to environmental stresses such as drought, pests and diseases.
5. **Sustainable agriculture:** Eco-genetic breeding can contribute to more sustainable agricultural systems that are less reliant on external inputs and more integrated into their ecosystems.

Challenges and Opportunities

Evolutionary principles play a crucial role in managing agricultural ecosystems, especially in relation to pests, diseases and weeds. Human activities such as crop breeding, genetic modification and land-use changes significantly affect the biological interactions within these systems. These changes can drive the evolution of pests and pathogens, sometimes leading to resistance against pesticides and herbicides which challenges sustainable crop production. Applying evolutionary knowledge and predictive models can help anticipate these adaptations and improve management strategies. Additionally, incorporating biodiversity and evolutionary approaches into agriculture supports the development of smarter, more resilient and sustainable farming systems that can adapt to changing environmental conditions and resource limitations. Integrating these concepts strengthens the foundation of eco-genetic breeding by emphasizing crops' long-term coexistence with their ecological partners and evolving challenges. While eco-genetic breeding holds great promise, there are also a number of challenges that need to be addressed:

- **Complexity of ecological interactions:** Ecological interactions are complex and can be difficult to predict and manage.
- **Lack of knowledge:** There is still a lack of knowledge about the genetic basis of many ecological traits.
- **Breeding for multiple traits:** Breeding for multiple traits, including both yield and ecological traits, can be challenging.
- **Regulatory hurdles:** Regulatory hurdles can make it difficult to commercialize new crop varieties, particularly those that have been developed using participatory breeding approaches.

Despite these challenges, there are also many opportunities for eco-genetic breeding:

- **Advances in genomics and phenomics:** Advances in genomics and phenomics are providing new tools for understanding the genetic basis of ecological traits.
- **Growing demand for sustainable agriculture:** There is a growing demand for sustainable agricultural practices that reduce reliance on external inputs and promote biodiversity.
- **Increased collaboration:** Increased collaboration between breeders, ecologists and farmers can help to overcome the challenges of eco-genetic breeding.

Conclusion

Eco-genetic breeding represents a promising approach to crop improvement that can enhance the sustainability, resilience and productivity of agricultural systems. By considering the ecological context in which crops are grown and breeding for improved interactions with pollinators, soil biota and natural enemies, eco-genetic breeding can reduce reliance on external inputs, promote biodiversity and enhance the overall health of agricultural landscapes.

ISSN: 3049-2289

While there are challenges to overcome, the potential benefits of eco-genetic breeding are significant and further research and development in this area are warranted.

References

1. Becker, C., Berthome, R., Delavault, P., Flutre, T., Freville, H., Gibot-Leclerc, S., & Roux, F. (2024). The ecologically relevant genetics of plant-plant interactions. *Trends in Plant Science*. https://doi.org/10.1016/j.tplants.2023.11.012
2. IFOAM Organics Europe. (2023). Sustainability in organic breeding: Improving the entire system or adjusting some genes? IFOAM Organics Europe Policy Briefing, November 2023. Rue Marie-Therese 11, 1000 Brussels, Belgium.

****

ISSN: 3049-2289

Environmental DNA/RNA (eNA) as an Advanced Tool for Pathogen Detection and Disease Surveillance in Aquatic Systems

Santhiya. V[1*], Jerlin mol. J. G[2], Saravanan. S[3] and Kaviarasu. D[4]
Department of Aquatic Animal Health Management
TNJFU- Dr. MGR Fisheries College and Research Institute, Ponneri

Intensification of aquaculture to meet global seafood demand has increased disease outbreaks, highlighting the need for rapid and sensitive diagnostics for early detection and better management. Traditional methods are invasive, laborious, and costly. Environmental DNA/RNA (eDNA/eRNA) acts a non-invasive alternative by detecting genetic material shed into water or sediment, enabling pathogen identification without host sampling. These approaches support early disease detection, risk mapping, and monitoring of elusive or endangered species. However, challenges such as nucleic acid degradation, environmental impacts on sensitivity, contamination risks, and the absence of standardized protocols are present. Continued refinement of eDNA/eRNA methods will strengthen aquatic health monitoring, biosecurity, and sustainable aquaculture.

Introduction

Aquaculture is one of the most rapidly growing food-producing sectors worldwide due to the increasing global demand for seafood. To meet this increasing global demand, farming practices have become increasingly intensive, which has resulted in frequent outbreaks of diseases. These outbreaks have led to substantial economic losses in many aquaculture producing countries and pose a significant threat to both cultured and wild aquatic fish populations. Traditional disease surveillance includes of capturing, dissecting, and examining host organisms and these are time consuming, invasive, expensive, and technologically complex. During the past decade, advancements in molecular biology have led to the development of non-invasive alternative techniques such as environmental DNA/RNA (eNA) techniques for efficient disease monitoring (MacAulay et al., 2022 & Bass et al., 2023).

Concept and Significance of Environmental DNA/RNA

Environmental DNA (eDNA) and environmental RNA (eRNA) refer to genetic material released into the environment as a result of normal biological processes such as excretion, mucus shedding, sloughed skin cells, reproductive activities, or decomposition of organisms. These nucleic acids remain suspended in water, sediment, and soil. eNA analysis enables researchers to identify organisms and detect pathogens like bacteria, viruses, fungi, and protozoa without physically encountering or capturing them. It has become an invaluable tool for biodiversity studies, conservation monitoring, and disease surveillance. With its origins in microbial ecology in the late 20th century, the field of eDNA has rapidly developed over the past 20 years. The term “environmental DNA” first appeared in 1987 and gained prominence in the early 2000s as more and more ecological and aquatic studies began to use it (Chouhan et al., 2023).

Methodological Advances in eDNA/eRNA Analysis

Modern eDNA/eRNA workflows involve the collection of environmental samples followed by nucleic acid extraction and molecular analysis. In order to concentrate DNA or RNA fragments, water samples are usually filtered using sterile membranes. After that, these are extracted using purification techniques based on chemicals or kits that eliminate inhibitors frequently present in aquatic environments. Detection of pathogen can be done using molecular techniques such as polymerase chain reaction (PCR), quantitative PCR (qPCR), digital droplet PCR (ddPCR), and next-generation sequencing (NGS). These technologies help in identification of species, quantification of pathogen loads, and even metabarcoding of entire microbial communities. The high sensitivity of these methods results in detection of pathogens even at very low concentrations which the traditional techniques fail to detect (Huver el al., 2015 & MacAulay et al., 2022).

Applications in Pathogen Detection and Surveillance

Environmental DNA/RNA has transformed pathogen detection and surveillance in aquatic ecosystems. Early detection of pathogens can be done using the eNA. By screening water samples, researchers can detect the presence of parasites, bacteria, viruses, and fungi long before infected hosts begin showing clinical symptoms. For example, the widespread distribution of pathogens such as *Aphanomyces astaci*, *Tetracapsuloides bryosalmonae*, and *Saprolegnia parasitica* has been confirmed through eDNA-based monitoring. This approach has significantly enhanced the understanding of pathogen ecology and helped in the development of early warning systems for aquaculture health management.

Environmental DNA has proven particularly valuable for wildlife disease surveillance of species that are rare and difficult to sample. Pathogens such as *Ribeiroia ondatrae* in amphibians, *Schistosoma mansoni* in snails, and various human waterborne pathogens such as *E. coli*, *Giardia, Enterococcus*, *Vibrio,* and *Cryptosporidium* species have been successfully detected in environmental samples using eDNA based analysis. In the trade of live animals, these techniques can be used for screening of transport water, thereby reducing the risk of disease spread and supporting biosecurity measures. These applications are especially important when animals are moved between ecosystems or released into natural waters for conservation or fisheries enhancement programs (Sieber., 2020 & Sieber et al., 2024).

Advantages of eDNA/eRNA-Based Approaches

The main advantage of eDNA/eRNA techniques is their non-invasive nature. There is no need to capture or sacrifice host organisms, thereby reducing stress on vulnerable or endangered species. These methods are highly sensitive, capable of detecting even trace amounts of DNA or RNA, and are effective even when pathogens are present at low levels. They help in simultaneous detection of multiple pathogens from the same sample and significantly reduce sampling time, cost, and effort. These techniques are effective in accessing remote locations, where traditional sampling is logistically challenging. Their adaptability across diverse taxa including fish, amphibians, molluscs, crustaceans, and microorganisms further highlights their utility in ecological and aquaculture systems.

Limitations and Challenges

Even though eDNA and eRNA are powerful analysis tools, they still come with several practical challenges. Environmental conditions such as temperature, pH, salinity, and UV exposure influence DNA degradation rates, affecting detection sensitivity. Moreover, the relationship between DNA concentration in water and actual level infection within host populations is not understood clearly. This poses challenges for quantifying infection levels. There is also a chance of inconsistent results. False positives may arise due to contamination, while false negatives may occur when pathogen load falls below detection thresholds. The results may be affected by differences in sampling volume, filtration techniques, primer design, and extraction efficiency. Therefore, standardized protocols and inter-laboratory validations are essential for enhancing reproducibility and reliability when eNA are used across studies.

Case Studies Demonstrating the Utility of eDNA

Several studies have demonstrated the effectiveness of eDNA in pathogen detection and disease surveillance. Monitoring of *Aphanomyces astaci* in crayfishes based on eDNA analysis has revealed its extensive spread in European freshwater bodies. In Switzerland, eDNA surveys successfully detected *Saprolegnia* sp. and *Tetracapsuloides bryosalmonae*, this helps in identifying areas with high disease risk. Another notable example is the detection of *Ribeiroia ondatrae*, where eDNA sensitivity was found to be

ISSN: 3049-2289

14 fg of parasite DNA and this was much greater than that of traditional PCR methods based on host tissues. Such examples illustrate how eDNA enhances understanding of pathogen ecology, host–parasite interactions, and environmental disease dynamics (Huver et al., 2015 & Sieber et al., 2024).

Conclusion

Environmental DNA/RNA represents a transformative advancement in aquatic pathogen detection and disease surveillance. Its non-invasive nature, high sensitivity, and ability to detect multiple pathogens from same sample simultaneously make it an indispensable tool for modern aquaculture and aquatic health management. Although limitations and challenges remain concerning standardization and interpretation, continuous advancements in molecular biology are expected to enhance the accuracy and predictive power of eDNA/eRNA approaches. Integrating these techniques into routine aquaculture health monitoring will contribute to early disease intervention, improved biosecurity, and sustainable aquaculture development.

References

Huver, J. R., Koprivnikar, J., Johnson, P. T. J., & Whyard, S. (2015). Development and application of an eDNA method to detect and quantify a pathogenic parasite in aquatic ecosystems. *Ecological Applications*, *25*(4), 991-1002.

Sieber, N. (2020). *Detection of aquatic wildlife pathogens from eDNA in water samples-validation and application in Switzerland* (Doctoral dissertation, ETH Zurich).

MacAulay, S., Ellison, A.R., Kille, P. and Cable, J., 2022. Moving towards improved surveillance and earlier diagnosis of aquatic pathogens: From traditional methods to emerging technologies. *Reviews in Aquaculture*, *14*(4), pp.1813-1829.

Bass, D., Christison, K. W., Stentiford, G. D., Cook, L. S., & Hartikainen, H. (2023). Environmental DNA/RNA for pathogen and parasite detection, surveillance, and ecology. *Trends in Parasitology*, *39*(4), 285-304.

Chouhan, N., Dekari, D., Choudhary, B., Singh, A., & Choudhury, T. G. (2023). Environmental DNA (eDNA) technology: Fisheries and aquaculture perspectives. *Indian J Anim Health*, *62*(2), 75-85.

Sieber, N., King, A., Krieg, R., Zenker, A., Vorburger, C., & Hartikainen, H. (2024). Large-scale eDNA monitoring of multiple aquatic pathogens as a tool to provide risk maps for wildlife diseases. *Environmental DNA*, *6*(1), e427.

*****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Indoor Gardening: A Garden within Walls

Surojit Ghosh, Md Faishal Ahmad, Aman Khan, Md. Ramjan, Mohd Javed, Muhammad Saqib Jamal
Center of Agricultural Education, faculty of agricultural Science, Aligarh Muslim University

The art of growing different plants inside the house is known as Indoor Garden. The main purpose of indoor gardening is to create a beautiful, attractive and lively atmosphere inside the house Indoor gardening serves as an effective means of bringing natural beauty into interior spaces. It enhances air quality, supports physical and mental well-being, and may even help reduce household expenditure. Indoor plants play a vital role in lowering indoor pollutants, as they absorb toxic substances and release oxygen. In doing so, they function as natural air-purifying agents. In an age characterized by digitalization and limited outdoor space, the promotion of indoor gardening has become increasingly important. This article emphasizes the need to incorporate indoor plants not only in living rooms and balconies but throughout the entire home, both to improve aesthetics and to promote better health.

Introduction

Modern people now spend more than 85% of their time indoors rather than outdoors as their primary living space. People are now able to connect to and remain linked to the computer because of the advancements in information technology. However, the spread of information technology also brings about a lot of stress, including techno stress, a condition that results from an inability to adjust to new technological developments in a healthy way. Modern cities face a number of health issues and societal challenges, including urbanization, climatic changes, ecological issues, environmental quality, and sustainable development, as a result of increased construction and changes in recent lifestyles. Trees and plants are essential for both environment and humanity. Having plants in house and office is pleasant. A happier, healthier environment results from having "breathing" plants in living and working space. Exposure to nature and trees can improve a variety of human health outcomes, including mental and physical well-being, children's attention and test scores and even property values. Plant enthusiasts are on the rise today, yet there is less and less outdoor area for cultivating plants. Due to this, indoor gardening is popular. Nowadays, indoor gardening and indoor planting are becoming increasingly prevalent. The inclusion of green plants indoors has generated a lot of interest because it is thought that they can enhance the standard of indoor built environments. The therapeutic and restorative effects of human-nature contact range widely, from the decrease of stress to the improvement of cognitive and social abilities.For those who spend their days indoors, having indoor plants in the house can help the air quality, which in turn can enhance cognitive function. Taking care of houseplants may be a fulfilling activity that teaches you new skills, encourages self-expression, and gives you a sense of accomplishment.

Indoor Gardening

Indoor gardening is the practice of creating a garden-like environment inside a building when there is not enough space outdoors. This can be done in homes, offices, restaurants, or any enclosed place. Plants are usually grown in pots, ceramic containers, or even recycled items like plastic bottles.

People have been keeping plants indoors for at least 5,000 years. Ancient Egyptians are believed to have brought ferns and palm trees inside their homes to make their living spaces more beautiful and closer to nature. Later, during the Victorian era, indoor plants became extremely popular. Terrariums were considered a sign of status and were also used as a source of comfort and happiness. After World War II, houseplants became widely available, making it easy for people to decorate their homes with attractive and

ISSN: 3049-2289

easy-to-grow plants. The tradition of carrying and growing plants dates back to times when travelers collected plants from tropical forests. Today, indoor gardening has become a modern trend.

Many studies have shown that working with indoor plants can reduce both physical and mental stress. Taking care of plants lowers diastolic blood pressure and reduces the activity of the sympathetic nervous system, helping people feel calm and relaxed (Hall and Knuth 2019; Callaghan and Mallory-Hill 2016; Ikei et al. 2014; Ikei et al. 2013; Smith and Pitt 2011). Green spaces have also been proven to reduce stress in workplaces. For example, employees who had roses nearby showed lower heart rate levels compared to those who did not. Indoor plants can improve attention, reduce stress, and increase job satisfaction, making workplaces healthier and more productive (Gilchrist et al. 2015; Hartig et al. 2014; Raanaas et al. 2011; Berto 2014).

Benefits of Indoor Plants

Plants help with mood and stress management and also offer long-term advantages such as bettering air quality, which may lessen headache occurrences, or by introducing moisture to the air, which helps with dry skin. Handling dirt, which contains bacteria, can encourage the diversity of your home's microbiome, which may be good for your stomach and skin.

- **Reduces stress level:** The presence of plants nearby has a relaxing impact that lowers blood pressure, provides more comfort and can lower stress levels on a physical and psychological level.
- **Blockage of the nose can be avoided:** Simply having plants nearby can help cut your risk of getting a cold and a stuffy nose by up to 30%. Plants accomplish this because their foliage raises the humidity and filters out airborne dust.
- **Purifies air:** In addition to capturing dust particles, plants help degrade dangerous airborne pollutants. They decrease carbon dioxide and turn it into oxygen, among other things. The air quality in the home is also improved by a healthy humidity level.
- **Plants reduce the risk of allergies**: When it comes to health and wellbeing, having indoor plants is a further factor to be taken into account. Children who grow up around plants have a lesser risk of developing allergies.
- **Plants make the house's acoustics better:** The acoustics in the home are improved by the ability of plant leaves to absorb background noise.
- **Plants promote restful sleep:** Houseplants cleanse the air improve the air quality and provide more oxygen. Additionally to their beauty and calming effects, they aid in better sleep.
- **Plants reduce the chance of headaches:** Plants' ability to filter the air can also help with headache relief. Formaldehyde is a gas that is used in the manufacture of leather and some carpets and can be found in any indoor setting. It is a common cause of headaches.Plants can aid in the removal of airborne benzene, trichloroethylene, and formaldehyde.

Common For Indoor Plants

Indoor plants are those that thrive in low light environments. These are perfect for places that don't get enough sunlight. Commonly used indoor plants are as follows:

Areca Palm

The areca palm is one of the easiest palms to care for inside since it can tolerate low light. The plant grows to become a dense shrub with slender, vivid green leaves. It is widely acknowledged to attract and release positive energy.

ISSN: 3049-2289

Snake Plant

One of the popular indoor plants that are simple to grow at home is the snake plant. Due to their elegant appearance, these plant species are suitable additions. The plant makes the air in the house more oxygenated and less carbon dioxide and chemically laden.

Ferns

Ferns are among the best and oldest indoor Indian plants, and they are popular indoor plants because of their lush green foliage. Ferns are excellent at cleaning the air. These peculiarly attractive small houseplants need regular care and just the right amount of sunlight

Spider Plants

Spider plants have a reputation for assisting in air purification. One of the simplest airpurifying plants to grow is the spider plant. It is efficient in removing airborne toxins like carbon monoxide, formaldehyde, and toluene.

Succulents

Due to their drought resistance, these plants only require watering when the ground is fully dry. They are available in a variety of sizes and forms to adorn your home and can purify the air.

Herbs

Small potted herbs may encourage to cook more frequently and consume healthier food in addition to simply looking nice in kitchen. Number of herbs, including chamomile and lavender, have been proved to lessen anxiety.

Marble Queen

The Marble Queen, also known as the money plant are simple to grow because they simply require infrequent watering and indirect sunlight. These plants can reduce indoor ozone levels, which can improve breathing and minimise your chance of developing respiratory illnesses. They can also remove volatile organic compounds (VOCs) from the air.

Necessities of indoor gardening:

- **Space:** You may have resorted to indoor gardening due to a shortage of outdoor garden area, but some inside room is still necessary. When designing your garden, keep in mind the requirements of your particular plants and their root systems to ensure they have the room they require to grow and flourish.
- **Light:** Some plants can survive with very little natural light, while others need it desperately to grow. Grow lights, whether LED or HID, are essential for the healthy growth of any plant that yields fruit or flowers.
- **Soil and Nutrients**: Soil for indoor gardening should be rich, porous and well drained with good water holding capacity. However, indoor plants need less water. Both over watering and under watering are harmful to indoor plants. Nutrient present in pot soil is adequate for satisfactory growth of house plants. Important constituents of potting media are bagasse, bark, cinders, clay, moss, peat moss, perlite, rice hull, saw dust, vermiculite etc. Report your plants and give them fresh soil as often as they need it to keep them happy and healthy.
- **Water:** Water is the simplest but one the most important things you indoor garden will require. Every plant is different and some will require more or less water than others.
- **Temperature and humidity:** It will also affect how much water they require at any given time of the year. It's important to research how much water your specific plants need to keep them in the healthiest condition.

Quality of Soil mixture:

It is important to have a quality soil mix for healthy plant growth. A high-quality container mix has the following general requirements:

- Dense enough to support the plant.
- Good nutrient-holding capacity.
- Allows water and air to pass through readily, yet retains adequate moisture.
- Free of insects, diseases and weed seeds

Recommended Mix

- **40% Coco peat / Peat moss** (Retains moisture, light, fluffy)
- **30% Perlite or pumice** (Improves drainage and aeration)
- **20% Compost or worm castings** (Provides nutrients)
- **10% Pine bark / Orchid bark** (Improves structure, mimics natural root environment)

References

1. Charles Hall and Melinda Knuth, "An Update of the Literature Supporting the Well-Being Benefits of Plants: A Review of the Emotional and Mental Health Benefits of Plants," *Journal of Environmental Horticulture* 37, no. 1 (2019): 30–38.
2. Amanda Callaghan and Sharon Mallory-Hill, "Biophilia and Nature-Based Features to Support Stress Reduction in Knowledge Workers," (2016).
3. Hiroko Ikei et al., "The Physiological and Psychological Relaxing Effects of Viewing Rose Flowers in Office Workers," *Journal of Physiological Anthropology* 33, no. 1 (2014): 6.
4. Hiroko Ikei et al., "Physiological Relaxation of Viewing Rose Flowers in High School Students," *Journal of Physiological Anthropology* 18 (2013): 97–103.
5. Andrew Smith and Michael Pitt, "Healthy Workplaces: Plantscaping for Indoor Environmental Quality," *Facilities* 29, no. 3–4 (2011): 169–87.
6. Karen Gilchrist, Christopher Brown, and Alessandro Montarzino, "Workplace Settings and Wellbeing: Greenspace Use and Views Contribute to Employee Wellbeing at Peri-Urban Business Sites," *Landscape and Urban Planning* 138 (2015): 32–41.

****

ISSN: 3049-2289

A Success Story of Keshav Hole: A Young, Educated, and Innovative Farmer Cultivating Muskmelon, Watermelon, Marigold, and Cucumber

Keshav Babanrao Hole
Patas-Daund Road, Birobawadi, Post-Patas, Tal-Daund, District-Pune, Maharashtra,
Email-keshavhole@gmail.com, Mobile Number-9975541272

In Birobawadi, Taluka Daund, District Pune,Maharashtra Keshav Babanrao Hole, A highly Educated young Innovative Farmer, has set an example by cultivating marigold, Muskmelon, watermelon, and cucumber using scientific and modern Agricultural methods.

Keshav has been engaged in cultivating these crops for the past 19 years, utilizing advanced techniques like drip irrigation, mulching Paper,Micro Spinklar , and Non-Woven crop covers. Recently, he experimented with polyester paper in cucumber cultivation, achieving record-breaking yields at reduced costs.

In today's fast-paced world, many young individuals strive for high-paying jobs, often sidelining traditional occupations like farming. However, Keshav Babanrao Hole, a highly educated young man from Pune,Maharashtra has chosen a different path. Hailing from Birobawadi village in Daund Taluka, Pune District, Keshav has pursued his passion for farming. With his family's 7.5-acre ancestral farmland, Keshav grows crops like Muskmelon, watermelon, marigold, and cucumber, generating an annual profit of INR 1 million (10 lakh).

Keshav Hole's Farming

Keshav owns 7.5 acres of irrigated land where Muskmelon, watermelon, marigold, and cucumber are the primary crops. He adopts strategic planning to maximize yields and minimize unnecessary expenses through innovative technology

Muskmelon Cultivation: Initiated stepwise in January using drip irrigation, mulching paper, and non-woven crop covers. Despite the higher cost of ₹18,000 to ₹20,000 per acre for crop covers, they help in weed control, pest management, and water conservation while increasing yields by 15–20%.

Watermelon and Marigold: Watermelon is planted on the second bed, and after harvesting it, marigold is cultivated on the same bed. This enables the use of one mulching paper for three consecutive crops, effectively reducing costs.

Cucumber: Sown in October with the use of polyester paper to lower production costs while increasing yield.

Key Farming Practices

1. Beds spaced six feet apart with single-row planting.
2. Focus on high-quality seeds and balanced use of organic, biological, and chemical fertilizers.
3. Annual soil testing and integrated pest management practices.
4. Use of compost fertilizers (5–10 tons per acre) and reduced reliance on external inputs.
5. Water-efficient practices like drip and sprinkler irrigation.

Innovative and Integrated Farming

Keshav emphasizes continuous learning and innovation:

1. Uses double-lateral drip irrigation on beds.
2. Produces residue-free (chemical-free) crops.
3. Reuses mulching paper for three crops.
4. Implements bamboo-supported low-cost shed nets.

5. Attracts pollinators by planting mustard and marigold.

Annual Income Plan

1. Muskmelon: Yield – 20 tons/acre; Profit (after ₹1 lakh expense) – ₹1–1.75 lakh/acre.

2. Watermelon: Yield – 30–35 tons/acre; Profit (after ₹60,000–70,000 expense) – ₹1 lakh/acre.

3. Marigold: Yield – 10 tons/acre; Profit (after ₹80,000 expense) – ₹1 lakh/acre.

4. Cucumber: Yield – 30 tons/acre; Profit (after ₹1.5 lakh expense) – ₹2 lakh/acre.

Keshav's Achievements

Keshav's efforts have been recognized with numerous state and national-level awards. He actively participates in workshops, seminars, and agricultural exhibitions, sharing his knowledge with farmers through training and social media platforms like WhatsApp and Facebook.

Vision and Goals

Keshav aspires to inspire and guide farmers towards scientific and sustainable farming practices. By focusing on crop rotation, balanced fertilization, and advanced technology, he believes that achieving expected yields is possible with proper management.

"Farming is a journey of constant learning and adaptation. Every day, I spend 10–12 hours in the field, exploring new technologies and applying them to improve my practices."

An Innovative Approach to Farming

Keshav owns 7.5 acres of irrigated farmland, where he primarily cultivates Muskmelons, watermelons, cucumbers, and marigold flowers. His interest in agriculture developed during his childhood alongside his education. Initially, the family farm produced sugarcane, onions, wheat, and millet, but the yields were not satisfying. In 2006, Keshav began experimenting with melon cultivation, which marked the beginning of his success. To combat rising temperatures and ensure the sustainability of his farming, Keshav adopted protected farming techniques.

Keshav has set up a cost-effective shade net structure using bamboo and polyester paper over 1.25 acres of his land, specifically for cucumber cultivation. The polyester paper helps regulate temperature, prevent flower drop, and control pests and diseases while conserving water and reducing fertilizer use. The protected farming method ensures better yields compared to open-field cultivation. His focus on modern technology and sustainable practices has significantly improved production.

Keshav has planted watermelons on 2.5 acres and melons on 2 acres. To reduce production costs and increase output, he combines organic, biological, and chemical fertilizers in a balanced manner. Melon cultivation typically begins in January, and Keshav employs modern technologies such as drip irrigation, mulching paper, and crop covers. Although crop covers cost an additional INR 18,000–20,000 per acre, they help control weeds, protect crops, conserve water, and increase yield by 15-20%. The improved fruit quality results in better market prices. After harvesting watermelons from the second bed, he plans to grow marigold flowers on the same plot.

Embracing Protected Farming

To make farming sustainable amid rising temperatures, Keshav has embraced protected farming methods. For cucumber cultivation, he built a low-cost shade net structure using bamboo and polyester paper over 1.25 acres. This structure helps control the microclimate and conserve resources, resulting in higher yields compared to open-field crops. By using mulching paper for cucumber planting, soluble fertilizers, and bacterial fertilizers, he has significantly reduced water use. Pest and disease control is managed as needed, further enhancing his productivity.

Keeping Detailed Records

Keshav places great emphasis on financial planning and crop management. He meticulously keeps a record of crop yields, profits, and losses, helping him plan for future seasons. Every year, Keshav assesses his profits and losses, creating a budget for the following year. He tracks key details such as crop planting, harvest dates, sales prices, and expenses, maintaining thorough records. This enables him to make informed decisions and improve his farming practices continuously.

Steady Progress Through Innovation

With his 7.5-acre farm, Keshav rotates crops like Muskmelons, watermelons, marigolds, and cucumbers, increasing both soil fertility and productivity. His hard work, dedication, and forward-thinking have resulted in remarkable success and economic stability. He is always looking for new ways to innovate and improve, studying the scientific methods behind each crop he grows.

Learning from Experts

Keshav's management of melon, watermelon, marigold, and cucumber cultivation has gained attention from experts and fellow farmers alike. He regularly interacts with agricultural scientists and progressive farmers to expand his knowledge. He reads extensively on farming techniques and documents expert advice in his journal. Before implementing new techniques, Keshav conducts small-scale trials on a portion of his land. This careful combination of study and experience allows him to refine his farming methods.

Awards and Recognition

Keshav credits his success to the blessings of his parents and hard work. In 2018, he was honored with the "Outstanding Farmer Award" by the Maharashtra Agriculture Department's ATMA initiative. Various social organizations have also recognized his contributions to farming.

Overcoming Challenges

Farming is not without its challenges. Climate change has made it difficult for vegetable farmers, with issues like uneven seed germination and pest infestations often leading to increased costs. Natural disasters can double management expenses, but Keshav has shown resilience, maintaining his crops despite adverse conditions. He continually seeks knowledge through study tours and training programs at institutions such as the Agricultural University in Rahuri and the Baramati Agricultural Science Center.

Incorporating Technology and Social Media

Keshav actively shares agricultural knowledge through Facebook and WhatsApp, participating in farmer gatherings, webinars, and online discussions. He connects with agricultural researchers and Ph.D students, ensuring a continuous exchange of ideas and technology. Despite facing a major setback during the COVID-19 lockdown, which resulted in a loss of INR 1-1.5 million due to market closures, Keshav remained determined, reinvesting his efforts into farming.

Building a Farm Brand

With guidance from experts, Keshav has successfully developed his farm into a thriving business. His farm brand, "Keshav Hole Agrotech Delicious Farm Fresh Fruits And Vegetables," is gaining recognition, with a growing demand for his residue-free watermelon, Muskmelon, and cucumber in the Pune and Mumbai markets. He also plans to diversify into agro-processing in the future, adding further value to his farm produce.

Earning INR 1 million Annually

Keshav Hole's farming techniques allow him to harvest up to 20 tons of melons, 30-35 tons of watermelons, 10 tons of marigolds, and 40 tons of cucumbers annually. This yields an impressive income of INR 1 million (10 lakh) per year. By adopting advanced farming techniques, maintaining detailed records, and embracing innovation, Keshav has become a role model for farmers in his community.

******

AGRICULTURE BULLETIN
ISSN: 3049-2289

Important Roles of Bog Gardens for Sustainable Life

Md Faishal Ahmad, Surojit Ghosh, Aman Khan
Centre of Agricultural Education, Faculty of Agricultural Science,
Aligarh Muslim University, Aligarh, Uttar Pradesh

Bog gardens play a significant role in promoting sustainable life by supporting ecological balance, conserving natural resources, and enhancing environmental resilience. These wetland ecosystems regulate water by absorbing excess rainfall, reducing flooding, and maintaining soil moisture. Their vegetation naturally filters pollutants, improving water quality and protecting groundwater sources. Bog gardens also support rich biodiversity and store large amounts of carbon, contributing to climate change mitigation. In addition to their ecological functions, they offer educational, aesthetic, and recreational benefits that encourage environmental awareness. Thus, bog gardens are vital for sustainable living and long-term environmental conservation.

Introduction

Few gardeners are fortunate enough to have naturally moist ground, let alone a true bog. In many regions, dry soils, fluctuating rainfall, and rapidly draining land make it difficult to cultivate the lush, moisture loving plants commonly found in wetlands. Yet the appeal of such plant sedges, irises, marsh marigolds, and other wetland species is undeniable for gardeners who admire their beauty and ecological value. For those passionate about creating diverse and sustainable landscapes, the absence of naturally wet soil can feel limiting. This challenge, however, has inspired many gardeners to explore the idea of creating artificial bog gardens, designed to mimic the conditions of natural wetlands.

Natural bogs take centuries to develop, forming slowly in glacial depressions or poorly drained basins. By contrast, a constructed bog garden allows gardeners to recreate these conditions on almost any site, even in dry or well drained areas. Using modern techniques such as lined trenches, controlled moisture systems, and specialized soil mixes, it becomes possible to sustain plants that thrive in constant dampness. Unlike marshes with standing water, a bog garden offers a continuously moist but soil filled environment an ideal habitat for many unique and ecologically significant plant species.

At the same time, incorporating a bog garden into an existing landscape requires thoughtful planning. It must blend harmoniously with the garden's overall design rather than appearing as an awkward or isolated feature. Whether part of a formal garden with geometric lines or a naturalistic landscape with flowing curves, a well planned bog garden enhances beauty, supports biodiversity, and contributes to environmental sustainability. When integrated thoughtfully, it becomes not only a horticultural achievement but also a living reminder of the role wetland habitats play in ecological balance. [Burrell-1997]

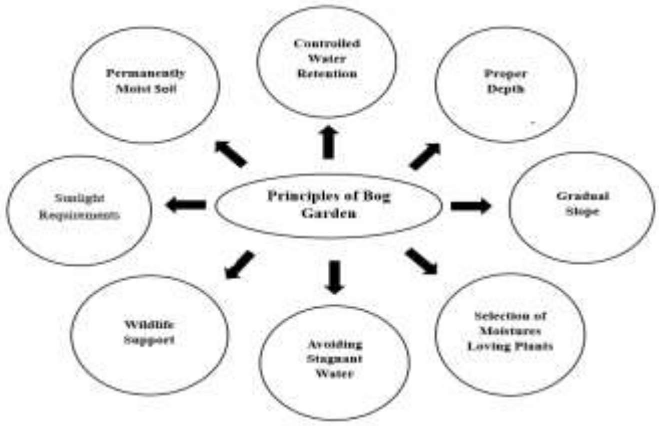
Definitions of Bog garden

A bog garden is a specially designed garden area where the soil is kept permanently moist but not waterlogged, creating conditions similar to a natural bog. It provides a habitat for moisture-loving, marginal, and semi-aquatic plants. Bog gardens may use poor natural drainage or be artificially created using pond liners, gravel layers, and controlled seepage to maintain constant moisture.[2]

Principles of Bog Garden

A bog garden is designed to replicate the conditions of a natural bog, where the soil remains constantly moist but not completely waterlogged. To successfully establish and maintain such an environment, several fundamental principles must be followed:[2]

ISSN: 3049-2289



Important Roles of Bog Gardens for Sustainable Life

Bog gardens are specialized wetland ecosystems characterized by waterlogged soils, high organic content, and unique plant species adapted to moist and nutrient-poor conditions. In recent years, bog gardens have gained great ecological and scientific importance because they contribute significantly to sustainable life. Their ability to regulate water, support biodiversity, store carbon, and purify the environment makes them essential components of natural and managed landscapes. This article discusses the key roles that bog gardens play in promoting sustainability and overall environmental wellbeing.[3]

1	**Natural Water Regulation** Bog gardens act as natural water managers. The peat-rich soil absorbs large quantities of water during heavy rainfall and releases it slowly over time. This helps in: ✓ Reducing surface runoff ✓ Preventing floods ✓ Maintaining groundwater levels ✓ Protecting nearby habitats from waterlogging Their natural water storage capacity makes them vital for climate resilient landscapes and sustainable urban development.
2	**Purification of Water** One of the most valuable functions of bog gardens is their role in water purification. The dense vegetation and organic matter act as natural filters that trap: ✓ Sediments ✓ Heavy metals ✓ Agricultural chemicals Improving water quality, bog gardens help protect streams, rivers, and groundwater resources, which is essential for sustainable living.
3	**Conservation of Biodiversity** Bog gardens support a wide variety of plant and animal species that are not found in other habitats. These include: ✓ Carnivorous plants such as pitcher plants and sundews ✓ Bog orchids ✓ Sphagnum moss ✓ Frogs, insects, birds, and butterflies By providing food, shelter, and breeding sites, bog gardens help maintain biodiversity and contribute to ecological balanc
4	**Climate Regulation and Carbon Storage** Bog ecosystems store large amounts of carbon in the form of peat. This stored carbon remains locked for centuries, helping to: ✓ Reduce atmospheric CO_2 ✓ Slow global warming ✓ Stabilize climate patterns Because they act as major carbon sinks, bog gardens play an essential role in climate change mitigation and long term sustainability.
5	**Soil Conservation** The dense root systems of bog plants bind the soil and prevent erosion. Bog gardens help: ✓ Protect topsoil ✓ Maintain soil fertility ✓ Prevent land degradation This is especially important in areas with heavy rainfall or fragile soils.

ISSN: 3049-2289

6	**Aesthetic and Recreational Benefits** Bog gardens are visually appealing due to their unique plant diversity and lush greenery. They offer: ✓ Peaceful spaces for relaxation ✓ Opportunities for photography ✓ Inspiration for landscaping ✓ Enjoyable experiences for nature lovers These recreational benefits improve mental well-being and promote a stronger connection with nature.
7	**Promotion of Environmental Awareness** By interacting with bog gardens, people develop a deeper appreciation for wetlands and their role in sustainability. These gardens promote: ✓ Awareness about conservation ✓ Responsible use of natural resources ✓ Sustainable lifestyle habits Such awareness leads to better environmental decisions at individual and community levels.

Conclusion

Bog gardens play a vital role in supporting sustainable life by regulating water, purifying the environment, conserving biodiversity, and storing carbon. Their ecological, educational, and aesthetic contributions highlight the importance of preserving these unique ecosystems. As environmental challenges intensify, integrating bog gardens into landscapes, public parks, and urban planning becomes essential for ensuring a healthier and more sustainable future.

References

[1] Burrell, C. Colston. *Garden Stories*. Brooklyn: Brooklyn Botanic Garden, June 1, 1997. Link- https://www.bbg.org/article/a_bog_garden

[2] Brickell, Christopher, ed. *RHS Encyclopedia of Gardening*. London: Dorling Kindersley, 2019.

- Squire, David. *Water Gardening: A Practical Guide*. London: New Holland Publishers, 2007.
- Royal Horticultural Society (RHS). "Bog Gardens." RHS Gardening Advice. Accessed November 20, 2025. https://www.rhs.org.uk/garden-advice

[3] Mitsch, William J., and James G. Gosselink. *Wetlands*. 5th ed. Hoboken, NJ: Wiley, 2015.

- Rydin, Håkan, and John K. Jeglum. *The Biology of Peatlands*. 2nd ed. Oxford: Oxford
- University Press, 2013.
- Richardson, Curtis J., and Michael J. Vepraskas. *Wetland Soils: Genesis, Hydrology, Landscapes, and Classification*. Boca Raton, FL: CRC Press, 2001.
- Cronk, James K., and Michael S. Fennessy. *Wetland Plants: Biology and Ecology*. Boca Raton, FL: CRC Press, 2001.

****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Progress and Prospects Animal Husbandry Mechanization in India

Pornima D. Rathod
SRF, AICRP on MAH, VNMKV Parbhani

Introduction

India has vast livestock and poultry resources that play a key role in the rural economy. Livestock supports landless and marginal farmers, contributing significantly to income, employment, and the national economy. From 2014–15 to 2020–21, the livestock sector grew at a Compound Annual Growth Rate (CAGR) of 7.93% (at constant prices), outpacing manufacturing (4.93%), services (4.82%), and agriculture (2.05%). In 2020–21, it contributed 4.90% to total GVA, compared to 8.96% from the crop sector. Over 20.5 million people depend on animal farming, with 87.7% of livestock owned by smallholders. The sector also provides about 50% direct and indirect employment to women, the highest among all sectors. Fisheries alone support 16 million people. To meet rising demand and reduce reliance on manual labour, mechanization is essential. Tools like automatic feeders, milking machines, and manure scrapers improve efficiency, ensure hygiene, enhance animal welfare, and make livestock farming more productive, sustainable, and profitable.

Role of AI and IoT Tools in Animal Husbandry

Application area	IoT Tools	AI Role	Benefit
1. Livestock Health Monitoring	• Wearable Sensors: Track body temperature, heart rate, activity, and rumination. • Smart Collars / Ear Tags: Collect real-time biometric and behavioral data.	• Predicts illnesses (like mastitis or lameness) early using machine learning models. • Analyzes anomalies in behavior or vitals for disease diagnosis.	Early detection reduces mortality and treatment costs.
2. Environmental Monitoring	• Climate sensors: Monitor temperature, humidity, and gas levels in barns. • Smart ventilation systems: Adjust airflow automatically.	• Optimizes barn conditions using AI algorithms for maximum animal comfort. • Predicts and prevents heat stress or cold shock.	Early detection reduces mortality and treatment costs.
3. Smart Feeding Systems	• Automated feeders and drinkers: Dispense food/water based on preset schedules or	• Adjusts feed ratios based on age, weight, and health data. • Tracks feed intake to	Efficient nutrition management improves feed conv ersion ratio.

ISSN: 3049-2289

	animal needs. • **Solar-powered automatic feeders** for goats and poultry • Low-pressure **nipple drinker systems** for water saving	optimize growth and reduce waste.	
4. **Reproductive Management**	Heat detection sensors (pedometers, tail-mounted sensors): Identify estrus behavior.	• Predicts optimal breeding time using behavior and hormonal data. • Assists in genetic selection through analysis of performance data.	Improves conception rates and genetic quality.
5. **Manure & Waste Management**	• Sensor-equipped manure pits or digesters to monitor volume and gas emissions. • Manual and semi-mechanized **dung scrapers**	• Predicts when waste systems need maintenance or emptying. • Optimizes nutrient recovery (e.g., biogas production or compost quality).	Reduces environmental impact and improves resource utilization.
6. **Decision Support Systems**	Devices that collect farm-wide data (e.g., RFID, cameras, drones, GPS collars).	• Integrates multisource data into dashboards. • Recommends actions for health, breeding, feeding, and culling.	Helps farmers make informed decisions faster and more accurately.
7. **Supply Chain and Traceability**	• GPS trackers and RFID tags for livestock transport.	• Monitors animal movement, predicts delivery times, and detects issues like stress during transit.	Ensures food safety, transparency, and animal welfare compliance

Quantitative and Qualitative Benefits of Mechanization

A. Labor Saving

- Time reduction in feed chopping, watering, or manure handling
- Women's labor burden reduced in household dairying
- Automating tasks can reduce the need for manual labor

ISSN: 3049-2289

B. Productivity Gains

- Increased milk yield via timely and balanced feeding
- Healthier animals due to improved housing/hygiene
- Reduced injury or stress during handling

C. Economic Returns

- Return On Investment (e.g., for chaff cutters, biogas units)
- Income diversification through value-addition (e.g., dung cakes, compost)

Challenges of Mechanization:

- **High Initial Investment Costs:** The initial cost of purchasing and installing machinery can be a barrier for some farmers.
- **Need for Skilled Manpower:** Operating and maintaining mechanized systems requires trained personnel, which may be a challenge in some areas.
- **Dependence on Technology:** Over-reliance on technology can create vulnerabilities if systems fail or if there are issues with maintenance or repairs.
- **Potential for Job Displacement:** In some cases, mechanization can lead to job losses in the short term, although it may also create new jobs in related fields.
- **Impact on Animal Welfare:** If not implemented properly, mechanization can sometimes lead to negative impacts on animal welfare, such as increased stress or reduced opportunities for natural behaviour's.

Overall, mechanization in animal husbandry offers significant potential for improving efficiency, productivity, and animal welfare, but it also presents challenges that need to be addressed to ensure its successful and sustainable implementation.

References

1. https://www.infah.org/animal-health/animal-husbandry.html
2. S.P. Singh and Vikas Pagare (2024) "Status and scope of mechanization in animal husbandry". Journal of Science for Society 6(2): 75-83.

****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Tobacco: The Green Bioreactor Revolutionizing Medicine and Industry

Nanda C[1], Gangadhara K[2]
[1]ICAR- NIRCA Research station, Hunsur, Karnataka.
[2]ICAR- NIRCA Research Station, Kandukur, AP.

Molecular farming is an innovative technology that uses plants to produce valuable proteins and biomolecules for agriculture, industry, and pharmaceuticals. Unlike traditional methods relying on microbes or mammalian cell cultures, molecular farming leverages plants as "bio-factories" to create medicines, vaccines, enzymes, and more. Among various crops, tobacco has emerged as the star platform for this green revolution due to its unique advantages.

Why Tobacco?

Tobacco is not just a smoking crop; it is an incredibly efficient and versatile production system. As a non-food and non-feed crop, tobacco significantly reduces concerns about food-chain contamination. It produces massive leaf biomass and contains high levels of soluble proteins, making it ideal for generating large quantities of recombinant proteins. In addition, tobacco's well-established genetic transformation protocols allow scientists to insert genes encoding valuable proteins quickly and reliably.

The ability to use different genetic approaches, including stable nuclear and chloroplast transformations as well as rapid transient expression, makes tobacco especially flexible. These technologies enable production of complex therapeutic proteins such as monoclonal antibodies for disease treatment, cytokines for immune modulation, and vaccines for infectious diseases like flu and norovirus.

Breakthrough Applications

Tobacco molecular farming has paved the way for exciting advances in various fields such as

- **Therapeutic Proteins & Antibodies production**: Tobacco is used to make complex monoclonal antibodies for diseases like cancer and autoimmune disorders. Newer platforms allow rapid transient expression, speeding up production timelines dramatically.
- **Vaccine production**: Tobacco is used to produce vaccine proteins for diseases such as influenza, norovirus, and even COVID-19. Some tobacco-made vaccines are in human clinical trials, leveraging scalable and cost-effective production.
- **Production of Cultivated Meat Growth Factors**: Companies like BioBetter use genetically engineered tobacco to produce growth factors ie., proteins essential for growing lab-cultured meat. This in turn paves the way for sustainable meat alternatives.
- **Production of Industrial Enzymes and Polysaccharides**: Tobacco continues to be a source of industrial enzymes used in food processing and biotech. It is also engineered to produce complex polysaccharides for novel vaccine components.

Emerging Technologies Enhance Tobacco's Role in Recent advances which include:

- **Chloroplast Genome Engineering**: Targeting the plastid genome allows exceptionally high protein yields and containment to prevent gene flow.
- **Hairy Root Culture Systems**: These cultures continuously secrete recombinant proteins, simplifying downstream purification and lowering costs.
- **Glyco-engineering**: Scientists are modifying tobacco's sugar-processing pathways to make

ISSN: 3049-2289

plant-produced proteins more human-like, improving safety and efficacy.

- **Synthetic Genetic Circuits**: These allow precise control of protein expression, optimizing yield while maintaining plant health.

Limitations to Consider

Despite its many perks, tobacco molecular farming is not without challenges. The yield of recombinant proteins can vary, and tobacco's plant-based post-translational modifications differ from humans', potentially affecting protein efficacy and safety. Downstream purification is often complex and costly, raising production expenses. Additionally, regulatory hurdles and public concerns about genetically modified organisms (GMOs) sometimes slow adoption. The crop's natural alkaloids, like nicotine, may need to be minimized for safer pharmaceutical applications.

The Future of Tobacco Molecular Farming

Tobacco's rapid growth rate, high biomass, and ease of genetic manipulation keep it at the forefront of plant-made pharmaceuticals and biotechnological products. Scientists continue to develop new techniques to overcome current limitations, such as glycoengineering to humanize sugar patterns and transient expression systems for faster protein production.

As interest grows in sustainable, scalable bioproduction, tobacco molecular farming holds promise for transforming not just medicine and agriculture but possibly even how we produce food and biofuels. This green bioreactor could play a pivotal role in meeting global health and environmental challenges in the years ahead.

References:

1. Stefan Schillberg, Ricarda Finnern (2021).Plant molecular farming for the production of valuable proteins – Critical evaluation of achievements and future challenges. Journal of Plant Physiology 258-259.
2. Henry Daniell, Stephen J. Streatfield and Keith Wycoff (2001). Medical molecular farming: production of antibodies, biopharmaceuticals and edible vaccines in plants. Trends in Plant Science Vol.6 No.5.
3. Marc Tschofen, Dietmar Knopp, Elizabeth Hood, and Eva Stoger. (2016). Plant Molecular Farming: Much more than Medicines. Annu. Rev. Anal. Chem. 9:271–94.
4. Richa Sao and Parmeshwar Kumar Sahu. (2019). Molecular Farming as an Approach for Production Of Useful Metabolites. Journal of Plant Development Sciences Vol. 11(12): 697-704

*****

ISSN: 3049-2289

The Great Indian Thrill: The Evolution and Future of Theme Parks in India

Ajay Kumar Dhangar[1], Md. Ramjan[2], Md. Javed[3], Vivek Kumar[4], Md Faishal Ahamd[5]
[1,2,3,5]Centre of Agricultural Education, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh
[4]Department of Genetics & Plant Breeding, Janta Mahavidyalaya Ajitmal, Auraiya, Uttar Pradesh

The Indian theme park industry has undergone a radical transformation, evolving from simple Ferris wheels and joy rides to a multi-faceted sector encompassing world-class amusement parks, water kingdoms, and culturally resonant experiential spaces. This article traces the industry's historical roots, analyses its current market dynamics and segmentation, examines the unique emergence of indigenous mythological and cultural themes, and discusses the significant challenges and future prospects. Drawing on industry reports, corporate data, and news citations, it presents a detailed overview of one of India's fastest-growing leisure and entertainment segments.

1. Introduction: From Picnics to Pixie Dust

For generations, entertainment for the Indian middle class was largely informal and low-cost cinema, picnics in public gardens, and visits to historical monuments. The concept of a paid, enclosed space dedicated solely to curated recreational experiences was nascent. The late 1980s and 1990s, coinciding with India's economic liberalization, began to shift this paradigm. The rise in disposable income, urbanization, and exposure to global entertainment standards created a fertile ground for the organized amusement park industry to take root and flourish (Price water house Coopers, 2023).

2. The Historical Foundations: The Pioneering Parks

The industry's genesis can be traced to a few landmark projects that demonstrated the public's appetite for such entertainment.

- **Appu Ghar Delhi (1984-2008):** Often nostalgically remembered as India's first major amusement park, Appu Ghar was inaugurated during the 1982 Asian Games. Its iconic roller coaster and giant ferris wheel became symbols of modern entertainment for a generation of North Indians. While it closed in 2008, its legacy proved the commercial viability of theme parks in India (Hindustan Times, 2008).

Fig.1 https://www.hindustantimes.com/delhi/

- **Essel World and Water Kingdom, Mumbai (1989 & 1999):** These twin parks, developed by the Essel Group, were the first to offer a comprehensive "day-cation" model. Essel World, with its dry rides, and Water Kingdom, as one of Asia's largest water parks, set a new benchmark for scale and variety, establishing Mumbai as a key market (Essel World, n.d.)

Fig 2. https://www.esselworld.in/about-us

ISSN: 3049-2289

- **Nicco Park Kolkata (1991):** Dubbed the "Disneyland of Bengal," Nicco Park emerged as the pioneering force in Eastern India. Developed with assistance from UNDP and FAO, it was one of the first to systematically attract family audiences and corporate partnerships, boasting over 35 million visitors to date (Nicco Parks & Resorts Limited)

Fig 3. https://www.niccoparks.com/about-us.html

3. The Modern Boom: Market Size and Corporate Entrants

The 21st century marked the industry's maturation, with corporate entities entering the fray and professionalizing operations.

- **Market Valuation and Growth:** The industry has seen explosive growth. According to the Indian Association of Amusement Parks and Industries (IAAPI), it was valued at approximately $400 million in 2018. It was projected to grow at a Compound Annual Growth Rate (CAGR) of around 12% to reach **$1.5 billion by 2025** (IAAPI, 2019 as cited in Financial Express, 2019). More recent analyses by PWC project the wider Indian media and entertainment market, of which amusement parks are a part, to continue its strong growth trajectory, further buoying the sector (PricewaterhouseCoopers, 2023).
- **Wonderla Holidays: The Gold Standard:** Listed on the Indian stock exchanges, Wonderla has become synonymous with safety, quality, and operational excellence. With highly successful parks in Bangalore (2005) and Kochi, and a third in Hyderabad (2016), Wonderla's strategy revolves around owning most of its land, ensuring high maintenance standards, and a clear focus on the "safety-thrill" combination. Their annual reports consistently show high visitor turnout and revenue growth, making them a market leader (Wonderla Holidays Limited, Annual Report 2022-23).
- **Adlabs Imagica (Now Imagicaa):** Launched in 2013 with an investment of over ₹1,600 crore, Imagicaa was a bold attempt to create an international-scale, destination theme park. Featuring IP-based dark rides like "Mr. India" and world-class coasters, it aimed to be a multi-day resort experience. While it faced initial financial restructuring, it signified a new level of ambition for the Indian industry (Hindustan Times, 2013).

4. A Unique Indian Segmentation: Beyond Roller Coasters

The Indian market has organically segmented into distinct categories, reflecting diverse consumer demands.

4.1. The Destination & Amusement Park:

These are large-scale parks designed as primary destinations for day-trips or short vacations. Examples include Wonderla, Imagicaa, and the established pioneers like EsselWorld.

4.2. The Water Park Specialist:

Capitalizing on India's long and hot summers, dedicated water parks have proliferated across the country, from major chains like **Atlantis Water Parks** in Delhi and Ahmedabad to numerous regional players. They are often the most profitable segment during the April-June quarter.

4.3. The Cultural and Mythological Innovator:

This is India's most distinctive contribution to the global theme park landscape, moving beyond imitation to innovation.

Ramoji Film City, Hyderabad: While a functional film studio, its scale and curated tourist experience make it a de facto theme park. Holding the Guinness World Record for the largest film studio complex, it attracts millions of visitors for its sets, shows, and attractions, effectively blending

ISSN: 3049-2289

cinema with tourism (Guinness World Records, n.d.).

- **Kingdom of Dreams, Gurugram:** A groundbreaking, though now struggling, venture by the Gurugram Metropolitan Development Authority. It fused performing arts, gastronomy, and grandeur. Its 'Culture Gully' was an indoor street showcasing Indian handicrafts and cuisines, and the Nautanki Mahal hosted large-scale Bollywood-style productions (India Today, 2010).

- **The Mythological Future: The Ayodhya Project:** The most significant development in this category is the planned **"Lord of the Universe" (Shri Ram) theme park** in Ayodhya. Announced by the Uttar Pradesh government, this project aims to transform the city into a global spiritual and cultural tourism hub, with the park narrating the epic of Ramayana through modern technology and immersive experiences. This represents a strategic use of indigenous narratives for tourism (The Times of India, 2023).

5. Formidable Challenges and Government Hurdles

The industry's growth has not been without significant obstacles.

- **High Operational Costs and Seasonality:** The capital expenditure for land and imported rides is enormous. Furthermore, footfall is heavily skewed to weekends and summer months, leading to underutilized capacity for much of the year, a challenge frequently highlighted in industry analyses (KPMG, 2019).
- **The GST Impasse:** The industry has long contested its Goods and Services Tax (GST) slab of 18%, which categorizes amusement parks alongside casinos and race courses. Industry bodies like IAAPI have lobbied for a reduction to 12%, arguing that parks are family entertainment, not vices, and a lower tax would boost affordability and growth (The Economic Times, 2019).
- **Infrastructure and Location:** Most major parks are located on the outskirts of cities, where land is affordable. However, this necessitates visitors to contend with often-congested transit, making accessibility a key factor in success.

6. The Future Trajectory: Immersive and Indigenous

The future of Indian theme parks is poised for further evolution, driven by several key trends:

- **Technology Integration:** The use of Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) in rides will become standard, offering new forms of immersive storytelling beyond physical coasters.
- **Hyper-Theming and IP Development:** The success of parks with strong themes (like Imagicaa's initial IP attempts) points towards a future where Indian parks will develop their own intellectual properties or license popular domestic film and comic characters.
- **The Spiritual & Cultural Niche:** The Ayodhya model could be replicated around other religious

ISSN: 3049-2289

and cultural sites, creating a unique sub-sector of "darshan and delight" parks that blend devotion with entertainment.

- **Mall-based Entertainment Centres:** While not traditional theme parks, the rise of large-scale, indoor entertainment zones within malls (like SMAAASH) provides convenient competition and acclimatizes a new generation to paid, high-quality recreational experiences (Knight Frank, 2022).

7. Conclusion

The journey of India's theme park industry reflects the nation's broader socio-economic narrative from a protected economy to a globalized one, from modest aspirations to world-class expectations. It has matured from simple amusement rides to a complex industry offering thrill-based, aquatic, and culturally profound experiences. While challenges like high taxes and seasonality persist, the sector's underlying drivers a young population, rising incomes, and a hunger for new experiences remain robust. The future will likely see a blend of global technology with deeply Indian stories, creating a theme park landscape that is not just successful domestically, but potentially exportable to the world.

8. References

1. Financial Express. (2019, January 28). *Indian amusement park industry to touch $1.5 bn by 2020: IAAPI*. Retrieved
2. IAAPI. (n.d.). *Indian Association of Amusement Parks & Industries*. Retrieved from https://www.iaapi.org/
3. KPMG. (2019). *India's Media and Entertainment Industry Report*. [Typically includes a section on amusement parks]. Retrieved from KPMG India publications.
4. Knight Frank. (2022). *The Great Relocation - India Real Estate Outlook*. [Includes data on retail and mall-based entertainment]. Retrieved from Knight Frank India research.
5. Wonderla Holidays Limited. (2023). *Annual Report 2022-23*. [Provides official financial and operational data]. Retrieved from https://www.wonderla.com/investor-relations/annual-reports/

*****

AGRICULTURE BULLETIN
ISSN: 3049-2289

Jaggery: A natural sweetener

Shubham Panwar[1], Rohit Kumar[2]
[1] Ph.D. Research scholar, Department of Agricultural Economics & Statistics
[2]Ph.D. Research scholar, Department of Agricultural Extension Education
Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, U.P.

Gur or jaggery is a coarse, healthy, traditional, unrefined sugar that ranges in colour from golden yellow to dark brown and is made by condensing sugar juice. Under various names, it is produced in nearly 25 countries, with an estimated annual production of 14 million tonnes. With 58% of the global production, India is the leading producer of jaggery in the unorganised agro-processing industry, followed by Colombia, which contributes 12%. About 13.2% of India's total sugarcane production is used to make Khandasari, a concoction of 0molasses and crystalline sugar, and jaggery. Uttar Pradesh is the leading producer of jaggery from sugarcane among all Indian states.

Jaggery and refined sugar are both sweeteners, but jaggery is considered a healthier alternative due to its nutrient content. Below is a comparison of their nutritional values per 100 gm.

Nutritive values of jaggery and sugar

Particular	Jaggery	Sugar
Sucrose (%)	65-85	99.5
Glucose, Fructose (%)	10-15	-
Proteins (%)	0.25	-
Fats	0.005	-
Calcium (%)	0.4	-
Phosphates (%)	0.045	-
Iron (mg)/100)	11	-
Copper (mg/100g)	0.8	-
Total minerals	0.6-10	0.05
Moisture (%)	3.10-10	0.2-0.5
Energy (K.Cal)	3.83	3.98

Importance of Jaggery (Gur)

Jaggery is much more complex than sugar since it is made up of longer chains of sucrose. It provides energy gradually as opposed to quickly since it digests more slowly than sugar. This is good for the body and releases energy for a longer amount of time. However, as it is ultimately sugar diabetics cannot safely eat it. Since iron vessels are used to make jaggery, a sizable number of ferrous salts (iron) are also produced during this process. This iron is particularly good for the health of people who are iron deficient or anaemic. Although jaggery leaves a little salty aftertaste on the tongue, it also contains trace amounts of mineral salts that are very beneficial to the body. These salts are present in sugar cane juice and are absorbed from the soil. Jaggery works well as a cleaning agent as well. Along with the stomach, intestines, and oesophagus, it also cleanses the respiratory system. Consuming jaggery is highly recommended for people who deal with dust on a daily basis. This can shield patients against conditions like asthma, cold or coughs, congestion in the chest, etc. Jaggery is well recognised for producing heat and giving the body instant vitality. As a result, greeting guests with a glass of water and jaggery is customary in various parts of India. A part from these applications, jaggery is used to make cattle feed, medicine manufacturing facilities, distilleries, ayurvedic pharmaceuticals, ayurvedic supplements, and ayurvedic diets. At the moment, jaggery is becoming more and more popular as a candy. Workers in cement industries and coal mines are also given jaggery to help them avoid dust allergies. Additionally, following severe calamities, the district government purchases jaggery and distributes it to the victims as a health benefit.

Medical properties of jaggery

While jaggery and other traditional sweeteners are used worldwide, their popularity is highest in South Asia and Latin America. When water is extracted from date palm sap or sugarcane juice, a

ISSN: 3049-2289

concentrated, raw sugar product is what is left over. Because of its high sugar content, jaggery should only be eaten in moderation, even though it has various biological properties and potential health benefits. Its biological traits and behaviours consist of the following:

Jaggery contains essential elements including Fe, Mg, and K. The production of red blood cells and the maintenance of electrolyte equilibrium are just two of the fundamental bodily processes that rely on these minerals. Jaggery contains phytochemicals and polyphenols, which are antioxidants that may help reduce oxidative damage and reduce the likelihood of chronic disease development. Flavonoids, one of the components of jaggery, may have anti-inflammatory properties that help reduce inflammation in the body. Jaggery is claimed to help with digestion. By promoting the digestive enzymes, it can lessen indigestion, constipation, and bloating. In many traditional medicinal systems, jaggery is given for respiratory ailments like colds and coughing. It is said to calm the throat and reduce respiratory discomfort.

Because of its iron concentration, jaggery may be used to treat or prevent iron-deficiency anaemia. Iron is necessary for the production of haemoglobin, the oxygen-carrying protein found in red blood cells. Certain women use jaggery because it is a naturally occurring source of carbohydrates that may help control hormone abnormalities.

Jaggery is claimed to help with digestion. By promoting the digestive enzymes, it can lessen indigestion, constipation, and bloating. In many traditional medicinal systems, jaggery is given for respiratory ailments like colds and coughing. Some women use it to improve menstrual symptoms like mood swings and stomach pains, and it is believed to reduce respiratory irritation. Jaggery has been applied topically to wounds in a number of traditional practices due to its potential antibacterial and wound-healing properties. Jaggery is commonly used to reduce the symptoms of coughs and colds when taken alongside other herbal remedies. It is said to have therapeutic benefits for respiratory health when paired with ginger and black pepper. A quick energy boost for athletes and high-energy people It is usually favoured by necessities.

Jaggery purifier blood

When consistently ingested, jaggery aids in blood cleansing and leaves the body in a healthy state. A number of blood disorders and diseases can be avoided by raising haemoglobin levels. Additionally, jaggery boosts immunity, which helps to avoid a number of blood-related problems.

Iron concentration

Because it includes a substantial quantity of iron and folate, jaggery helps prevent anaemia. Jaggery powder also offers rapid energy, avoiding exhaustion and body weakness. When taken alongside meals that are high in vitamin C, jaggery enhances the body's capacity to absorb iron.

Mineral composition

Jaggery contains minerals and antioxidants, namely zinc and selenium, which help lower the risk of damage from free radicals. These minerals and antioxidants also help the body become more resistant to certain infections.

Cosmetic benefits

Jaggery has several natural properties that help to maintain the health of the skin for a very long time. It provides the skin with the nutrition it needs because of its high concentration of various minerals and vitamins.

Jaggery's impact on digestion

Jaggery speeds up the digestive process by encouraging the release of digestive enzymes. In addition to protecting against issues like gas, stomach parasites, and constipation, proper digestion also helps regulate bowel motions. This is highly beneficial for maintaining the proper operation of the digestive system. When the digestive system functions flawlessly, intestinal issues are successfully avoided and dyspepsia is decreased.

Jaggery speeds up the metabolism.

Jaggery's high potassium content and strong mineral content help in weight management. This aids by reducing the body's capacity to retain extra water. Jaggery's potassium boosts metabolism, maintains electrolyte balance, promotes muscle growth, and aids in weight loss.

Jaggery helps to balance hormones.

Particularly for women who experience mood swings prior to their periods, jaggery has numerous beneficial advantages. The underlying reason of mood swings is the body's fluctuating hormone levels. Consuming jaggery causes the release of endorphins, which are feel-good hormones. This relaxes the body, which makes women feel better.

Improves brain function

Additionally, jaggery helps prevent serious issues with the body's nervous system. It has many inherent characteristics that support the healthy operation of the nervous system. This allows people to continue living their normal, healthy lives.

Treats respiratory issue system

Frequent jaggery consumption can protect against a number of respiratory disorders, such as asthma and bronchitis. Experts claim that a person's respiratory system benefits from consuming jaggery, a naturally occurring sweetness, in the right amount along with sesamum seeds. The properties of jaggery aid in regulating body temperature, which is very beneficial for those with asthma. Additionally, keep in mind that jaggery contains anti-allergy properties.

Processing of jaggery

The production of high-quality jaggery is mostly determined by the agronomic management techniques used in the production of sugarcane and jaggery. Agronomic methods include choosing a variety of cane, managing soil conditions, planting and fertiliser timing, irrigation schedules, crop protection against pests and diseases, harvesting cane, and post-harvest cane care. Selecting sugarcane genotypes with a high sucrose content is necessary to produce high-quality jaggery. Low-salinity, well-drained loamy soils are ideal for growing sugarcane, which yields high-quality jaggery. It is best to plant the crop between January and March and harvest it when it is at its most mature, depending on the variety. Because of delayed planting and crushing of immature or overmature cane used to prepare jaggery, lower quality and less recovery of jaggery will be obtained. N, P, and K fertilisers should be used as directed; too much nitrogen lowers the quantity and quality of jaggery. It is not advisable to expose the crop to either moisture stress or waterlogging. Before crushing to make high-quality jaggery, dead canes, water shoots, spoilt canes, and canes infested with rats should be thrown away. Harvesting the cane at the base of the clump requires caution because the lower part of the cane is high in sucrose. As soon as the cane is harvested, it should be crushed to extract the juice.

Otherwise, the quality and recovery of the jaggery would deteriorate as the cane weight would decrease by roughly 5–8% and the juice would recover by 2% in 2–3 days.

The opaque liquid sugarcane juice can range in colour from light yellow to dark green to grey, depending on the colour of the cane. It contains a number of soluble and insoluble contaminants, as well as mud, wax, and other nutritional components. Jaggery is a traditional unrefined sugar made from sugarcane or palm sap. The process of making jaggery involves several steps. First, fresh sugarcane is harvested and crushed to extract the juice. This juice is then filtered to remove impurities and is boiled in large, shallow pans over a fire. As the juice thickens, it is continuously stirred to prevent burning. During this process, impurities rise to the surface and are skimmed off. Once the juice reaches a thick, golden-brown consistency, it is poured into molds or left to cool and solidify into blocks. The final jaggery product is then packed and stored for consumption. Jaggery is widely used as a natural sweetener in various dishes and is known for its rich flavor and health benefits.

ISSN: 3049-2289

Conclusion

Jaggery, also referred to as "medicinal sugar," has numerous health benefits and can be used in pharmaceutical formulations as well as in daily life. One of India's oldest and most important rural cottage industries, the jaggery industry is the country's largest unorganised sector. Enhancing high-quality and hygienic jaggery through the use of cutting-edge techniques, beginning with the extraction, cleaning, clarification, cooling, moulding, and packaging processes, is essential to the profitability of the jaggery industry. Using different sources to make different types of jaggery—solid, liquid, and granular—will also improve the quality of the produce. Herbal clarifiers are increasingly being used instead of pharmaceutical ones. Because of its lower moisture content and propensity to flow freely, granular jaggery has more benefits than lumped jaggery. However, the method has yet to be developed and made commercially available. Value-added jaggery has a considerable export potential and might command high market prices when nutritional additives are added. Improved quality through technological advancements in jaggery preparation, packaging, and added value can increase profits for growers and processors.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Cashew Production, Processing & Export Performance in India

Dr. Ranjit Patil & Dr. Shatrughn Bhusanar
Assistant Professor,
D Y Patil Agriculture & Technical University, Talsande, Kolhapur, MS

Cashew is a highly demanded dry fruit in India and abroad, valued for its nutritional, medicinal, and culinary uses. It is a major cash crop in regions like Konkan and an important source of foreign exchange for the country. India is among the world's leading cashew cultivators and exporters, with Kerala, Karnataka, Maharashtra, Andhra Pradesh, and Goa being the key producing states. Despite expansion in area, cashew productivity remains inconsistent, indicating the need for improved crop management and yield enhancement measures. Though exports have declined in the past decade, global demand for processed cashews remains strong, especially in Asian and European markets. The cashew processing industry generates rural employment, boosts farmer incomes and supports small-scale enterprises through value-added products. With sustainable practices, modern processing facilities, e-commerce promotion and policy support, India can further enhance its position as a global hub for cashew cultivation, processing and exports.

Introduction

Cashew is well known everywhere as a delicious dry fruit. In India, there is huge demand for cashews in all seasons. They are consumed raw or used in sweets, gravies, garnishing, and other food products. Cashew is one of the major crops that earns valuable foreign exchange. The cashew business is one of the fastest-growing and most demanded businesses. For farmers in the Konkan region, cashew is an important cash crop. Rich in nutrients, cashew provides ample energy and is therefore also called the powerhouse of energy. Cashews are rich in protein and effective in reducing inflammation, improving memory, and relieving arthritis pain. Cashew kernels contain protein, iron, vitamins, potassium, phosphorus, magnesium, zinc, and other nutrients essential for good health. The monounsaturated fats in cashew help keep the heart healthy. Copper and antioxidants present in cashew help in maintaining glowing and healthy skin. Cashews are widely used in various food products.

The cashew processing industry has vast business opportunities. By processing raw cashews into finished products, income can more than double. Farmers in cashew-growing regions can earn good profits with minimal investment. Kerala is a leading state in cashew processing, housing more than two-thirds of the processing units in India. Besides Kerala, Karnataka and Maharashtra's coastal regions also have well-developed processing industries. One of the strengths of this industry is the ability to store raw cashews for a long time, making domestic and international trade possible. Globally, three major cashew products are traded—raw cashew, cashew kernel, and cashew shell liquid. However, the cashew processing industry in India is largely unorganized and scattered.

With rapid growth in India's dry fruit processing sector, cashew offers major commercial opportunities. India, which imports raw cashews and processes them, has become a leading exporter of processed cashews. The global demand for cashew is also rising due to innovative snack foods, bakery products, and sweets. Cashew processing units can be established in many places depending on the availability of raw materials. With growing demand, cashew has emerged as one of India's most valuable export-oriented crops. India is among the world's leading producers in cashew cultivation, processing, refining, and exports.

ISSN: 3049-2289

Table No. 1: India's Cashew Area & Production in the Last 10 Years

Year	Area (000 Ha)	Production (000 MT)
2014-15	1030	745
2015-16	1037	671
2016-17	978	745
2017-18	1062	817
2018-19	1105	743
2019-20	1125	703
2020-21	1159	738
2021-22	1184	752
2022-23	1195	782
2023-24	1199	795

From table no.1, it is seen that, area under cashew crop increased from 1030 thousand ha in 2014-15 to 1199 thousand ha in 2023-24. However cashew production is increased from 745 thousand MT in 2014-15 to 795 thousand MT in 2023-24. The highest production was recorded in 2017-18 (i.e. 817 thousand MT), while the lowest was in 2015-16 (i.e. 671 thousand MT).

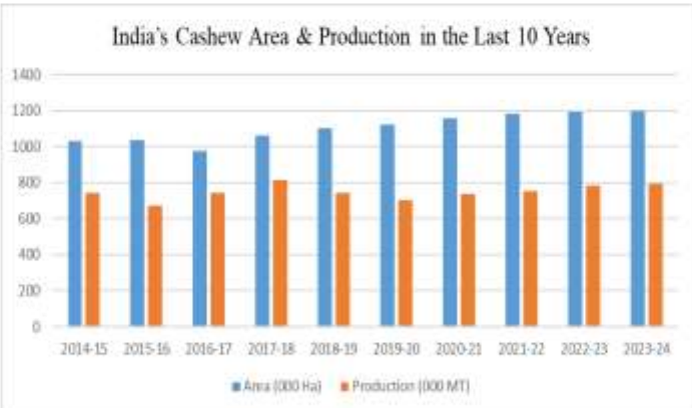


Fig. 1. India's Cashew Area & Production in the Last 10 Years

Table No. 2: India's Cashew Export in the Last 10 Years

Year	Quantity (MT)	Value (Rs. Crores)
2014-15	134,567	5565.77
2015-16	103,130	5024.77
2016-17	92,175	5303.37
2017-18	90,062	5945.35
2018-19	78,170	4579.17
2019-20	84,330	4018.13
2020-21	70,088	3112.22
2021-22	75,450	3377.40
2022-23	59,581	2868.72
2023-24	65,801	2808.80

From table no. 2, it is seen that, India exported the highest volume of cashew in 2014-15, around 134,567 MT, worth Rs. 5565.77 crore. Since then, exports have declined significantly, reaching 65,801 MT in 2023-24, worth Rs. 2808.80 crore. This shows a decline trend in both export quantity and value over the past decade, highlighting new business opportunities for Indian cashew producers to expand exports.

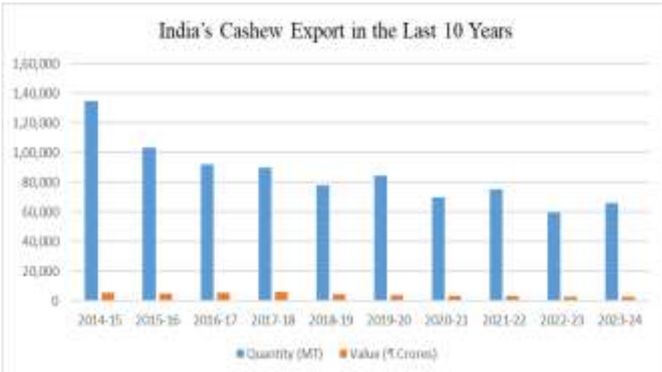


Fig. 2. India's Cashew Export in the Last 10 Years

ISSN: 3049-2289

Table No. 3: Major Cashew Importing Countries from India (2024-25)

Sr. No.	Country	Quantity (MT)	Value (Million USD)
1	UAE	10,066.80	80.79
2	Vietnam	26,745.73	42.75
3	Japan	5,111.62	37.13
4	Netherlands	5,009.36	35.77
5	Spain	3,599.47	28.81
6	Saudi Arabia	3,524.99	28.81
7	Kuwait	1,294.05	10.58
8	Qatar	1,273.18	10.07
9	Germany	1,690.95	8.33
10	USA	1,115.53	7.90

From the table no.3, it is clear that in 2024-25, Vietnam imported the highest volume of cashews from India 26,745.73 MT worth of USD 42.75 million. The UAE ranks second, followed by Japan, Netherlands, Spain, Saudi Arabia, Kuwait, Qatar, Germany, and the USA. This data shows that India's cashew exports are mainly concentrated in Asian and European markets.

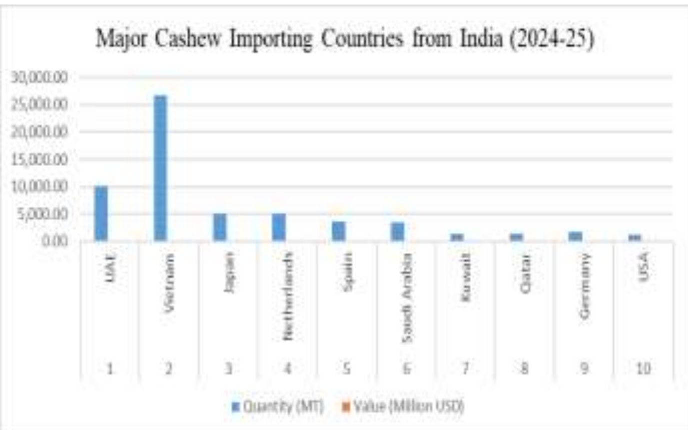


Fig. 3 Major Cashew Importing Countries from India (2024-25)

Cashew production in India is concentrated in states like Maharashtra, Kerala, Andhra Pradesh, Odisha, and Goa. In Maharashtra, districts along the Konkan coast such as Sindhudurg, Ratnagiri and Raigad produce large quantities of cashews, which also have strong international demand. While India has many cashew processing industries, Maharashtra still lacks sufficient processing units. If more processing units are promoted in Maharashtra, it could boost farmers' incomes significantly.

In 2023-24, cashew was cultivated on about 1.199 million hectares in India, yielding 0.795 million MT. Along with high production, India is also recognized globally for cashew processing and export of cashew kernels. Kerala leads in cashew production and processing, with more than two-thirds of units located there, while the rest are spread across other states. In recent years, India has emerged as a global hub for cashew processing. India is the world's largest exporter of cashews, accounting for over 15% of global exports, supplying to more than 50 countries. The UAE, Japan, Netherlands, Saudi Arabia, USA, UK, Canada, France, Israel, and Italy are among the top destinations.

Economic Importance of Cashew Processing Industry

1. **Employment in Rural Areas** – Processes such as shelling, drying and packaging provide large-scale employment, especially for women.
2. **Foreign Exchange** – Millions of tons of cashews are exported annually and earned billions of dollars in foreign exchange.
3. **Stable Market** – Cashews are in demand year-round, ensuring stable domestic markets and good prices for farmers.
4. **Infrastructure Development** – Setting up cashew industries in rural areas leads to local infrastructure development and strengthens the rural economy.
5. **Value Addition** – Processed products such as roasted cashews, spiced cashews, cashew butter, and cashew-based sweets add significant value.

ISSN: 3049-2289

6. **Opportunities for Small-Scale and Cooperative Enterprises** – With low investment, small-scale industries and cooperatives can easily establish cashew processing units.

Future Opportunities

To strengthen the sector, it is essential to adopt sustainable farming and processing methods, develop new cashew-based products, establish cold chain and modern processing facilities, promote e-commerce and online marketing for domestic and global customers and encourage women and self-help groups.

The cashew processing industry plays a vital role in the Indian economy. With its contribution to rural employment, farmer incomes, foreign exchange earnings and value-added products, the industry is continuously expanding. With the right policy support, adoption of modern technology, innovation in processing, sustainability and increased value-added production, India can not only maintain but also strengthen its leading position in the global cashew export market.

Conclusion

Cashew is not only a nutritious and highly demanded dry fruit but also an important export-oriented crop for India. There is steady increase in cashew cultivation area in India over the last decade, while production showed fluctuations with only marginal overall growth. Though exports have declined in the last decade, India still holds a leading position in global cashew processing and supply. With strong domestic demand, vast international markets, and opportunities for value addition, the cashew industry provides immense scope for farmers, entrepreneurs, and cooperatives. Strengthening processing facilities, adopting modern technology, promoting sustainable practices, and expanding into new markets can further boost rural employment, farmer incomes, and foreign exchange earnings, ensuring India's continued dominance in the global cashew trade.

References:

1.https://www.entrepreneurindia.co/page/cashew-processing-industry/

2. Mr. G. Prabhakaran & Dr. G. Nedumaran2 (2022). Cashew production benefits and opportunities in India, MAAYAN INTERNATIONAL JOURNAL OF COMMERCE, Vol. 1(1):6-15.

3. Arpita Tinani & Dhaval Tinani (2023). Growth of the Cashew Industry in India in relation to its Current Status and Future Opportunities. Journal of Emerging Technologies and Innovative Research, Vol. 10(3):146-156.

*****

ISSN: 3049-2289

The Vital Role of Bumblebees in Our Ecosystem

Rumki H.Ch. Sangma, Khrieketou Kuotsu, Sandip Patra, H.D. Talang, Y. Bijen Singh, W.S.Philanim, A.R. Singh and P. Baiswar
ICAR-Research Complex for NEH Region, Umiam-793103, Meghalaya

Introduction

Animal pollinators contribute to the output of more than one-third of the world's agriculture products. Proper pollination is necessary for the ideal fruit set and production. Managed and wild bee pollinators are estimated to be responsible for agricultural output worth up to $210 billion in crop production and productivity (Button and Elle, 2014). In the modern agriculture practices, the most widely used managed pollinators are honey bees. However, several issues have led to decline in population of managed honeybees. The lack of sufficient pollinators has led to a decreased in output of most agricultural crops. Given these challenges with managed honey bee pollinators, it is important to understand the role and functions of wild pollinators in agriculture. An increase in crop outputs has been associated with a higher diversity of pollinators since many crops depend on wild pollinators for pollination.

Among the wild pollinators, bumblebees belonging to Apidae family are important pollinators. They are eusocial insects that form colonies with a single queen. According to reports, there are around 250 species of bumblebees in the world. (Goulson *et al*., 2008). They are the most significant crop pollinators among wild bees. They are characterized by their sturdy, round bodies covered in soft hair, or setae, which usually have bands of black and yellow. Due to their large size and hairy body they can collect and deposit large amount of pollen. Better pollination by transfer of more pollens results in better quality and quantity of fruits. Pollination by bumblebees and other insect pollinators play a crucial role in increasing crop production and productivity and maintaining biodiversity. Despite their significance they are threatened by climate change, habitat loss, pesticides use and diseases. Therefore, conservation measures are necessary to preserve these insects and guarantee the sustainability of ecosystems and the availability of food.

Biology:

Bumblebees have a robust, round hairy body which is divided into three major segments: head, thorax, and abdomen. They have warning coloration, often consisting of contrasting black and yellow/orange/white banding. Their size varies greatly, ranging from the queen to little workers. Male bumblebees can grow up to 16 mm (0.6 in) in length, workers range from 11 to 17 mm (0.4 to 0.7 in), and queens can reach up to 22 mm (0.9 in) (Yadav *et al*., 2009). Pollen is gathered and carried around by the dense hair covering their bodies, known as setae. They are able to remain active in colder climates than most other bees because of their thick hair, which acts as insulation. A specialized pollen-collecting device called pollen basket, or corbicula, is located on the fourth segment of worker bees hind legs. As generalist feeders, bumblebees collect pollen and nectar from a broad range of flowers. They possess a long tongue/proboscis which aid in obtaining nectar from deep flowers as a result, bumblebees are more efficient than honeybees at pollinating deep flowers. The tip of their abdomen also has a stinger, but unlike honey bees, bumblebees can sting repeatedly if provoked because they retain their sting after usage.

Social Structure:

Bumblebees are eusocial insects and they live in colonies, have different divisions of labor or castes. Each colony has a queen, workers, and drones (males). Bumblebee colonies are smaller and less sophisticated, and do not survive more than one summer. Colonies rear one generation per year. Near the end of the colony cycle, new queens appear and depart the colony soon after. The new queens leave the nest after they have mated in search of an overwintering site and hibernate until the following

ISSN: 3049-2289

spring. The remainder of the colony, including the old queen, dies off at the end of the year.

Bumblebees don't generate a lot of honey like honey bees do since their colonies don't hibernate. The annual life cycle begins with the new queen emerging from hibernation, starts foraging and lay the first brood (solitary phase). The colony's social phase begins with the emergence of the first worker (eusocial phase). The newly emerged worker bees become the work force collecting nectar and pollen for the colony. The queen stops foraging and is engaged solely in egg laying, while the workers take over all nest duties. Bumblebees make their nest underground, usually in abandoned burrows, birds nests or leaf heaps. Unlike honeybee colonies, colony size varies between species and may involve several hundred workers or just a few dozen. Depending on the species and habitat the colony produces drones and new queens.

Foraging Behaviour:

Bumblebees have complicated foraging habits. Species and environmental factors influence the flights and foraging range. Bumblebees can forage up to 1-2 kilometers away from their nest and are renowned for their flower fidelity. By detecting an electric field, bumblebees can distinguish flowers that have recently been visited by other bees. They can also identify flowers by their temperature. After visiting a flower, bumble bees leave a fragrance imprint that discourages them from returning until the fragrance fades. They utilize these indicators to determine whether the flowers are rewarding or unrewarding. Bumblebees can forage effectively at different environmental conditions where other pollinators are inactive. They can forage at low temperatures, during cloudy, foggy and rainy days making them important pollinators suitable even in high altitude ecosystems.

Pollination Services:

A major contributor to the high quality and high production of any crop is pollination. A successful pollination occurs when pollen from male anther is transferred to female stigma which results in ideal fruit set and production. Pollination takes place with the help of abiotic and biotic agents such as wind, water, insects, birds, animals etc. Among these agents, insect pollination is the most efficient. Numerous insects such as solitary bees, honeybees, and bumblebees play an important role in pollination of agricultural and horticultural crops, flowering trees and wild flowers which is essential for sustainable agriculture and healthy ecosystem.

Among wild bees, bumblebees are significant pollinators of both cultivated and wild plants. Effective pollination highly depends on morphology of flowers and ethology of pollinators (Wahengbam *et al*., 2019). Plants with long corolla such as red clover and field bean require long tongue insects like bumblebee for pollination. Tomato plants are pollinated by vibrations which are often performed by bumblebees. The pollens from flowers of Solanaceae and Ericaceous plants are difficult to obtain by bees and are more efficiently released by sonication. Bumblebees are skilled at sonicating flowers, an ability known as buzz pollination (Buchmann, 1983) which cannot be accomplished by honey bees. During buzz pollination, vibration is produced with the help of its flight muscles which cause the pollen to separate from the anthers (King and Buchmann, 1996). Buzz pollination is particularly effective for plants such as tomatoes, peppers, and blueberries. The large size body can accommodate more pollen and have better contact with flowers. Bumblebees are exceptionally effective pollinators for many high-value agricultural crops such as red clover, cucumber, water melon, cotton, tomato, pepper, kiwifruit, and strawberry. They can also fly in narrow spaces which makes them suitable pollinators in even in green houses.

Bumble bee, *Bombus haemorrhoidalis* foraging and pollinating different flowers (PC: R.H.Ch. Sangma)

Decline in Population:

Despite their important role in pollination, there are several factors leading to decline of bumblebee population which is a direct threat to biodiversity. Indiscriminate use of pesticide, climate change, habitat change and diseases are some of the major causes affecting the population of bumblebees. In the agriculture sector, with the aim of increasing production, the use of pesticides have increased over the years to manage insect pests and diseases. The indiscriminate use of pesticides results in exposure of bees to pesticides leading to direct mortality. Pesticide contaminants negatively affect brood development and memory which affects the bees foraging behavior, navigation, and reproduction. Exposure to pesticides also weakens their immune systems, making them more vulnerable to diseases. The intensification of agricultural practices has also resulted in loss of habitat for the bumblebees. The practice of monoculture has led to reduced diversity of floral resources. The nesting sites and forage plants have greatly reduced as a result of the fragmentation and destruction of natural habitats brought on by urbanization, agricultural growth, and infrastructural development. The number of bumblebees has been decreasing globally as a result of several factors, and climate change is also one of the factors. Current climate change particularly rising temperature has an impact on population distribution and overall health of bee species. It has also affected the floral diversity and flowering period of plants that the bumblebees depend on for their survival.

Conclusion:

Bumblebees are important pollinators for many wild plants and agricultural crops, crucial for the sustainability of our natural and agriculture ecosystem. Their unique biology and behavior helps in pollinating plants which are not possible by other insect pollinators. However, the challenges they face have led to alarming population declines that threaten ecological balance and agricultural productivity. More research must be done on habitat restoration, agricultural practices, use of safe insecticides and landscape modifications that benefits bumblebees. By valuing and safeguarding bumblebees, we ensure not only their survival but also our ecosystems and the sustainability of global agriculture.

Reference:

Buchmann, S.L., 1983. Buzz pollination in angiosperms. In: Jones CE, Little RJ (eds) Handbook of Experimental Pollination Biology. Scientific and Academic Editions, NY, pp 73–113.

Button, L. and Elle, E., 2014. Wild bumble bees reduce pollination deficits in a crop mostly visited by managed honey bees. *Agriculture, ecosystems & environment*, 197, pp.255-263.

Goulson, D., Lye, G.C. and Darvill, B., 2008. Decline and conservation of bumble bees. *Annu. Rev. Entomol.*, *53*(1), pp.191-208.

King, M.J. and Buchmann, S.L., 1996. Sonication dispensing of pollen from Solanum laciniatum flowers. *Functional Ecology*, pp.449-456.

Wahengbam, J., Raut, A.M., Satinder Pal, S.P. and Banu, A.N., 2019. Role of bumble bee in pollination. *Annals of Biology* 35(2) : 290-295.

Yadav, S.P., Yadav, S., Sharma, D. and Sangwan, N., 2009. Bumblebees, life cycle and their role in pollination-a review. *Int J Res Sci*, *5*(9), pp.60-75.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Plant protease inhibitor: an breakthrough in pest management

Monisha U[1], Veeraragul R[2]
[1*]Department of agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore
[2*]Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab

Plant-derived protease inhibitors (PIs) represent a promising class of anti-insect defense proteins that target digestive proteases in herbivorous insects and nematodes. By inhibiting trypsin, chymotrypsin, and other serine, cysteine, aspartic, or metallo-proteases in the insect midgut, PIs reduce nutrient acquisition, delay development, and increase mortality. Advances in functional genomics, structural biology (e.g., AlphaFold3), CRISPR-based genome editing, and multi-gene stacking have accelerated the deployment of PIs in transgenic and cis-genic crops. This article summarizes recent mechanistic insights, key success stories, limitations, and future directions for PI-based pest management.

Biochemical and Structural Basis of PI Action

Plant PIs belong to several superfamilies (e.g., Bowman-Birk, Kunitz, Pin-II, cystatins, metallocarboxypeptidase inhibitors). Most of the insect targeted PIs are serine protease inhibitors (trypsin/chymotrypsin inhibitors) that bind the target enzyme with dissociation constants (Ki) in the nanomolar to picomolar range. High-resolution structures and molecular docking studies show that the reactive-site loop of the inhibitor mimics a canonical substrate, forming a stable, non-covalent complex that blocks the catalytic triad (Ser-His-Asp) of the pest protease (Leung *et al.,* 2000).

Efficacy in Transgenic and Cis-genic Systems

- Cowpea trypsin inhibitor (CpTI): Transgenic tobacco, cotton, and rice expressing CpTI showed 40–70% reduction in larval weight of *Heliothis virescens*, *Helicoverpa armigera*, and *Chilo suppressalis* (Mir *et al.,* 2023).
- Potato protease inhibitor II (Pin-II): Constitutive expression in tea (*Camellia sinensis*) reduced *Ectropis oblique* and *Hyposidra infixaria* growth rates by 55–68% and increased larval mortality by 40% under field conditions (Duan *et al.,* 1996).
- Multigene stacking: Co-expression of mustard trypsin inhibitor-2 (MTI-2) + potato aspartic protease inhibitor in rice provided additive mortality against *Cnaphalocrocis medinalis* and *Scirpophaga incertulas* (Pandey *et al.,* 2022).
- Plastid transformation: Chloroplast-localized expression of a barley trypsin inhibitor in potato achieved >100-fold higher accumulation than nuclear transgenes without pleiotropic effects (Lombardi *et al*., 2025).

Types of blocking of the enzymes:

Mode	Description	Mechanism Type
A. Direct blockage of the active center (canonical inhibition)	The inhibitor directly binds to the enzyme's active site, physically blocking substrate access.	Typical of trypsin-like proteases; forms a stable enzyme–inhibitor complex.
B. Indirect blockage of the active center	The inhibitor binds near the active site, altering the enzyme's conformation and indirectly preventing catalysis.	Changes enzyme structure without binding directly to the catalytic site.
C. Adjacent or exosite binding	The inhibitor binds at a site adjacent to the catalytic center (an "exosite"), preventing substrate binding through steric hindrance.	Seen in certain allosteric or noncompetitive inhibition mechanisms.
D. Allosteric interaction	The inhibitor binds at a remote site (not the active site) causing allosteric (shape-changing) effects that reduce enzyme activity.	Alters enzyme configuration so that the active site no longer fits the substrate properly.

Synergistic and Combinatorial Approaches:

Synergistic PI-based strategies markedly enhance efficacy and delay resistance. Co-expression with Bt Cry toxins imposes severe fitness costs on Bt-resistant survivors, slowing resistance evolution 5–10-fold. Combining PIs with pest-specific dsRNA yields near-complete mortality (>98 % in *Leptinotarsa decemlineata*) via dual protease suppression. CRISPR-mediated activation of endogenous PI promoters (e.g., SlPin2) achieves 8–18 fold overexpression without foreign DNA, delivering robust cis-genic resistance compatible with non-GMO regulatory pathways. These multilayered approaches provide high-potency, durable pest control with negligible non-target effects (Leung *et al.,* 2000).

PI in pest management:

Plant protease inhibitors (PIs) offer a highly targeted, environmentally safe pest management tool by disrupting only the digestive proteases of herbivorous insects and nematodes, while remaining harmless to mammals, pollinators, and most beneficial predators. Engineered crops expressing enhanced or stacked PIs routinely reduce pest damage by 50–90 % in field trials, cutting insecticide applications by 30–70 % and delivering yield gains of 15–40 % in high-pressure environments (cotton, rice, potato, tomato, tea). Because PIs are biodegradable proteins and impose strong selection against resistance when pyramided with Bt toxins or RNAi, they slow the emergence of resistant pest populations far more effectively than single-mode chemical or Bt-only strategies. Cisgenic/CRISPR-edited PI lines further ease regulatory approval and public acceptance, positioning PIs as a cornerstone of next-generation integrated pest management and sustainable agriculture (Leung *et al.,* 2000).

References:

Leung, D., Abbenante, G., & Fairlie, D. P. (2000). Protease inhibitors: current status and future prospects. *Journal of medicinal chemistry*, *43*(3), 305-341.

Mir, R. R., Kumar, A., Pandey, M. K., & Thudi, M. (Eds.). (2023). *Genomics-based breeding of crops for food and nutritional security in 21st century-volume 2*. Frontiers Media SA.

Duan, X., Li, X., Xue, Q., Abo-El-Saad, M., Xu, D., & Wu, R. (1996). Transgenic rice plants harboring an introduced potato proteinase inhibitor II gene are insect resistant. *Nature biotechnology*, *14*(4), 494-498.

Pandey, A., Yadav, R., & Sanyal, I. (2022). Evaluating the pesticidal impact of plant protease inhibitors: lethal weaponry in the co-evolutionary battle. *Pest Management Science*, *78*(3), 855-868.

Lombardi, L., Genio, V. D., Albericio, F., & Williams, D. R. (2025). Advances in peptidomimetics for next-generation therapeutics: strategies, modifications, and applications. *Chemical Reviews*, *125*(15), 7099-7166.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Cucurbit Fruit Flies Management by Pheromone Trap -Case study

Ram Prakash Sharma[1] and Neha kumari [2]
[1]Krishi Vigyan Kendra, Madhepura, B A U, Sabour, Bhagalpur
[2]Sardar Ballbh Bhai Patel University of Agriculture and Technology, Merrut UP.

Cucurbits (Bitter gourd, bottle gourd, sponge gourd, ridge gourd, pointed gourd, ivy gourd, snake gourd cucumber, pumpkin etc. are the most popular vegetable cultivated throughout India. Cucurbit fruit fly, Bactrocera cucurbitae (Coquillett), is one of the most devastating pests of cucurbits in crop growing areas. The extent of damages varies between 30% to 100%, depending on crop season in which it grown and type of cucurbit species. Infestation mainly observed in young, green, soft skinned fruits. The female fly inserts the eggs 2 mm to 4 mm deep in the fruit tissues, and the maggots feed inside the fruit. Mature maggots pupate in the soil at 0.5 cm to 15 cm below the soil surface. Instead of repeated application of chemical insecticides farmers feel difficulties in maintaining fruit quality and hence got lowest price of their produce. Pesticide residue another problem for marketing the produce. Keeping in this view an alternative forfruit fly management was tested under Frontline Demonstration (FLD) conducted under farmer field conditions to assess losses and to measure the efficacy of pheromone traps in trapping the adult flies. The trail resulted in 17.39% increase in yield along with complete reduction in the usage of chemical pesticide which was applied earlier. This resulted in reducing the cost of cultivation nearly INR. 24015 per hectarewhich was spent earlier on agrochemicals.

Introduction

Cucurbits are the most popular vegetable cultivated throughout India. In India commonly cultivated cucurbits are bottle gourd (Lagenaria *siceraria*), bitter gourd (*Momordica charantia L.*), sponge gourd (*Luffa cylindrica*), ridge gourd (Luffa acutangula), pointed gourd (*Trichosanthes dioica*Roxb), snake gourd (*Trichosanthescucumerina*), Ivy gourd (*Coccinia grandis*), water melon (*Citrullus lanatus*),cucumber (*Cucumissativus*), pumpkin(*Cucurbita pepo*) are the most popular vegetables cultivated throughout India. These vegetables have nutritive and medicinal values. However, cucurbit fruit fly *Bactroceracucurbitae* (Coquillett) (Diptera:Tephritidae)] is the significant limiting factor in cultivating quality fruits and a high yield. It causes major losses to allcucurbits. The maggots of fruit fly feed inside the fruit as well as on the fruit pulp or, occasionally, on the flowers, roots, stems, and tender leaf stalks. The fruit fly, *Bactroceracucurbitae* (Coquillett) is widely distributed in temperate, tropical, and sub-tropical regions of the world. It has been reported to damage 81 host plants and is a major pest of cucurbitaceous vegetables, particularly thebottle gourd (*Lagenaria siceraria*), bitter gourd (*Momordica charantia L.*), sponge gourd (*Luffa cylindrica*), ridge gourd (Luffa acutangula), pointed gourd (*Trichosanthes dioica*Roxb), snake gourd (*Trichosanthescucumerina*), Ivy gourd (*Coccinia grandis*), water melon (*Citrullus lanatus*), cucumber (*Cucumissativus*), pumpkin (*Cucurbita pepo*) etc. Its populations increases when the temperatures fall below 32°C, and the relative humidity ranges between 60% to 70% (Rakshitet.al.2011). The infectedflowers and fruits fall down prematurely or rot on the plant and resulting reduction in yield. Young maggotleaves the necrotic region and move to the healthy tissues, where they often introduce various pathogens and hasten the fruit decomposition.

Depending on the environmental conditions and susceptibility of the crop species, the extent of losses varies between 30 to 100% (Gupta and Verma, 1992; Dhillon et al., 2005a, b, c; Shooker et al., 2006).Since conventional insecticides are being more or less effective but problem of pesticide residue, many health hazards and impact of chemicals on non-

ISSN: 3049-2289

target organisms its surrounding, the present trial was undertaken to assess the efficacy of pheromone trap aiming to substitute an eco-friendly and sustainable pest management system in cucurbits(Nasiruddin et. al, 2010)

Materials and Methods

Frontline Demonstration (FLD) conducted under farmer field conditions during 2021-22, 2022-23 and 2023-24 to assess losses and to measure the efficacy of pheromone traps in trapping the adult flies. The farmers were selected based on diagnostic field visit conducted during crop season who cultivate cucurbitaceous vegetables. The farmers were identified in different villages of Madhepura district north Bihar, India. The main purpose of the demonstration is to popularize the use of pheromone traps to monitor the pest population and then adopt non-chemical management practices for fruit fly (Sapkota et.al).

During 2021-22, 2022-23 and 2023-24 47, 10 cucurbits (Bottle gourd) growing farmers were selected and crop was sown during July month. Machan method (Trails) with recommended spacing and standard packages and practices was followed. Manures and fertilizers were applied as per recommendations. Container traps and lures were supplied as criticalinputs to the farmers. Traps were installed at late vegetative stage just before flowering @ 6 trap per acre hanging with stick. A separate control plot maintained with pesticide spray alone. Number of fruit flies per trap was counted on weekly basis and damage was calculated and yield was recorded out of 20 harvests.

Results And Discussion

The incidence of fruit flies was recorded throughout the crop season. The trial resulted in complete control of fruit flies in pheromone trap installed plots compared to pesticide sprayed plots. The fruit infestation with flies was completely under control in trail plot. The highest incidence was noticed in trail no. 01 where chemical spray was uses. The number of fruit flies trapped per week was recorded in pheromone traps, the highest being in trail no. 1 (45 flies/ trap/week) (Tables 1 and 2). The average yield recorded 17.39 per cent increase in trap installed plots. This also resulted in reducing the cost of pesticide application nearly Rs.24015.65 per hectare that was spend on purchase and application ofagrochemical.

Table 1: Cucurbits fruit fly management

Trail No.	Farmer's method of control (Pesticide spray)		FLD recommendation			
	Yield (q/ha)	Pest incidence (%)	Yield (q/ha)	Pest incidence (%)	No, of flies/ trap/week	Per cent increase in yield
1	284.87	20	336.80	Nil	45	18.23
2	278.73	22	334.46	Nil	37	19.99
3	282.25	23	321.95	Nil	41	14.07
4	283.75	27	335.50	Nil	32	18.24
5	269.35	20	310.57	Nil	42	15.30
6	278.25	22	308.47	Nil	37	10.86
7	281.27	23	334.80	Nil	44	19.03
8	273.73	27	331.46	Nil	41	21.09
9	277.25	20	327.65	Nil	38	18.18
10	279.65	22	332.50	Nil	43	18.90
	278.91	22.60	327.42	Nil	40	17.39

Table 2: Cost of production and economics of trails.

Trail No.	Farmer's method of control (Pesticide spray)		FLD recommendation (Pheromone trap installation)		Reduction in Gross cost (Rs).	Increase in Gross return (Rs.)
	Gross cost (Rs.)	Gross return (Rs.)	Gross cost (Rs.)	Gross return (Rs.)		
1	45980.00	112300.00	43930.00	136400.00	2050.00	24100.00

2	43633.50	106685.00	41752.50	129580.00	1881.00	22895.00
3	42714.90	104439.00	40873.50	126852.00	1841.40	22413.00
4	46848.60	114546.00	44829.00	139128.00	2019.60	24582.00
5	47307.90	115669.00	45268.50	140492.00	2039.40	24823.00
6	45470.70	111177.00	43510.50	135036.00	1960.20	23859.00
7	46618.95	113984.50	44609.25	138446.00	2009.70	24461.50
8	45360.00	111730.00	43380.00	135830.00	1980.00	24100.00
9	44730.00	111100.00	42750.00	135200.00	1980.00	24100.00
10	46407.90	114769.00	44368.50	139592.00	2039.40	24823.00
Mean	45507.25	111640.00	43527.18	135655.60	1980.07	24015.65 (21.51%)

Conclusion

Keeping in view the economic importance of the cucurbits fruit fly and the crop, it can be managed locally at the growers fields using pheromone traps or other non- chemical methods of control like bagging of fruits, field sanitation augmentative releases of biological control agents, and soft insecticides. Use of pheromone traps helps in local area monitoring and management of fruit fly. In the present experiment the average yield recorded 17.39 per cent increase in trap installed plots. This also resulted in reducing the cost of pesticide application nearly Rs.24015.65 per hectare that was spend on purchase and application of agrochemical. So we can conclude that use of pheromone traps in cultivation of cucurbits play vital role in the management of fruit fly infestation at farmers field level.

Acknowledgment

The authors express their gratitude to the Senior Scientist & Head of Krishi Vigyan Kendra, Madhepura, Bihar Agricultural University, Sabour (Bhagalpur) for the essential assistance provided during the experiment.

References

Rakshit A, Karim A R, Hristovska T, Norton G W. 2011. Impact assessment of pheromone traps to manage fruit fly on sweet gourd cultivation. Bangladesh J Agri Res ;36(2):197-203.

Gupta D, Verma A K. 1992. Population fluctuations of the maggots of fruit flies *Dacus cucurbitae* Coquillett and *D. tau* (Walker) infesting cucurbitaceous crops. Adv. Pl. Sci. 5: 518-523

Dhillon M K, Naresh J S, Singh R, Sharma N K 2005a. Evaluation of bitter gourd (*Momordica charantia* L.) genotypes for resistance to melon fruit fly, Bactrocera *cucurbitae*. Indian J. Pl. Prot. 33(1): 55-59

Dhillon M K, Naresh J S, Singh R, Sharma N K. 2005b. Influence of physico-chemical traits of bitter gourd, *Momordica charantia* L. on larval density and resistance to melon fruit fly, *Bactrocera cucurbitae* (Coquillett). J. Appl. Ent. 129 (7): 393-399.

Dhillon M K, Singh R, Naresh J S, Sharma H C .2005c. The melon fruit fly, *B. cucurbitae*: A review of its biology and management. J. Insect Sci. 5: 40-60 [Online]. Available on: http://www. Insectscience.org. [Retrieved on: 7 th Oct., 2007].

Shooker P, Khayrattee F, Permalloo S 2006. Use of maize as a trap crops for the control of melon fly, *B. cucurbitae* (Diptera:Tephritidae) with GF-120. Bio-control and other control methods [Online]. Available on: http\\www.fcla. edu/FlaEnt/fe87 p354.pdf. [Retrieved on: 20 th Jan. 2008]

Nasiruddin M, Alam S N, M, Jasmine HS, Karim AN, Rajotte E. 2010.Management of cucurbit fruit fly, *Bactrocera cucurbitae*, in bitter gourd by using pheromone and indigenous bait traps and its effect on year-round incidence of fruit fly. 2010 : 10

AGRICULTURE BULLETIN
ISSN: 3049-2289

Speed Breeding: A Robust Tool to Accelerate Crop Breeding

Ritabrata Sarkar[1], Anurag Kumar[2], Pramod Kumar Meghwal[1], Souvik Ghosh[1] and Sudhir Kumar[1]
[1]Department of Genetics and Plant Breeding, [2]Department of Molecular Biology and Biotechnology, ICAR-Indian Institute of Agricultural Biotechnology, Ranchi, Jharkhand

Speed breeding is an advanced plant improvement technique that accelerates generation cycles by manipulating environmental conditions such as photoperiod, temperature, soil moisture, planting density, CO_2 concentration, and plant growth regulators. By increasing light duration, adjusting growth temperatures, regulating water stress, and harvesting immature seeds, researchers can drastically shorten crop life cycles—getting up to six generations per year in several major crops. Speed breeding also provides a robust platform for integrating high-throughput phenotyping, genotyping, marker-assisted selection, and gene-editing approaches, thereby enhancing the development of high-yielding, stress-tolerant, and nutritionally superior cultivars.

Introduction

The rising global population and environmental changes pose a threat to food security, as the current rate of improving important crops is insufficient to meet future needs. This slow progress is partly due to the long-life cycles of many crop plants. Researchers have introduced a technique called 'speed breeding' to overcome this by dramatically shortening the time it takes for a plant to reproduce. Using this method, researchers can achieve up to 6 generations annually for crops such as spring wheat, barley, chickpea, and pea, and 4 generations for canola, effectively doubling or tripling the speed compared to standard greenhouse practices. Speed breeding (SB) techniques, particularly when implemented within fully enclosed, controlled-environment growth chambers, offer a powerful platform to accelerate various plant research activities. Speed breeding could act as a foundational platform that brings together high-throughput phenotyping and genotyping methods, genomic or marker-assisted selection, and gene-editing tools for improvement of the traits in crop species.

Brief History of Speed Breeding

In 1990s, NASA in association with Utah State University developed a new breeding technique to grow crops in space, and developed first dwarf wheat variety “USU-Apogee”. In 2018, Sreya Ghosh (JIC), Luis Yanes (Earlham Institute), Oscar Gonzalez (Quadram Institute), Marcela Mendoza (Aarhus University), and Ricardo Ramirez-Gonzalez (JIC) created a bench-top controlled environment growth chamber for speed-breeding crop plants and named it “GrowCab”. Researchers at the John Innes Centre and the University of Queensland, developed speed breeding to accelerate crop breeding cycles. Thereafter, Lee Hickey and co-workers, at University of Sydney, John Innes Center and University of Queensland coined the term ‘Speed Breeding.’

Speed Breeding: Concept and Mechanism

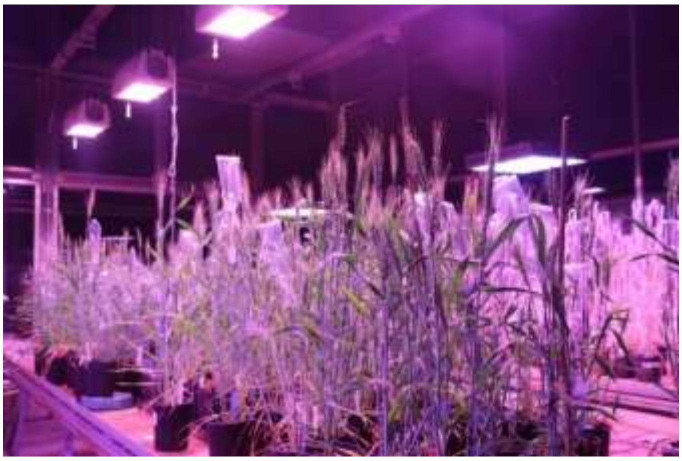
Speed breeding is an innovative plant science technique that involves the management of environmental conditions under which crops are grown to drastically reduce the time it takes to complete a plant generation, thereby accelerating crop breeding and research. This concept relies on two primary mechanisms:

1. Manipulating Light (Prolonged Photoperiods)

The core principle of speed breeding involves extending the duration of the light period (photoperiod) a plant receives each day, often combined with high-intensity lighting. Plants naturally move from the vegetative stage (growth of leaves and stems) to the reproductive stage (flowering and seed production) based on cues like day length. By providing enhanced and intense lighting for a prolonged period (sometimes up to 22 hours per day) in a controlled environment, such as a

ISSN: 3049-2289

glasshouse or growth chamber, the plant's development rate is significantly accelerated. This intense, day-long light regime tricks the plant into maturing and flowering much faster than it would under natural or typical greenhouse conditions. This rapid development shortens the plant's overall life cycle.



2. Harvesting Immature Seeds

The second key step in this technique further reduces the generation time by interrupting the natural cycle before the seed is fully matured and dried out on the parent plant. Once the seeds reach a viable stage, they are harvested early (immaturely). These green, immature seeds are then immediately subjected to techniques that induce rapid germination (e.g., specific drying or scarification treatments). This eliminates the long, natural drying and dormancy period that occurs after seeds ripen on the parent plant, allowing the next generation to be sown almost immediately.

Components to be Optimized for Speed Breeding Programme

Speed breeding depends on the adjustment of different environmental conditions outlined below.

1. Adjustment of the photoperiod conditions

Different crop species—and even different genotypes within the same species—respond differently to day length when it comes to flowering and seed production. Therefore, identifying the ideal light spectrum, brightness, and duration needed to stimulate flowering in each crop and genotype is essential. Light sources that provide photosynthetically active radiation (PAR) in the 400–700 nm range, at intensities between 360 and 650 μmol/m²/s, have been effectively used across different crop species.

2. Control of the temperature conditions

Adjustments to air and soil temperatures influence how plants germinate and grow, promoting faster development, flowering, seed production, and maturation. Extremely low or high temperatures can trigger various effects on plant growth rates, including the transition from vegetative to reproductive phases. Most crops need temperatures between 12 and 30 °C for successful germination, while the ideal temperature range for growth, flowering, and seed formation is generally 25 to 30 °C.

3. Control of soil moisture levels

Water stress in the soil can greatly influence plant growth and development, impacting traits like plant height, time to flowering, and seed formation and maturity. Conditions such as drought or flooding can induce earlier flowering and maturation, which can be utilised in speed breeding. Drought triggers earlier flowering, that acts as an "escape mechanism" in most of the crops that helps ensure the production of the next generation. After flowering, lowering soil moisture levels can speed up grain filling and maturation. In several crops, speed breeding has involved from decreasing watering from daily to twice a week between four and six weeks after flowering, and then stopping watering entirely during the final week before harvest.

4. Plant population density

High-density planting involves cultivating crops at densities higher than those needed for maximum yield. When plants are crowded, they grow taller because they compete for light, which accelerates their shift from vegetative to reproductive growth.

5. Adjusting carbon dioxide concentrations

Increased carbon dioxide (CO_2) levels can enhance plant growth and accelerate the transition from

ISSN: 3049-2289

vegetative to reproductive stages in several species. However, crop species and even genotypes within the same species differ in how they respond to higher CO_2 concentrations. Speed breeding that relies on regulating CO_2 levels required specialized equipment, including growth chambers, CO_2 cylinders, and regulators, as well as additional operating expenses. It also requires strict compliance with health and safety protocols when managing CO_2 levels.

6. Application of nutrients, hormones, and tissue culture techniques

Plant nutrients and hormones are used to speed up growth, stimulate flowering and seed formation, and to promote the germination of immature seeds in vitro. Different response to plant growth regulators are observed when they are used in controlled conditions—such as greenhouses and growth chambers—where photoperiod and temperature can be precisely regulated. For example, using a combination of auxin and cytokinin hormones resulted in 100% in vitro flowering and 90% seed set in faba bean. Likewise, applying 6-benzylaminopurine four days after flowering enhanced seed set in faba bean.

Challenges of speed breeding

The use of speed breeding techniques offers a promising strategy to expedite traditional breeding programs. Nevertheless, successful implementation of this technology demands specialized knowledge, robust and integrated plant phenomics resources, suitable infrastructure, and continuous financial investment to support research and advancement. The widespread adoption of speed breeding is hindered by several key challenges like limited access to suitable facilities, lack of trained personnel, operational changes, securing long-term funding etc.

Conclusion:

The application of speed breeding can accelerate the development of high performing cultivars with phenotypically desirable traits by reducing the amount of time, space and resources invested in the selection and genetic advancement of superior crop varieties, enabling breeders to release improved varieties more quickly. Efficient workflows that minimize labour and use low-cost facilities are essential for successfully incorporating speed breeding technology into crop improvement programs. When combined with conventional breeding, marker assisted selection, and gene-editing methods, speed breeding can improve the selection of elite genotypes and lines with beneficial traits—such as higher yield, improved nutritional quality, and resistance to biotic and abiotic stresses. Techniques such as single seed descent method, single plant selection method are particularly well suited to this approach. Despite these advantages, the use of speed breeding in many developing countries—especially within public breeding programs—remains limited due to shortages of skilled breeders and technicians, inadequate infrastructure, and unreliable water and electricity supplies. Additionally, a lack of supportive government policies and funding hampers the adoption and long-term implementation of speed breeding in these programs.

Reference:

Watson, A., Ghosh, S., Williams, M. J., Cuddy, W. S., Simmonds, J., Rey, M.-D., Asyraf Md Hatta, M., Hinchliffe, A., Steed, A., Reynolds, D., Adamski, N. M., Breakspear, A., Korolev, A., Rayner, T., Dixon, L. E., Riaz, A., Martin, W., Ryan, M., Edwards, D., Hickey, L. T.. (2018). Speed breeding is a powerful tool to accelerate crop research and breeding. Nature Plants, 4(1), 23–29. https://doi.org/10.1038/s41477-017-0083-8

Shimelis, H., Gwata, E. T., & Laing, M. D. (2019). Crop improvement for agricultural transformation in Southern Africa. In R. A. Sikora, E. R. Terry, P. L. G. Vlek, & J. Chitja (Eds.), Transforming Agriculture in Southern Africa, 1st, ed. (pp. 97–103). Routledge. https://doi.org/10.4324/97804 29401701

Wanga, M. A., Shimelis, H., Mashilo, J., & Laing, M. D.. (2021). Opportunities and challenges of speed breeding: A review. Plant Breeding, 140(2), 185–194. https://doi.org/10.1111/pbr.12909

AGRICULTURE BULLETIN
ISSN: 3049-2289

Impact of Fortified Rice on Nutritional Outcomes Among Women: A Growing Strategy to Strengthen Micronutrient Intake and Well-Being

Kamakshi Kamalini jali [1], Ipsita Rautaray[2], Aswini Kumar Sahoo[3], Amar Bikram Sahoo[4], S.Kshanti Somnath[5]
MSc. Research Scholars (Department of Food and Nutrition)
Odisha University of Agriculture and Technology, Bhubaneswar

Malnutrition, the lack of micronutrients continues to be a widespread issue in public health disproportionately impacting women in their reproductive years. Since staple foods make up the majority of consumption in developing countries fortifying rice has become an effective approach to provide vital vitamins and minerals without requiring changes, in dietary habits. This article investigates the effects of fortified rice on nutritional results in women assessing its effectiveness in reducing anemia and neural tube defects examining the cost-effectiveness of the program and tackling logistical and societal obstacles, including public misunderstandings. Combining data and policy analysis this study asserts that rice fortification is more than just a nutritional additive; it serves as a vital tool, for promoting gender-equitable public health.

Introduction

The Green Revolution of the century stands as a significant milestone in human history. Through the development of high-yield cereal varieties and advanced farming methods global famine was largely. Caloric needs for billions were met. Nevertheless this success in agriculture came with a drawback: it emphasized volume over nutritional value. Although the output of calorie- staples such as rice, wheat and maize surged, the production and intake of nutrient-rich pulses, vegetables and animal proteins largely remained stagnant or became inaccessible, to the impoverished1. This change led to a contradiction termed " hunger." Currently than two billion individuals worldwide experience micronutrient shortages even though they intake sufficient calories. They feel satiated. Lack the vital vitamins and minerals needed for proper bodily functions. Rice plays a role in this matter.

It serves as the food source for, over half of the global population especially in middle-income nations (LMICs) across Asia, Africa and Latin America. In nations such as Bangladesh, Cambodia and regions of India rice may account for much as 70% of daily caloric consumption2. Yet the contemporary milling technique generates a gap. To manufacture the polished rice favored by buyers the husk, bran and germ are taken away. These layers hold the bulk of the grain's nutrients, such, as B vitamins, iron and zinc. What is left is the endosperm—abundant in starch yet devoid of nutrients. For at-risk groups to maintain a varied diet depending on polished rice leads straight to malnutrition. Fortification—the addition of crucial micronutrients, to food—provides a scientifically validated widely applicable method to recover this diminished nutritional benefit.

The Burden of Malnutrition: A Gendered Crisis

Hidden hunger does not affect all genders equally. Women aged 15–49 years carry the load of micronutrient shortages because of the specific physiological requirements related to menstruation, pregnancy and breastfeeding.

The Anemia Epidemic

Iron Deficiency Anemia (IDA) stands as the prevalent nutritional ailment worldwide. As reported by the World Health Organization (WHO) anemia impacts 30% of women who are not pregnant and 40% of pregnant women globally3. In developing countries these rates exceed 50%. For women anemia represents a socio- burden. It leads to tiredness lowered mental performance and decreased ability to perform physical labor. In economies where women engage in strenuous physical work this results in reduced earnings and economic slowdown.

ISSN: 3049-2289

The Intergenerational Cycle

The effects of malnutrition reach well beyond the mother herself. A mother suffering from malnutrition has an increased chance of delivering a baby with birth weight. Such newborns are at risk of growth retardation, developmental cognitive impairments and weakened immune systems. This establishes an " cycle of malnutrition " wherein the mothers disadvantages are biologically passed down to her child4. Additionally a lack of folate, around the time of conception is the leading cause of Neural Tube Defects (NTDs) including spina bifida and anencephaly. These heartbreaking birth anomalies can mostly be avoided if the mother maintains folate levels prior, to realizing she is expecting—a critical period frequently overlooked by conventional supplementation efforts.

The Art of Strengthening: Where Innovation Embraces Heritage

Enhancing rice with nutrients is more complicated than fortifying salt or wheat flour. Since rice is eaten as a grain nutrients cannot just be sprinkled on as a powder as these would be washed off when rinsed—an everyday habit, in many cultures. To address this issue food scientists invented Hot Extrusion Technology.

The Extrusion Process

The procedure starts by grinding broken rice grains into a powder. This powder is combined with a designated "premix" of micronutrients (Iron, Folic Acid and Vitamin B12) and water to create a dough. The dough is then pushed through a device known as an extruder, which shapes the dough into kernels resembling rice in shape, size and color by applying heat and pressure. These formed grains are known as Fortified Rice Kernels (FRK). To guarantee consistency the FRK are dried before being combined with milled rice usually at a proportion of 1:100 (1 kg of FRK incorporated into 100 kg of natural rice).

Nutrient Bioavailability

Selecting the iron fortificant is essential. Ferric Pyrophosphate is the compound utilized since it is white (preventing rice discoloration) and fairly stable. To improve the uptake of this iron in the system formulations frequently incorporate citric acid and trisodium citrate nowadays. The addition of Vitamin B12 is also crucial for vegetarian groups, with minimal dietary B12 consumption.

Impact on Nutritional Outcomes: The Clinical Evidence

The effectiveness of enriched rice has been thoroughly evaluated through controlled experiments and extensive pilot initiatives.

1. Hematological Improvements

An organized evaluation of rice fortification initiatives has revealed enhancements in hemoglobin concentrations and decreases in anemia rates. For example, research conducted among school-aged children and women in India indicated that intake of iron-enriched rice, via the

The midday meal program substantially raised iron reserves (concentrations) over a period of six months6. In contrast, to iron supplements (pills) which frequently lead to discomfort and poor compliance fortified rice offers a "passive" mild-dose approach that steadily and safely enhances nutrient levels.

2.Reducing Neural Tube Defects

Countries requiring acid fortification in wheat flour (like the USA and Canada) have observed a 25% to 50% decline in NTD rates. Fortifying rice provides protection for communities where rice, rather than wheat is the main staple. By guaranteeing a level of folic acid consumption for all women of childbearing age fortified rice serves as a biological safeguard, for embryo development7.

3.Functional Health Benefits

In addition to indicators fortification influences functional well-being. Addressing deficiencies of Vitamin B12 and iron results, in energy, improved focus and strengthened immune response. For girls this may lead to improved academic achievement; for grown women it equates to greater efficiency and an improved standard of living.

ISSN: 3049-2289

4. Economic Viability: The Copenhagen Consensus

Public health initiatives are frequently evaluated based on their return, on investment (ROI). In this context rice fortification stands out. The Copenhagen Consensus, a group of Nobel Prize winners and economists has repeatedly identified micronutrient fortification as one of the budget-friendly development strategies globally. The expense to enhance rice with nutrients is projected to raise the price by merely 1% to 2%—approximately $0.40 to $0.60 USD per individual annually. Conversely the economic damage caused by anemia (through decreased productivity and medical expenses) can reduce a country's GDP by percentage points. For every dollar spent on fortification the anticipated return, in gains is about $9 to $30 fueled by a healthier more efficient labor force and lowered healthcare costs.

Challenges to Implementation

Despite the clear benefits, scaling up rice fortification involves significant hurdles.

Supply quality Assurance : The effectiveness of the intervention depends on preserving the 1:100 blending ratio. Should this ratio deviate the rice becomes either ineffectual or possibly

A metallic flavor establishing a system that enables local millers to obtain premium FRK and mix it precisely calls for government regulation.

The "**Plastic Rice"** Misconception: Possibly the greatest obstacle is social, than technical. In nations the launch of fortified rice has sparked rumors that authorities are handing out "plastic rice." Since FRK are made from flour and might float differently or dissolve after soaking consumers frequently confuse them with artificial substances. Tackling this issue demands Information, Education and Communication (IEC) initiatives.

Fortified rice embodies the intersection of food science, economic considerations and health policy. It tackles the " hunger" that quietly diminishes the potential of countless women. By converting a serving of rice into a carrier of vital nutrients countries can lessen anemias impact shield future generations from avoidable birth defects and strengthen women with the energy necessary to succeed.

References

- Bouis HE, Hotz C, McClafferty B, Meenakshi JV, Pfeiffer WH. Biofortification: a new tool to reduce micronutrient malnutrition. Food Nutr Bull. 2011;32(1 Suppl):S31-S40.
- Muthayya S, Sugimoto JD, Montgomery S, Maberly GF. Global Trends in Rice Production, Trade, Supply, and Consumption Ann N Y Acad Sci. 2013;1324(1):7-14.
- World Health Organization. Global Anaemia Estimates, 2021 Edition. Geneva: World Health Organization; 2021.
- Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet. 2013;382(9890):427-451.
- Steiger G, Müller-Fischer N, Condo D, Schmitt H. Fortification of rice: technologies and nutrients. Ann N Y Acad Sci. 2014;1324(1):29-39.
- Perignon M, Fiorentino M, Kuong K, et al. Enhancing Micronutrient Status in Cambodian Schoolchildren through Fortified Rice: A Double-Blind Cluster-Randomized Study. 2016;8(1):29.
- De-Regil LM, Suchdev PS, Vist GE, Walleser S, Peña-Rosas JP. Home Fortification of Complementary Foods with Multiple Micronutrient Powders for Improving Health and Nutrition in Children Under Two Years: A Cochrane Systematic Review

AGRICULTURE BULLETIN
ISSN: 3049-2289

Farm Pond: A Climate Resilient Technology for Vidarbha Region

V. P. Pandagale[1], A.R. Mhaske[2] R.S. Patode[3] A.B. Chorey[4] and S.N. Dongardive[5]
[1] Ph.D. Scholar, Dept. of SWCE, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.)
[2] Head, Department of Soil & Water Conservation Engg. Dr. PDKV, Akola (M.S.)
[3] Senior Scientist (SWCE), AICRP for Dryland Agricutlure, Dr. PDKV, Akola (M.S.)
[4]Chief Scientist, AICRP for Dryland Agricutlure, Dr. PDKV, Akola (M.S.)
[5] Project Assistant, Dept. of SWCE, Dr. PDKV, Akola (M.S.)

Water harvest is one of the key components of rainfall farming in semi-arid region. Harvesting surplus of runoff and in ponds and recycling the same for providing supplemental irrigation to kharif crop or pre-sowing to rabi crop. Due to climate change the behaviour of rainfall become erratic and Uncas Fari and there is high intense storm at short duration out lead at large intensity storm far long duration. Due to their sustainable naturally ground water recharging and building at good amount of soil moisture is decreased. Therefore, some tunes rainfall occurs make than water requirement of the crop and during the erratically growth stages of crop due to gap in rainfall water stress condition occurs which directly reduced the crop yield directly upto 50%. Therefore, harvesting the excess runoff in the pond and recycling it for providing partiture regulation during water stress period is the need at day.

Salient Findings

Geographical Situation the Vidarbha region with eleven districts is located between between 17^{0}57' - 21^{0}46' N Latitude and 75^0 57'- 80^0 59' E Longitude having total geographical area of 97.23 lakh ha which is 31.61% of Maharashtra. It covers an area of about 97.23 lakh hectares accounting for about 31.6 per cent of Maharashtra's total area. Area under cultivation in the region on different settings and agro-climatic zones has varying degrees of potentiality for agricultural use. The average production of the principal crops of the region is below the national average and hence there is much scope for increasing total production. The productivity of the land is closely related to the inherent soil characteristics and hence the appraisal of soil and land resource is the prerequisite for a rational land use planning and sustainability of agriculture in the region Vidarbha. region in Maharashtra comprises 11 districts viz. Yavatmal, Akola, Amravati, Wardha, Buldhana, Washim, Nagpur, Chandrapur, Bhandara, Gadchiroli and Gondia. This region has, for various reasons, remained backward industrially as well as agriculturally. Livelihood of around 65% rural population of this region is dependent on agriculture and allied activities. However, agriculture in this region is comparatively less productive than the State and National averages. Cotton is the most important cash crop of western Vidarbha region. Eight of eleven districts of Vidarbha are primarily cotton growing. Cotton farming is the backbone of the farmers of Yavatmal, Akola, Amravati, Wardha, Buldhana and Washim districts of western Vidarbha. An estimated 12 lakh ha is under cotton production in Vidarbha. However, with about 400-600 mm of annual rainfall and very limited irrigation facilities at disposal, cotton farmers are often exposed to higher risks that many a times result in loss of income.

Farm Pond

Farm Pond is a dug-out structure with definite shape and size having proper inlet and outlet structures for collecting the surface runoff flowing from the farm area. It is one of the most important rainwater harvesting structures constructed at the lowest portion of the farm area. Depending on the source of water and their location, farm ponds are grouped into four types: 1) Excavated or Dug out ponds 2) Surface ponds 3) Spring or creek fed ponds and 4) Off stream storage ponds.

ISSN: 3049-2289

Table: Types of water stress and underlying causes in semiarid and dry sub-humid tropical environments.

	Dry spell	Drought
Meteorological		
Frequency	Two out of three years	One out of ten years
Impact	Yield reduction	Complete crop failure
Cause	Rainfall deficit of 2 to 5 week during crop growth periods	Seasonal rainfall below minimum seasonal plant water requirement
Agricultural		
Frequency	More than two out of three years	One out of ten years
Impact	Yield reduction or complete crop failure	Complete crop failure
Cause	Low plant water availability and poor plant water uptake capacity	Poor rainfall partitioning, leading to seasonal soil moisture deficit for producing harvest (where poor partitioning refers to a high proportion of runoff and non-productive evaporation relative to soil water infiltration at the surface

Soil Type

The districts such as Amravati (located in the west Vidarbha), Yawatmal Akola and Washim have the presence of black type of soil. In the Maharashtra, the northern parts of Gondia, Chandrapur, Gadchiroli, and Nagpur have the presence of clay type of soil. The draining capacity of this soil is very low. Hence, it is fertile soil. This soil cannot seep water quickly because of its high sediment content. For construction of farm pond, the soils must have low hydraulic conductivity with minimum seepage and percolation so that water can be retained. Different types of farm ponds: surface, spring and off stream. Soils with a low infiltration rate are most suitable for construction of pond.

Table: Major soil types of Vidarbha region (lakh ha)

Sr. No.	District	Coarse shallow	Medium deep black	Deep black	Laterite & Lateritic	Yellow Brown Soils	Salt Affected
1	Amravati	1.84	4.58	1.21	-	-	0.61
2	Akola	0.71	6.12	1.44	-	-	1.68
3	Buldhana	3.50	2.69	1.13	-	-	0.45
4	Yavatmal	5.73	0.91	2.01	-	-	-
5	Wardha	2.51	2.64	1.78	-	-	-
6	Nagpur	1.11	1.34	0.34	-	2.87	-
7	Bhandara	-	-	0.15	-	3.98	-
8	Chandrapur & Gadchiroli	0.65	0.78	1.32	0.84	2.94	-
	Vidarbha	**16.05**	**19.06**	**9.38**	**0.84**	**9.79**	**2.74**

Table: Infiltration rates of different types of soil

Sr. No.	Soil type	Infiltration rate (cm/hr)
1	Coarse sand	2.0-2.5
2	Fine sand	1.2-2.0
3	Fine sandy loam	1.2
4	Silty loam	1.0
5	Clay loam	0.8

The soils having outcrops and stones must be avoided for digging farm ponds. The soil profile depth must be investigated before digging of the pond. The soils having good depth of >1 m, free of stones, low Ph, Ec and ground water level may be chosen for site selection for farm pond.

ISSN: 3049-2289

Need to do

To effectively address the issue, the following regulatory and policy measures need to be seriously considered.

- The extraction of groundwater to store it in farm ponds should be strictly prohibited.
- In any watershed area, considering the overall sustainability of the water resource and the carrying capacity of the area, the total number of farm ponds that can be constructed should be fixed.
- It is important to control the enlargement of the size and depth of farm ponds by farmers beyond the sanctioned norms.
- Changes required in the provision of subsidy: small farmers who depend solely on rainfall should be the focal point for this.
- Alternatives to the plastic lining: The high-micron plastic paper, which is used for lining the farm pond is costly and harmful for the environment. Therefore, there is a pressing need to research on cost-effective and environment-friendly alternatives to the plastic lining.
- The refusal to adopt a grant model, wherein the farmers would passively receive financial assistance, will make the farm pond programme a social enterprise, achieving scale and impacting a large population.

Current water crisis:

- Variability of monsoons has increased in India and groundwater tables is rapidly depleting.
- A number of peninsular regions like Bundelkhand, Vidarbha and Marathwada have been facing recurring drought-like situations.
- The severe drought prevailing in the country has caused distress in more than 250 of 600-plus districts across 11 states, affecting about 330 million people.

Benefits of farm ponds:

- It helps in enhancing water control.
- It contributes to agriculture intensification and boost farm incomes.
- It collects excess runoff during rainy period.
- They are cost-effective.
- Stored water can be used for supplemental irrigation to crops.
- It is useful as drinking water for cattle's during drought situation.
- It can be used for spraying pesticides.
- It conserves soil and moisture.

References:

1. Banerjee, Shoumojit 2016. Maharashtra Water Crisis: Section 144 Imposed in Ahmednagar District, 22 April, http://www.thehindu.com/news/national/othe r states/maharashtra-water-crisis-section-144-imposed-in-ahmednagar district/article8508750.ece.
2. Decipher IAS 2016. Budget 2016 At a Glance, 2 March, http://decipherias.com/dailynews/ daily-current-affairs1st-march-2016-budget-at a-glance.
3. TOI 2015. Maharashtra Government Wants Ponds in All Farms in Marathwada, Times of India, 18 September, http://timesofindia.indiatimes.com/india/Ma harashtra government-wants-ponds-in-all-farms-in-Marathwada/articleshow/49007507.cms

AGRICULTURE BULLETIN

ISSN: 3049-2289

TALEs: Arms and Ammunition of Xanthomonas

Anurag Kumar[1,2]*, Hemlata Singh[3], Shambhu Krishan Lal[1], Sudhir Kumar[1], Lalchand[1,2]

[1]*ICAR–Indian Institute of Agricultural Biotechnology, Ranchi 834003, Jharkhand, India.*

[2]*ICAR-Indian Agricultural Research Institute, Pusa, New Delhi 110012 India.*

[3]*Department of Botany, Physiology & Biochemistry, CBS&H, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar*

Introduction

Rice is one of the major global important crops across the world. To ensure food and nutritional security the development of newer crop varieties is the need of hour. This entails considering a number of factors, including yield and resistance to biotic and abiotic stress. The biotic stress affecting the crop yield includes the plant disease caused by bacteria, fungi and viruses as well as damage caused by insect pests and nematodes. Among the bacterial disease, bacterial leaf blight caused by *Xanthomonas oryzae* pv. oryzae (*Xoo*) is the deadliest which is well characterized by its **'Kresek'** symptoms. Transcription activation like effectors (TALEs) are the DNA binding protein deployed by these Ɣ-proteobacteria through Type III secretion system are the major key determinants of the rice-*Xoo* interaction(Hutin et al., 2015). These proteins are essential warfare for *Xoo*-rice interactions, mostly by influencing the expression of host gene. An N-terminal type III system secretion signal, which directs the protein's translocation into host cells via a type III secretion system; a central repeat region (CRR) made up of tandem repeats of 33–35 amino acid residues, each of which contains repeat-variable residues (RVDs) that interact with the host DNA via its RVDs; a recently discovered transcription factor binding (TFB) motif; three nuclear localization signals, which direct the protein's translocation into the host nucleus; and a highly conserved C-terminal acidic activation domain, which permits transcription. The conserved core repeat region made up of 33–34 amino acids determine the selectivity of these TAL effectors. As the name implies, transcription activator-like effectors, or TALEs, work by imitating transcription factors found in plants. The CRRs often have almost identical repeats, but they vary in numbers and configuration. The repeat variable residues (RVDs) located at positions 12 and 13 interact directly with host effector binding elements (EBEs) in the promoters of host genes and regulate their expression(NIÑO-LIU et al., 2006) by specifically targeting a class of genes called *SWEETs*.

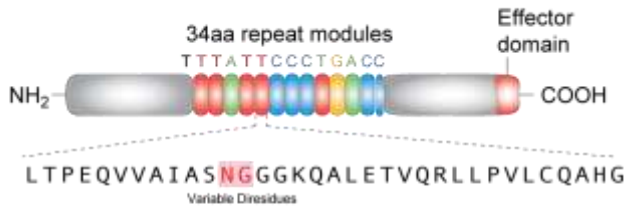


Fig:- TALe protein: Showing central repeat regions (https://2013.igem.org/File:Tale1.png)

A crucial class of sugar transporters known as *SWEETs* (Sugars will eventually be exported transporters) genes are necessary for a number of physiological functions in plants, such as growth, development, and reactions to external stimuli. *SWEETs* have been divided into four clades according on their phylogeny and substrates. Members of clade III are involved in the transport of sugars like sucrose, while members of clades I, II, and IV are involved in the efflux of monosaccharides like glucose, galactose, and fructose (Chen et al., 2012). Clade III is the largest of those clades and has the greatest number of *SWEET* genes from both dicots and monocots.

DNA Binding Specificity

The specificity of a TALE protein is determined by the quantity of its repeats and the identity of the RVDs: the overall number of repeats correlates with the length of the DNA target, and each RVD specifies the nucleotide recognized at its corresponding location. Significantly, TALE target sites invariably possess a thymine (T) just upstream of the initial repeat, a prerequisite that seems essential for optimal binding (Boch et al., 2009).The correlation between repeat-variable di-residues (RVDs) and their corresponding preferred nucleotides was initially discovered in 2009 by two autonomous research groups, who elucidated the DNA-recognition code of transcription activator–like effectors (TALEs) (Boch et al., 2009; Moscou & Bogdanove, 2009). According to this coding, the HD RVD preferentially binds cytosine (C), NG binds thymine (T), NI binds adenine (A), NN recognizes either guanine (G) or adenine (A), N* interacts with C, IG also binds T, and NS can pair with any nucleotide (A, C, G, or T). Four RVDs—HD, NN, NI, and NG—represent about 75% of all naturally occurring variants, despite the fact that there are many different types (Moscou & Bogdanove, 2009).Structural research released in 2012 offered additional mechanistic understanding of the one-repeat-to-one-nucleotide recognition principle. High-resolution TALE–DNA complex structures deciphers that each repeat is composed of two α-helices connected by a loop that contains RVD. According to Deng et al. (2012a) and Mak et al. (2012), these repeats form a right-handed superhelix that encircles the major groove of DNA. The hypervariable 13th residue of each RVD creates base-specific contacts, while the 12th position residue helps to maintain repeat stability instead of direct DNA binding.

Conclusions and Future Perspective

With numerous applications documented in recent years, TALEN-based targeted genome modification has quickly emerged as a key technique in genome engineering (Joung & Sander, 2012; Marx, 2012; Mussolino & Cathomen, 2012; Pennisi, 2012). However, due to a number of difficulties, plants continue to advance more slowly than other organisms. First, the efficiency of TALEN DNA-targeting needs to be improved. Many TALEN pairs exhibit little to no nuclease function, despite the fact that shortened TALENs have successfully produced knockouts in rice and Brachypodium (Shan et al., 2013; Zhang et al., 2013). Although broad design guidelines are currently available, efficiency may be increased by upgrading TALE scaffolds, optimizing FokI variants, strengthening linkers, and modifying spacer lengths. Second, some plant species require effective delivery systems, particularly those that are difficult to change, like wheat. Third, in order to improve precision DNA repair over NHEJ and enable targeted insertions, replacements, and trait introduction, a deeper comprehension of homologous recombination is necessary. Fourth, in order to increase the options for genome manipulation, TALEN applications should be extended to more crop species by modifying validation and delivery methods and integrating TALEs with other functional domains, such as activators, repressors, recombinases, methylases, and nickases (Mahfouz & Li, 2011; Curtin et al., 2012). TALENs provide a potent platform for plant genome modification despite present constraints (Baker, 2012). Compared to conventional transgenic crops, they allow for quick, accurate, marker-free genome alterations without introducing foreign DNA, which may allay regulatory worries (Kuzma & Kokotovich, 2011). TALENs are positioned to lead the next wave of plant genome engineering as adaptable molecular scissors.

References:

- Baker, M. (2012). Gene-editing nucleases.
- Boch, J., Scholze, H., Schornack, S., Landgraf, A., Hahn, S., Kay, S., ... & Bonas, U. (2009). Breaking the code of DNA binding specificity of TAL-type III effectors. *Science*, *326*(5959), 1509-1512.
- Chen, L. Q., Qu, X. Q., Hou, B. H., Sosso, D., Osorio, S., Fernie, A. R., & Frommer, W. B. (2012). Sucrose efflux mediated by SWEET proteins as a key step for phloem transport. *Science*, *335*(6065), 207-211.
- Curtin, S. J., Voytas, D. F., & Stupar, R. M. (2012). Genome engineering of crops with designer nucleases. *The Plant Genome*, *5*(2).
- Deng, D., Yan, C., Pan, X., Mahfouz, M., Wang, J., Zhu, J. K., ... & Yan, N. (2012). Structural basis for sequence-specific recognition of DNA by TAL effectors. *Science*, *335*(6069), 720-723.

- Hutin, M., Sabot, F., Ghesquière, A., Koebnik, R., & Szurek, B. (2015). A knowledge-based molecular screen uncovers a broad-spectrum Os SWEET 14 resistance allele to bacterial blight from wild rice. *The Plant Journal*, *84*(4), 694-703.
- Joung, J. K., & Sander, J. D. (2013). TALENs: a widely applicable technology for targeted genome editing. *Nature reviews Molecular cell biology*, *14*(1), 49-55.
- Kuzma, J., & Kokotovich, A. (2011). Renegotiating GM crop regulation: Targeted gene-modification technology raises new issues for the oversight of genetically modified crops. *EMBO reports*, *12*(9), 883-888.
- Mahfouz, M. M., Li, L., Shamimuzzaman, M., Wibowo, A., Fang, X., & Zhu, J. K. (2011). De novo-engineered transcription activator-like effector (TALE) hybrid nuclease with novel DNA binding specificity creates double-strand breaks. *Proceedings of the National Academy of Sciences*, *108*(6), 2623-2628.
- Mak, A. N. S., Bradley, P., Cernadas, R. A., Bogdanove, A. J., & Stoddard, B. L. (2012). The crystal structure of TAL effector PthXo1 bound to its DNA target. *Science*, *335*(6069), 716-719.
- Marx, V. (2012). Genome-editing tools storm ahead. nature methods, 9(11), 1055-1059.
- Moscou, M. J., & Bogdanove, A. J. (2009). A simple cipher governs DNA recognition by TAL effectors. *Science*, *326*(5959), 1501-1501.
- Mussolino, C., & Cathomen, T. (2012). TALE nucleases: tailored genome engineering made easy. *Current opinion in biotechnology*, *23*(5), 644-650.
- NIÑO-LIU, D. O., Ronald, P. C., & Bogdanove, A. J. (2006). Xanthomonas oryzae pathovars: model pathogens of a model crop. *Molecular plant pathology*, *7*(5), 303-324.
- Pennisi, E. (2012). The tale of the TALEs.
- Shan, Q., Wang, Y., Chen, K., Liang, Z., Li, J., Zhang, Y., ... & Gao, C. (2013). Rapid and efficient gene modification in rice and Brachypodium using TALENs. *Molecular plant*, *6*(4), 1365-1368.
- Zhang, Y., Zhang, F., Li, X., Baller, J. A., Qi, Y., Starker, C. G., ... & Voytas, D. F. (2013). Transcription activator-like effector nucleases enable efficient plant genome engineering. *Plant physiology*, *161*(1), 20-27.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Space Breeding: Farming Beyond Earth

Souvik Ghosh[1,2]*, Deblina Pal[1,2], Ritabrata Sarkar[1,2], Anurag Kumar[1,2] and Lalchand[1,2]
[1]ICAR–Indian Institute of Agricultural Biotechnology, Ranchi 834003, Jharkhand, India.
[2]ICAR-Indian Agricultural Research Institute, Pusa, New Delhi 110012 India.

Since humans first ventured into space, scientists have been curious about how the unusual conditions beyond Earth, especially microgravity and cosmic radiation, affect the way plants grow. Over the years, many experiments have been carried out to understand these effects and to explore whether space can help us develop better crop varieties. When seeds or plants are grown in space, they face extreme radiation and weightless conditions, which often trigger unique genetic and physical changes like variations at the cellular and molecular level, alterations in chromosomes and shifts in biochemical pathways. The DNA damage and chromosomal changes caused by cosmic radiation create a wide range of natural mutations. Such mutations can be extremely valuable, as they may produce new crop types that are more resilient and adaptable to tough environments on Earth. This article entails all the necessary details of space breeding including how the space-induced genetic changes occur, what recent space-growing experiments have discovered, and how these insights can shape future space-breeding programmes for next-generation crops.

Introduction

Space breeding (also called space mutagenesis or aerospace breeding) is a unique technique in which seeds or plant materials are sent into space (typically 200–400 km altitude) and exposed to microgravity and intense cosmic radiation to trigger genetic changes, leading to the development of new and improved plant varieties with desirable characters. The formal development of space breeding began with Chinese researchers in 1987. Since then, China has built a strong national research network dedicated to this field, leading to major breakthroughs and impressive progress over the last two decades. Space breeding is a new brand of plant breeding, the next generation plant breeding, which use different cosmic rays as the source of induction of mutation in hoping to get some novel, useful and improved versions of the previous strains of plants, which can reshape the agriculture. It is a modern and powerful method for creating improved crop mutants. Above the ozone layer, the space environment gradually loses gravity, air, magnetic protection and normal atmospheric pressure. This region is exposed to intense cosmic radiation, whose effects on living organisms are still not fully understood. Space also functions as an extreme vacuum. As interest grows in the possibility of sustaining life on Mars, scientists are carrying out extensive laboratory studies and other research to explore how life might adapt to such conditions. Scientists use spacecraft, satellites, and even high-altitude balloons to send seeds beyond Earth, where they are exposed to space conditions that trigger natural mutations. When these seeds are grown back on Earth, the next generation of plants often shows noticeable genetic variations. Cauliflower seeds exposed to space conditions have shown remarkable changes, including altered plant size, modified curd structure, and improved resistance to black rot. Similarly, rice varieties with strong resistance to blast disease have been developed through space-flight -induced mutagenesis.

Different Changes in Plants, both cytologically and genetically

Cytological changes refer to observable modifications in the cell, chromosome structure and behaviour at the cellular level. Exposure to the harsh environment of space can alter the normal shape and structure of plant cells. For instance, experiments have shown that cells in the cotyledons of pine and in the root meristems of some plants tend to become more rounded in space. Under microgravity, surface tension increases and the usual mechanical forces that keep cells in place are reduced, leading to these rounder cell shapes and changes in how cells attach to one another. An increase in cell elongation has been noticed in wheat and maize seedlings. There are also changes in chromosome segments and also several distinct types of chromosomal aberrations due to space breeding. Approximately 75–100% of mutations occur at naturally polymorphic sites in the genome, suggesting space radiation preferentially targets specific chromosomal regions. When cosmic radiation causes double-strand breaks (DSBs), the broken segment may be lost entirely, resulting in deletion of genes within that region. Duplications can occur through aberrant recombination following radiation-induced breaks. This leads to increased gene dosage effects for the duplicated region. When cells divide, any chromosomal breaks that are not repaired correctly can cause two centromeres to join together, forming what are known as dicentric chromosomes. As these abnormal chromosomes are pulled to opposite sides of the cell, they stretch into bridges that eventually snap. The break produces chromosomal pieces without centromeres, which are usually lost, resulting in missing genes. This type of chromosomal damage has been commonly seen in rice and wheat that have been exposed to space conditions. Plants grown in space were exposed to stronger sunlight compared to those grown on Earth, which may be why they began producing chlorophyll sooner than the plants grown under normal ground conditions. In plants, exposed to space conditions, normal cell division tends to slow down, while chromosomal abnormalities become more common compared to plants grown on Earth. This pattern of mutation appears to be widespread across many plant species, showing that the space environment consistently triggers these genetic changes. A slow rate of cell division was observed in the plants grown in Biosatellite II. Weightlessness and microgravity play signficant roles in the subcellular organelles that make up a cell. The cell walls of higher plants grown in weightless conditions were only about one third as thick as the cell walls of plants grown under normal gravity on Earth. Plants grown in space for 24 days showed a 54% drop in cellulose content in their cell walls, and mung bean seedlings had an 18% decrease in lignin. Space grown seedlings also showed a noticeable reduction in their protein content and in the levels of important enzymes. Pine cells grown in space showed a decrease in the number of nucleoli, while wheat seedlings displayed a clear increase in the size of their nuclei. In contrast, the root caps of maize did not show any noticeable changes under space conditions.

Plants grown in space can also show developmental changes as they mature. In one study, Arabidopsis plants were sent into space at the cotyledon stage and were able to grow and flower normally. However, their male and female reproductive parts became sterile. Although the overall shape of these organs looked normal, the plants failed to produce fertile structures because the light conditions in space were not suitable. When Arabidopsis plants were grown from seed on the International Space Station, genome wide analysis showed that many cytosine bases in their DNA had different methylation patterns compared to plants grown on Earth.

Conclusion

The journey of space breeding has transitioned from laboratory curiosity to agricultural reality. Today, the varieties developed through cosmic mutagenesis are no longer confined to research papers as they grace farmers' fields across continents and appear on dining tables worldwide. This remarkable trajectory from the vacuum of space to the fertility of Earth is marked by tangible achievements that validate decades of scientific vision and perseverance. The most celebrated success story remains the Space Lotus No. 36, a testimony to the transformative power of cosmic mutagenesis. Developed by Guangchang County in Jiangxi Province through multiple space missions since 1994, this variety has achieved extraordinary market penetration, covering over 80% of China's total white lotus cultivation area, spanning more than 20 million mu (1.33 million hectares). From the cosmic radiation that mutates seeds orbiting Earth, to the harvest reaped by farmers in fields below, space breeding represents one of humanity's most elegant solutions to the challenge of feeding a growing world facing climate change. These are seeds with a story written among the stars, now returning to Earth to nourish humanity's future.

Bibliography

Basi, S., Subedi, L. P., KC, G., & Adhikari, N. R. (2006). Cytogenetic effects of gamma rays on indica rice radha-4. *Journal of the Institute of Agriculture and Animal Science*, *27*, 25-36.

Belfield, E. J., Gan, X., Mithani, A., Brown, C., Jiang, C., Franklin, K., ... & Harberd, N. P. (2012). Genome-wide analysis of mutations in mutant lineages selected following fast-neutron irradiation mutagenesis of Arabidopsis thaliana. *Genome research*, *22*(7), 1306-1315.

Chengzhi, L. (2011). Agronomy in space–China's crop breeding program. *Space Policy*, *27*(3), 157-164.

Cowles, J. R., Scheld, H. W., Lemay, R., & Peterson, C. (1984). Growth and lignification in seedlings exposed to eight days of microgravity. *Annals of Botany*, 33-48.

Halstead, T. W., & Dutcher, F. R. (1987). Plants in space.

Il'in, Y., & Parfenov, G. (1979). Biologicheskiye Issledovaniya na Biosputnikakh "Kosmo".

Keqiang, X., Liangbo, Y., Xianglian, Z., Jinxing, X., & Dong, J. (2004). Selection of lotus from seeds re-onboard in space satellite. *Acta Agriculturae Nucleatae Sinica*, *18*.

Kordyum, Y. L., & Chernyayeva, I. I. (1983). *Peculiarities in formation of Arabidopsis Thaliana (L.) Heynh, generative organs under space flight conditions* (No. NASA-TM-77263).

Li, J. G., Wang, P. S., Zhang, J., & Jiang, X. C. (1999). Development and prospect of plant mutation breeding induced by aviation and spaceflight in China. *Hang Tian yi xue yu yi xue Gong Cheng= Space Medicine & Medical Engineering*, *12*(6), 464-468.

Li, Y., Liu, M., Cheng, Z., & Sun, Y. (2007). Space environment induced mutations prefer to occur at polymorphic sites of rice genomes. *Advances in Space Research*, *40*(4), 523-527.

Liu, L. X., Guo, H. J., Zhao, L. S., Wang, J., Gu, J. Y., & Zhao, S. R. (2009). Achievements and perspectives of crop space breeding in China. *Induced plant mutations in the genomics era*, *42*(1), 213-215.

Mohanta, T. K., Mishra, A. K., Mohanta, Y. K., & Al-Harrasi, A. (2021). Space breeding: the next-generation crops. *Frontiers in plant science*, *12*, 771985.

Moore, R., Fondren, W. M., McClelen, C. E., & Wang, C. L. (1987). Influence of microgravity on cellular differentiation in root caps of Zea mays. *American journal of botany*, *74*(7), 1006-1012.

Thimann, K. V. (1968). Biosatellite II experiments: preliminary results. *Proceedings of the National Academy of Sciences*, *60*(2), 347-361.

Wu, H., Huang, C., Zhang, K., & Sun, Y. (2010). Mutations in cauliflower and sprout broccoli grown from seeds flown in space. *Advances in space research*, *46*(10), 1245-1248.

Xiao W, Yang Q, Chen Z et al (2008) Blast-resistance inheritance of space-induced rice lines and their genomic polymorphism by microsatellite markers. Sci Sin Agric 4:3952–3958

Zhou, M., Sng, N. J., LeFrois, C. E., Paul, A. L., & Ferl, R. J. (2019). Epigenomics in an extraterrestrial environment: organ-specific alteration of DNA methylation and gene expression elicited by spaceflight in Arabidopsis thaliana. *BMC genomics*, *20*(1), 205.

ISSN: 3049-2289

Current Developments in Anti-Inflammatory Diets: Nutritional Techniques to Lower Chronic Inflammation and Improve Health

[1]Ipsita Rautaray , [2]Aswini Kumar Sahoo, [3]Amar Bikram Sahoo,
[4]Kamakshi Kamalini Jali, [5]S. Kshanti Somanath
M. Sc. Research scholars, Department of food and nutrition, College of community science, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar

Chronic inflammation damages body tissue, leading to issues such as heart diseases, diabetes, stiff joints, or even cancer. Instead of brief swelling that fades fast, long-term inflammation sticks around, putting constant pressure on cells. Choosing the right meals may ease this, strengthening immunity while calming internal irritation naturally. Food packed with protective compounds, plant fibers, essential nutrients, and good-quality oils helps neutralize destructive particles, also keeping digestion steady. Fish and flax seeds give you omega-3s that calm swelling; berries and green leafy vegetables pack polyphenols with similar effects. Spices such as turmeric or ginger shut down signals that cause inflammation inside the body. Gut bacteria thrive on fiber, helping reduce chronic flare-ups throughout your system. Eating habits like the Med-style way, mostly plants, or part-time meat plans highlight beans, whole grains, nuts, plus colorful produce. This kind of eating eases stress on joints while boosting heart function and mental sharpness. Pickles, yogurt, dosa, idli feed good bacteria - white bread and fried snacks do the opposite. Swapping processed junk for real food could slow illness and make daily life feel better. Switching up your meals slowly, using bright, different ingredients, good-for-you fats, or flavorful seasonings, might increase benefits. More research suggests teaming up nutrition plans with doctor support and community programs could help lower long-term swelling issues and linked problems across large groups.

Introduction

The persistent immune response damaging tissues - known as chronic inflammation - plays a central role, contributing significantly to widespread conditions such as cardiovascular issues, metabolic disorders, joint problems, or tumor development. Although acute inflammation arises rapidly and fades within hours or days, serving as a protective mechanism through coordinated immune signaling pathways. Long-lasting forms frequently lack clear signs yet result in increased cellular stress coupled with changes in energy processing. Instead of depending on a fixed approach, dietary patterns targeting inflammation involve different nutritional tactics designed to improve immune activity, lower pro-inflammatory markers, while enhancing overall health by having items rich in bio-active compounds. Nutritional approaches to chronic inflammation could improve everyday functioning, metabolic processes, or resistance to disease. By adjusting food intake, individuals may lower oxidative damage. Research on complete dietary patterns, particular protective foods, shifts in intestinal microbes, or tailored nutrition based on genetic markers has advanced quickly.

The Scientific Foundation of Diets That Reduce Inflammation

Mechanisms of Inflammation and Dietary Modulation

Prostaglandins, ROS, or IL-6 - along with tumor necrosis factor-alpha and different cytokines

appear in persistent inflammation caused by continuous immune responses. One central mechanism includes activating NF-κB together with COX-2, which are transcription factors switching on genes tied to inflammation. Food-based factors might affect this inflammatory pathway via multiple channels.

Blocking COX-2 that accelerates inflammation, while also decreasing NF-κB function.

Maintaining balance between substances that cause inflammation and those that reduce it.

ISSN: 3049-2289

The reduction in oxidative stress occurs when antioxidants - natural or artificial - neutralize ROS through different pathways.

lowering control of genes via chemical tags during body responses to injury or infection.

High intake of refined carbohydrates or saturated fats may boost these cell messages, which increases inflammatory responses.

Some important Anti-Inflammatory Nutrients and Bio-active Compounds

Fatty acids including EPA and DHA are found in sea animals; because of this, they contribute to making resolvins, which reduce swelling. Meanwhile, these substances decrease molecules linked to inflammation - like eicosanoids or cytokines - through their action.

Fruits, vegetables, or tea often provide polyphenols. These compounds boost cellular protection while lowering oxidative damage; at the same time, they inhibit NF-κB pathways.

Dietary fibers - soluble or insoluble - support good gut microbes, also shielding the intestinal lining. As a result, inflammation drops and toxins move out more easily.

Vitamin C, D, and E, alongside trace zinc or selenium, help strengthen the body's natural defenses. Each one plays a role in maintaining immune function by enhancing internal protective systems.

Curcumin, present in turmeric, acts as an antioxidant; at the same time, it blocks certain enzymes linked to inflammatory processes.

Fermented items together with fiber support good gut microbes, raising helpful types while increasing short-chain fatty acids. These changes help balance immune responses and expand the variety of microbiota.

Role of Gut Microbiome and Immune Regulation

A key player in controlling immune stability while reducing chronic inflammation is the gut’s microbe collection. These varied organisms produce SCFAs, particularly butyrate, that fight swelling through:

maintaining gut lining integrity - prevents toxins from escaping through alternative pathways.

maintaining immune balance through contact with mucosal immune cells.

Changing microbial products to manage how the immune system reacts across the body.

A main part of modern approaches to reducing inflammation involves eating mostly unprocessed plant foods - especially high-fibre and fermented options - that support gut microbes in varied and useful ways.

Anti-Inflammatory Diet include :

Fruit and vegetables provide the key vitamins and other minerals. Packed with fibre, they support healthy digestion. Their antioxidants lower body-wide inflammation and reduce cell damage.

Raspberries, blueberries or strawberries contain antioxidants called Anthocyanins that affect cytokines and prevent cell oxidation.

Leafy greens like spinach or amaranth can provide carotenoids, vitamin K, and folate, which helps communication between immune cells.

Sulforaphane is a compound that occurs in brassicas like broccoli, cauliflower, or cabbage. It inhibits inflammation-causing factors while boosting the body’s defenses against harmful organisms.

Such meals pack nutrients that support metabolism, yet also reduce bodily inflammation.

Healthy Fats

Fats from foods may affect inflammation, depending on their composition.

Plant sources have more omega-3 fatty acids and they include flaxseed and chia. They also appear in fatty fish like salmon, sardines or mackerel. These fats do not promote inflammation. They reduce it by creating molecules that compete with the ones triggered by omega-6.

Nuts, Seeds, and Legumes

Almonds, walnuts, flaxseeds, and chia seeds are great sources of lignans, vitamin E or omega-3s. These improve blood vessel functioning and reduce oxidative stress. Lentils, beans, and chickpeas contain soluble fiber, magnesium, or polyphenols. They can improve our insulin response and lower inflammation markers like the C-reactive protein.

Whole Grains

Eating oats will allow you to take in the complex carbs you need daily. It also contains many minerals as well as phytochemicals that help with inflammation. Microbes produce butyrate when they break down soluble fibre found inside food. These substances enhance the gut's barrier and also decrease inflammation pathways. Eating more fiber helps to keep our immune system stable and reduces inflammation.

Herbs and Spices

Common spices often include plant-based substances that reduce swelling, such as:

Curcumin, present in turmeric, inhibits COX-2 pathways as well as NF-κB signals.

Ginger has shogaol along with gingerol - each can regulate immunity and work as an antioxidant. Research indicates they support balanced body reactions, at the same time lowering oxidative damage effectively.

Garlic has sulfur-based compounds like allicin - possibly aiding heart health by cutting down inflammatory markers through biochemical pathways.

Still, responses may differ from person to person based on how fast their body processes substances as well as how often they use them.

Taste along with wellness may improve when adding spices regularly - this small change enriches dishes while promoting better health via common kitchen habits

Principal Anti-Inflammatory Dietary Patterns

Mediterranean Diet

The Mediterranean way of eating has strong support for cutting down inflammation. Rich in veggies, fruit, and whole grains - also including legumes, nuts, plus olive oil - it forms a balanced approach. Moderate amounts of wine and fish fit into the plan. Research links it to reduced signs of inflammation, like CRP and IL-6. People sticking to this approach tend to face lower chances of heart problems, diabetes, or thinking difficulties. Key factors include eating plenty of polyphenols while keeping omega-3 and omega-6 fats in balance.

Plant-Based and Flexitarian Diets

Vegans, vegetarians, or people eating mostly plants usually focus on veggies, fruit, and grains - though certain plans allow meat occasionally. Switching to more plant-focused options tends to boost fiber, polyphenols, antioxidants; this can reduce bodily inflammation while slowing cell damage over time. Instead of cutting out entire food categories, adaptable eating patterns offer a realistic way to feel better physically while also supporting environmental health.

Emerging Variants of Anti-Inflammatory Diets

New ways of eating are emerging, blending traditional with modern nutrition via simple pairings.

The Nordic Diet uses regional grains, root vegetables, or fatty fish - delivering inflammation-lowering effects much like those seen with Mediterranean eating patterns.

DASH diet: Designed for those with high blood pressure, this approach lowers inflammation by cutting salt - instead emphasizing foods rich in nutrients but low in fat or sodium.

Custom meals based on gut health: combining DNA-related food reactions with microbiome data to create tailored advice that reduces inflammation, using focused eating plans.

These diets reflect today's habits - prioritizing personal preferences while supporting environmental stability.

ISSN: 3049-2289

Health Impacts and Outcomes

Cardiovascular Health and Metabolic Syndrome

Better food picks help blood vessels stay healthy, limit cell damage, while cutting down on bodywide swelling tied to weight gain, high blood pressure, rigid arteries, or poor insulin response. Lower levels of bad cholesterol, fewer fats in the bloodstream, along with weaker markers of inflammation turn up in lab results. Data from medical studies and broad population reviews suggest meals rich in plants or similar to traditional Mediterranean habits might reduce chances of getting type 2 diabetes and heart-related issues.

Cognitive Function and Neuro-inflammation

If oxidative stress or ongoing inflammation occurs in the body, conditions such as Parkinson's or Alzheimer's may develop.

This might be addressed with vitamins that stop amyloid-beta clusters from forming, calm down hyperactive brain immune cells, while also supporting links between neurons. Foods rich in omega-3s, natural compounds from bright-colored plants, or pigments in vivid vegetation may guide these bodily functions toward better outcomes. Regular intake of green leafy vegetables, dark blue berries, yet fatty fish often goes hand-in-hand with clearer cognition instead of worsening mental function.

Joint Health & Autoimmune Conditions

Adjusting what you eat could support recovery in long-term joint conditions such as rheumatoid arthritis or osteoarthritis. Antioxidant-rich items, curcumin, along with omega-3 fats may lower swelling, discomfort, and buildup of fluid. Research highlights flaxseed oil, plus berries and turmeric pills - also fatty fish including salmon or tuna - for their ability to combat joint and muscle irritation.

Immune Support and Prevention of Disease

In short, choosing anti-inflammatory foods supports gut health - also helping immune balance and protecting cells, so sickness is less likely over years. Research shows adding more plant-based items, good fats, fermented options, or herbs into daily meals cuts immediate illness risks while lowering odds of lasting problems like growths, glucose issues, or blocked arteries.

Practical Applications

Incorporating Anti-Inflammatory Foods into Daily Life

To increase antioxidants, eat bright-colored fruits and veggies every day - try adding Amla at breakfast or pairing carrots with midday meals. Because varied colors suggest diverse nutrients, rotate options like bell peppers, spinach, or root crops including yam and sweet potato on different days. Shifting choices regularly supports broader vitamin coverage without complex scheduling.

Choose brown rice instead of white, or try barley - both are better than refined carbs. Oats work well too, replacing sugary breakfast picks.

Include avocado one day, nuts the next - try sunflower seeds too; use olive oil instead of butter for healthier fat intake.

To boost omega-3 intake, try eating fish twice weekly - or choose flaxseed instead. Another option is chia seeds, which also help raise levels effectively - both are simple switches.

Spicing meals with ginger might reduce inflammation; garlic could have alike effects. Turmeric acts in a comparable way.

Diet changes may happen slowly - over time, this could lead to lasting health improvements.

Diet Planning and Food Choices

To ensure enough nutrients come with food, cooking involves:

The weekly menu focuses on fresh components instead of packaged ones, using simple methods to highlight natural flavors while reducing additives found in ready-made dishes.

Nutrients combined with healthy fats, along with slow-digesting carbs, followed by lean protein.

Pick veggies at their natural ripeness - this enhances nutrition while minimizing environmental impact.

Cutting back on trans fats while reducing sugary foods - less processed meat at the same time.

Fermented items like dosa, idli, yogurt, or kanji may boost gut microbe diversity. Such changes can lower inflammation by supporting dietary habits aligned with varied daily routines while maintaining environmental balance over time.

Conclusion

Anti-inflammatory diet blends classic food habits with current research findings. These meals focus on whole, lightly processed ingredients rich in key nutrients; instead they boost intake of antioxidants, omega-3 fats, fiber, as well as phytochemicals from plants. Each part supports better immune response, lowers swelling, enhances metabolic rate, heart function, brain health, plus general condition. Diets mainly based on plants - like semi-vegetarian or Mediterranean patterns - work best against inflammation. As evidence grows, customized diet strategies could offer clearer answers for personal health targets.

Nutritional strategies lowering long-term inflammation tend to work more effectively if woven into standard medical care along with community health efforts, paired with food policy changes. Integrating such components could extend life expectancy while improving daily living conditions worldwide.

Reference

1. Calder, P. C. (2020). Omega-3 fatty acids and inflammatory processes: From molecules to man. *Biochemical Society Transactions*, 45(5), 1105–1115.

2. Estruch, R., Ros, E., Salas-Salvadó, J., Covas, M. I., Corella, D., Arós, F., Gómez-Gracia, E., Ruiz-Gutiérrez, V., Fiol, M., Lapetra, J., Lamuela-Raventós, R. M., Serra-Majem, L., Pintó, X., Basora, J., Muñoz, M. A., Sorlí, J. V., Martínez, J. A., Martínez-González, M. A., & PREDIMED Study Investigators. (2018). Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extra-virgin olive oil or nuts. *New England Journal of Medicine*, 378(25), e34.

3. Koh, A., De Vadder, F., Kovatcheva-Datchary, P., & Bäckhed, F. (2016). From dietary fiber to host physiology: Short-chain fatty acids as key bacterial metabolites. *Cell*, 165(6), 1332–1345.

4. Pandey, K. B., & Rizvi, S. I. (2009). Plant polyphenols as dietary antioxidants in human health and disease. *Oxidative Medicine and Cellular Longevity*, 2(5), 270–278.

5. Satija, A., Bhupathiraju, S. N., Spiegelman, D., Chiuve, S. E., Manson, J. E., Willett, W., Rexrode, K. M., & Hu, F. B. (2017). Healthful and unhealthful plant-based diets and the risk of coronary heart disease in U.S. adults. *Journal of the American College of Cardiology*, 70(4), 411–422.

6. Simopoulos, A. P. (2018). An increase in the Omega-6/Omega-3 fatty acid ratio increases the risk for obesity. *Nutrients*, 8(3), 128.

7. Zeevi, D., Korem, T., Zmora, N., Israeli, D., Rothschild, D., Weinberger, A., Ben-Yacov, O., Lador, D., Avnit-Sagi, T., Lotan-Pompan, M., Suez, J., Mahdi, J. A., Matot, E., Malka, G., Kosower, N., Rein, M., Zilberman-Schapira, G., Dohnalová, L., Pevsner-Fischer, M., Bikovsky, R., Halpern, Z., Elinav, E., & Segal, E. (2015). Personalized nutrition by prediction of glycemic responses. *Cell*, 163(5), 1079–1094.

8. Calder, P. C. (2017). Marine omega-3 fatty acids and inflammatory processes: Effects, mechanisms and clinical relevance. *Biochimica et Biophysica Acta (BBA) - Molecular and Cell Biology of Lipids*, 1861(8), 461–470.

9. Ghosh, S., DeCoffe, D., Brown, K., Rajendiran, E., Estaki, M., Dai, C., Yip, A., Gibson, D. L., & Clandinin, M. T. (2014). Diet in the management of weight loss. *Gut*, 63(11), 1747–1758.

Hariri, M., & Ghiasvand, R. (2016). The effect of curcumin (turmeric) on Alzheimer's disease: An overview. *Advances in Biomedical Research*, 5(1), 12.

ISSN: 3049-2289

New Developments in Alternative Proteins: Technological Advancements and Nutritional Consequences

[1]Aswini Kumar Sahoo, [2] Ipsita Rautaray, [3]Amar Bikram Sahoo,
[4]Kamakshi Kamalini Jali, [5]S. Kshanti Somanath
M.Sc. Research scholars (Department of food and nutrition college of community science,
Odisha University of Agriculture and Technology (OUAT), Bhubaneswar

Alternative proteins are shaking up the perception how we think about feeding everyone, less harm to the planet, fewer limits than old-school meat, chicken and eggs. Scientists now extract protein from plants more efficiently, using methods like high-moisture extrusion, and flavor regulation without fake flavors. Lab-grown meat takes cells and grows them into tissue, sometimes even printed layer by layer by bio-printing. Microorganisms brewed in tanks offer another path, while robots help collect insect-based protein faster. These options aren't just substitutes, they pack solid nutrition, with decent amino acids and better absorption than some expect. Processing tweaks have cut down stuff that blocks nutrient uptake, making them safer to eat. On top of that, natural helpers like plant chemicals, good gut bacteria, and antioxidants add perks beyond basic nourishment. Still, making alternative proteins isn't easy, matching taste and texture takes work, producing them cheaply at large scale is tough, also meeting strict safety rules matters a lot. When these foods move from small markets into everyday meals, teaming up across fields helps, so does clear labeling; that way progress keeps going, people pick wisely, plus the whole food setup becomes more resilient.

Introduction

Alternative proteins (APs) provide a possible solution for future food needs due to rising global population and ecological issues tied to traditional animal farming. These include plant-derived, lab-made meat, microbial sources, or those from insects collectively known as APs. Their creation aims at fulfilling dietary protein demand with less harm to ecosystems. This review discusses recent developments in science and technology aimed at improving methods of production and design of these proteins to assess health impacts, advantages, and limitations.

Technological Developments in Alternative Proteins

Plant-Based Protein Innovations

Plant-based protein is still the best-selling form of alternative protein. While most of these proteins lack one or two amino acids that are considered essential and have a more globular structure than animal proteins, numerous studies continue to improve their nutritional, flavor, and processing performance

Extraction and Processing:

Common approaches for the isolation and concentration of plant-based proteins from soy, peas, lentils, or cereals are physical, or chemical treatments. Methods like ultra filtration, iso-electric separation, or other advanced processes, including targeted fermentation, are used because they generally increase output, enhance quality, and decrease nutrient -inhibitors.

Texture and Structure:

Due to controlled heat and pressure altering plant protein structures, high-moisture extrusion along with shear cell methods are now commonly used to create fibrous textures similar to minced meat. These processes help boost tenderness, bite resistance, and overall eating sensation in vegan meat alternatives. Meanwhile, novel substances like hydro-colloids or bio-polymers have enhanced water holding capacity, gel formation, plus fat dispersion.

Flavor and Aroma Regulation:

Food producers now mask unpleasant tastes in legume proteins thanks to advances in flavor science that allow precise ingredient coating. To boost

ISSN: 3049-2289

appeal, today's products often rely on time-tested blends, using compounds from fermentation alongside herbal extracts instead of synthetic additives.

Cultured Meat and Cellular Agriculture

The production of cultured meat - often called lab-made or cell-derived meat - has improved greatly due to new techniques for developing muscle cells, growing self-replicating cell strains, while using specialized environments that trigger cell maturation.

Cell lines: Muscle stem cells from farm animals are cultured in bioreactors. In order to improve cell growth while decreasing reliance on animal-based serum, scientists use genetic as well as epigenetic methods.

Bio-printing combined with novel edible frameworks has enabled complex tissue designs, promoting blood vessel formation alongside organized muscle fibers. Instead of traditional materials, researchers explored collagen-mimicking proteins as well as plant-derived sugars for these structures.

Culture Media: Researchers focus on low-cost, serum-free options - boosted with essentials like vitamins or amino acids, to support cell function. New methods from synthetic biology emerge; some recycle media parts to cut waste. These steps aim at efficiency without complex additives.

Microbial and Fermentation-Derived Proteins

Fungal-based protein, together with bacterial and yeast sources, is produced by means of microbial fermentation, which efficiently converts raw materials into premium biomass. This process also includes micro-algae as one of its key contributors.

Precision fermentation involves making specific proteins, such as those that give taste and color to plant-based meats, using engineered microbes. This approach allows for targeted production while enabling large-volume output at the same time.

Bioreactor efficiency improves through changes in feed-stock mix - like crop leftovers - and adjustments in pH levels, heat, airflow, and redox conditions; these upgrades increase output while lowering costs.

Downstream processing turns microbial biomass into edible products by using separation techniques; these help achieve desired taste and nutrition. Methods like filtration or drying play a key role here, improving product quality while meeting consumer needs. Each step adjusts texture, flavor, or nutrient levels, making them suitable for use in foods people actually eat.

Insect-Based Proteins

Insects are turned into powder, also isolated as protein for foods, thanks to rich protein levels along with efficient feed use.

Farming automation, along with improved boiling or freezing methods, boosts quality, drying advances also contribute. Safety sees gains through these updated practices rather than outdated ones. Each step from harvest to finish becomes more consistent when machines assist. Changes in handling reduce risks while maintaining product standards. Efficiency rises without sacrificing care in processing.

Protein recovery: Removing fat may improve how well proteins dissolve or form emulsions; this effect could increase when enzymes break down the structure.

For developing products, insect proteins may support nutritional value while adding diversity in baked items, besides improving snack options along with substitutes for meat.

Nutritional information about Alternative Proteins

Protein Quantity and Quality

The biological role of Alternative proteins depends on their varied amino acid makeup as well as how easily they're digested.

Amino acid completeness varies: some plant sources lack lysine, methionine, or tryptophan, but animal proteins generally provide all of these. Potential gaps in plant-based intake may be compensated by rotation of sources, mixing options, or added enrichment.

It has been documented that fiber and some anti-nutrients, such as phytates, tannins, or enzyme blockers, lower the digestibility of Alternative

ISSN: 3049-2289

protein when compared with other dietary proteins. These substances generally decrease when Alternative protein is processed, thereby improving the absorption of its nutrients in the body.

Functional Proteins: Cultured meat and microbe-based proteins come very close to conventional animal-based protein in quality, with their high digestibility and balanced amino acid profiles.

Micro-nutrients and Bio-availability

Switching from animal-based proteins to Alternative protein alters micro-nutrient consumption.

Fermentation increases absorption of iron and zinc from plants, although compounds like phytates may limit the availability of minerals; similarly, methods such as enrichment or standard processing improve availability through slight changes in protein structure during food preparation.

Vitamin B12: Due to the fact that this nutrient is found only in animal products, individuals who follow a strict vegan diet are at risk of deficiency. The options to rectify low levels include microbial production by using state-of-the-art fermentation techniques or supplementation in general.

Iodine deficiencies, along with low calcium levels, iodine deficiencies occur in people shifting from milk to plant-based drinks, so alternative sources or enriched foods may help-especially among older adults.

Health Benefits and Risks

Alternative protein s may boost wellness, but questions linger.

Active components with practical functions

Besides providing important nutrients, Alternative proteins contain bioactive compounds which may also provide benefits to health in diverse ways.

Saponins, phytosterols, and polyphenols are active substances present mainly in protein-rich plants, which provide help in reducing fats in the blood, acting simultaneously against oxidative damage.

Active components with practical roles

Alternative proteins include active compounds that may support health in various ways.

Saponins, phytosterols and polyphenols, are active compounds found mainly in plants rich in protein; these substances help lower fats in the blood while also acting against oxidative damage.

Probiotics or prebiotics: Improving gut microbiome could mean that fermented proteins boast impressive live cultures.

Some active principles, such as omega-3s or curcumin variants, act upon key biological markers responsible for swelling and, hence, reduce inflammation. These compounds act on cellular signals in immune responses and change pathways related to chronic irritation processes.

Challenges in Alternative Protein Development

Technological Challenges

The complex shape and behavior of proteins complicate efforts to match the texture, taste, or moisture found in traditional meat. While plant-based options improve, mimicking animal protein fully remains a challenge due to how these molecules interact under heat or pressure. Because structure affects mouthfeel, small differences can reduce similarity. Although new methods help adjust consistency, replicating natural juiciness is still limited by available ingredients.

The expense of growth materials, along with strict bioprocessing demands, still limits large-scale lab-grown meat production from being cost-effective.

To ensure safety in new protein sources, rigorous checks plus oversight are needed - focusing on microbes and allergic reactions.

Safety, Nutrition, and Knowledgeable Consumer Selection

Apart from broad application, careful assessment of safety and nutrition must come first - especially for novel APs like insect-based or microbe-derived proteins.

ISSN: 3049-2289

So people can see how Alternative proteins differ from regular proteins, labels need clear info - therefore, nutrition details should be open. While transparency helps compare benefits or risks, honest packaging supports better choices - hence, straightforward data matters just as much.

Conclusion

Alternative proteins were once captured very narrow section of the market, yet thanks to progress in extraction methods, manufacturing techniques, and Food processing, they have become easier to access. Improvements in amino acid profiles, digestibility, and bioactive components help define the distinct nutritional traits and possible health effects of different plant-based or other alternative proteins. These proteins could play a key role in efficient and effective diets; even so, challenges around taste, large-scale production, and safety testing remain unresolved. Developing such new protein options and strengthening worldwide food supply chains. Improvement and development of Alternative protein depends on collaboration across disciplines, combining efforts among researchers, Food science experts, dietitians, and government advisors through shared goals.

AGRICULTURE BULLETIN
ISSN: 3049-2289

The Nutritious Crop Revolution: Biofortification for a Healthier World

Deblina Pal[1,2], Souvik Ghosh[1,2] and Ritabrata Sarkar[1,2]
[1]ICAR–Indian Institute of Agricultural Biotechnology, Ranchi-834003, Jharkhand, India.
[2]ICAR-Indian Agricultural Research Institute, Pusa, New Delhi-110012 India.

Introduction

Every day, millions rely on staple foods such as rice, wheat and maize to satisfy their hunger, yet their bodies remain nutritionally deprived. This widespread problem doesn't always resemble traditional starvation. A child may look healthy while lacking the crucial vitamins and minerals needed for proper growth, cognitive development and immune function. As global efforts intensify to find long-term solutions to malnutrition, researchers are shifting their focus away from supplements and fortified foods and toward improving the crops themselves. With biofortification, nourishment begins in the field, long before the harvest reaches consumers.

"Hidden hunger" describes a condition where individuals consume enough calories but lack essential micronutrients, leading to undernutrition and poor diet quality (Ofori et al., 2022). Global reports show that the number of affected people rose to 828 million in 2021—46 million more than in 2020 and about 150 million more since the start of the COVID-19 pandemic (WHO, 2022). Because micronutrient deficiencies are not always visible, children may suffer from fatigue, frequent illness and learning difficulties, while pregnant women with iron deficiency face increased health risks. In many low-income regions, diets heavily depend on nutrient-poor staple crops, creating a persistent nutritional gap that requires an affordable, scalable and sustainable solution.

Biofortification involves enhancing the nutritional quality of food crops through conventional breeding, genetic techniques, or specific agronomic methods. Rather than altering dietary habits, it increases the levels of key vitamins and minerals in staple foods that people already consume daily. The aim is to provide a sustainable, affordable way to improve nutrient intake, especially for populations most vulnerable to deficiencies.

How Biofortification Works?

Biofortification relies on four main approaches. Agronomic methods improve mineral availability and uptake in plants (Zulfiqar et al., 2021). The other three conventional breeding, genetic engineering and gene editing focus on developing improved crop varieties with higher micronutrient content, better nutrient bioavailability and lower levels of antinutrients (Srinivas et al., 2023; Dwivedi et al., 2023).

a. Agronomic Biofortification

This involves enriching the soil or fertilizer with minerals like zinc or selenium so that plants absorb more of them. It is especially useful in regions where soil itself is nutrient-poor and it can be implemented quickly compared to breeding methods.

b. Conventional Breeding

Plant breeders enhance nutrient levels by selecting naturally nutrient-rich varieties and crossing them with high-yielding cultivars. Through repeated cycles of selection, crossing and evaluation, they develop new lines that combine improved nutrition with strong productivity (Pandey et al., 2016). Marker-Assisted Selection (MAS) further accelerates this process by using molecular markers to identify plants carrying the desired traits (Zheng et al., 2019). A well-known example is golden rice, created through conventional breeding to elevate beta-carotene levels. Similarly, studies by Nachimuthu et al. (2014) highlight how conventional breeding has successfully increased micronutrient content in crops such as rice, wheat and beans.

ISSN: 3049-2289

c. Genetic Engineering

When conventional breeding cannot sufficiently elevate certain nutrients, genetic engineering provides a more targeted solution. Golden Rice is the most widely recognized example, engineered to synthesize beta-carotene, the precursor of vitamin A. Although genetically modified crops remain a topic of public debate, they offer significant potential for reducing micronutrient deficiencies. Unlike traditional breeding, genetic engineering can introduce entire metabolic pathways missing in a crop, direct nutrient production specifically to edible tissues such as the endosperm and combine multiple traits within a single variety—making nutrient enhancement faster, more precise and more effective.

Transgenic approaches have produced several notable successes, including high-lysine maize, soybeans enriched with unsaturated fatty acids, provitamin A– and iron-rich cassava and Golden Rice with elevated provitamin A. Numerous studies have also demonstrated significant improvements in iron content in rice by introducing genes involved in iron uptake and storage. These include nicotianamine aminotransferase (Takahashi et al., 2001), te iron transporter OsIRT1 (Lee & An, 2009) and the nicotianamine synthase genes OsNAS1 and OsNAS2 (Zheng et al., 2010; Trijatmiko et al., 2016). Iron accumulation has further been enhanced by expressing ferritin genes from soybean (Vasconcelos et al., 2003) and common bean (Lucca et al., 2002). More advanced iron-biofortified rice lines have been generated by combining multiple iron-related genes to optimize uptake, transport and storage (Masuda et al., 2012).

d. Gene editing

Gene editing enables precise, targeted alterations in an organism's DNA—such as knockouts, knock-ins, or specific base changes using tools like CRISPR-Cas, TALENs and other engineered nucleases. A notable example is the Golden Rice cultivar Kitaake, developed through CRISPR-Cas–mediated insertion of a 5.2-kb carotenogenesis cassette containing the CrtI and maize PSY genes. This knock-in approach produced grains with 7.9 μg/g dry weight of β-carotene in the endosperm (Dong et al., 2019).

Conclusion

Genetic biofortification offers a powerful strategy to fight hidden hunger by using modern gene-editing tools like CRISPR/Cas9 to enhance the nutrient content of staple crops. This targeted approach helps address vitamin and mineral deficiencies, particularly in regions affected by malnutrition. Despite its promise, challenges such as ensuring editing precision, minimizing off-target effects and addressing ethical and ecological concerns remain. Responsible progress requires collaboration among scientists, policymakers, regulators and communities. With careful development and oversight, genetic biofortification can contribute to a more food-secure world, improving public health and supporting sustainable agriculture.

References:

Dong L, Qi X, Zhu J, Liu C, Zhang X, Cheng B et al (2019) Supersweet and Waxy: Meeting the Diverse Demands for Specialty Maize by Genome Editing. Plant Biotechnol J 17(10):1853–1855. https://doi.org/10.1111/pbi.13144

Dwivedi SL, Garcia-Oliveira AL, Govindaraj M, Ortiz R (2023) Biofortification to avoid malnutrition in humans in a changing climate: enhancing micronutrient bioavailability in seed, tuber and storage roots. Front Plant Sci 14:1119148.

Lee S, An G (2009) Over-expression of OsIRT1 leads to increased iron and zinc accumulations in rice. Plant Cell Environ 32:408–416. https://doi.org/10.1111/j.1365-3040.2009.01935.x.

Lucca P, Hurrell R, Potrykus I (2002) Fighting iron deficiency anemia with iron-rich rice. J Am Coll Nutr 21:184S-S190. https://doi.org/10.1080/07315724.2002.10719264

Masuda H, Ishimaru Y, Aung MS, Kobayashi T, Kakei Y, Takahashi M et al (2012) Iron biofortification in rice by the introduction of multiple genes involved in iron nutrition. Sci Rep 2:534. https://doi.org/10.1038/srep00543

Ofori KF, Antoniello S, English MM, Aryee AN (2022) Improving nutrition through biofortification– a systematic review. Front Nutr 9:1043655.

Srinivas KR, Anand PK, Babu S (2023) Biofortification: A responsible research and innovation strategy for the G20. T20 Policy Brief October 2023.

Takahashi M, Nakanishi H, Kawasaki S, Nishizawa NK, Mori S (2001) Enhanced tolerance of rice to low iron availability in alkaline soils using barley nicotianamine aminotransferase genes. Nat Biotechnol 19:466–469. https://doi.org/10.1038/88143.

Vasconcelos M, Datta K, Oliva N, Khalekuzzaman M, Torrizo L, Krishnan S et al (2003) Enhanced iron and zinc accumulation in transgenic rice with the ferritin gene. Plant Sci 164:371–378. https://doi.org/10.1016/S0168-9452(02)00421-1.

WHO (2022) UN Report: Global hunger numbers rose to as many as 828 million in 2021. World Health Organization (WHO): Geneva, Switzerland.

Zheng L, Cheng Z, Ai C, Jiang X, Bei X, Zheng Y et al (2010) Nicotianamine, a novel enhancer of rice iron bioavailability to humans. PLoS ONE 5(4):e10190. https://doi.org/10.1371/journal.pone.0010190.

Zulfiqar U, Hussain S, Maqsood M, Ishfaq M, Ali N (2021) Zinc nutrition to enhance rice productivity, zinc use efficiency and grain biofortification under different production systems. Crop Sci 61(1):739–749

ISSN: 3049-2289

Molecular Farming and Its Role in Next-Generation Biotherapeutics

Anurag Kumar[1,2*],Shambhu Krishan Lal[1],Sudhir Kumar[1],Lalchand[1,2],Ritabrata Sarkar[1,2]
[1]ICAR–Indian Institute of Agricultural Biotechnology, Ranchi 834003, Jharkhand, India.
[2]ICAR-Indian Agricultural Research Institute, Pusa, New Delhi 110012 India.

Plant molecular farming is the use of plant cells or plants as expression platforms to produce the various metabolites or molecules of medical/economic importance. The production of medications, vaccines, enzymes, and valuable biomolecules is being transformed through molecular farming. This field represents one of the most creative convergences between biotechnology and agriculture. Rather than cultivating crops solely for food, feed, or fiber, molecular farming utilizes plants as living biological manufacturing units capable of producing sophisticated medicinal proteins, antibodies, vaccines, industrial enzymes, and nutraceuticals. This approach takes advantage of plants' remarkable cellular mechanisms, which can effectively and sustainably synthesize high-value compounds, properly fold complex proteins, and perform detailed post-translational modifications. By incorporating specific genes that code for target molecules into plant DNA, researchers enable plants to produce desired substances through their normal metabolic activities. Various plants including tobacco, corn, rice, lettuce, and numerous fruits and vegetables can be modified to manufacture pharmaceutical compounds or industrial biomolecules. This approach has several benefits, including safety (plants cannot host human infections), cost-effectiveness (low resource needs), scalability (only by increasing culture area), and environmental sustainability (low carbon footprint).Finding a target gene, creating an appropriate vector, and introducing this genetic material into plant cells by various methods such as Agrobacterium-mediated transformation, gene gun delivery, or plant viral vectors are the usual steps in the molecular farming process. The plant starts making the desired chemical/metabolites in its targeted tissues after it has been incorporated or temporarily expressed. Following growth, the plant material is harvested, and the desired ingredient is removed, refined, and downstream processed to create the finished product. Depending on the usage and urgency, both transient systems—where expression happens quickly without genomic integration—and stable expression systems—where the gene integrates into the plant genome—are employed. Viral vector-based transient expression is particularly useful in emergency situations like pandemic epidemics since it may produce large amounts of protein in less than two weeks. Nowadays, molecular farming has a wide range of increasingly significant applications. Vaccines against influenza, rabies, norovirus, hepatitis B, and even COVID-19 are made from plants in the pharmaceutical industry. Additionally, they are capable of producing complicated therapeutic proteins like enzymes utilized in enzyme replacement therapy and monoclonal antibodies.

Plant-based pharmaceutical production's primary benefit lies in circumventing bacterial system limitations, which cannot execute human-like post-translational modifications, or mammalian systems, which prove costly, demand intensive cell-culture infrastructure, and present viral contamination risks. Plants, conversely, remain naturally free from human pathogens, avoid producing endotoxins, can achieve proper protein folding and glycosylation, and can be modified to customize glycan structures. A notable example includes taliglucerase alfa (brand name Elelyso), the world's first FDA-approved plant-made medication developed from genetically engineered carrot root cell cultures to treat Type 1 Gaucher disease a rare genetic disorder. As far as algal system is concerned the microalga Chlamydomonas reinhardtii is the mostly used algal system used for molecular farming**.** Plant-based production platforms are also useful for diagnostics, as plant-produced proteins and antibodies are utilized in laboratory assays and quick diagnostic procedures. The food industry, detergents, paper processing, leather treatment, and other industries that need large-scale enzyme production can all profit from plants' ability to generate enzymes. Additionally, scientists are investigating edible vaccines, which could make mass immunization easier by doing away with the need for syringes, cold storage, and specialized medical infrastructure. Edible vaccines are therapeutic proteins or immunogens expressed in edible plant tissues like tomatoes or bananas. Molecular farming has significant advantages from both an economic and environmental standpoint. Conventional biomanufacturing systems demand significant energy usage, costly fermenters, and rigorous sterile conditions. Plants, on the other hand, require much less resources to grow—sunlight, CO2, water, and soil. Expanding greenhouse or field culture can be a straightforward way to scale production, allowing for quick reactions to unexpected spikes in the demand for vaccines, biologics, or specialist enzymes around the world. The environmental impact is far smaller than that of traditional production processes, and there are very few safety issues associated with human pathogen exposure. Molecular farming has difficulties despite its potential. Genetically modified organisms continue to be a major source of public perception problems. Clear containment measures are necessary to avoid cross-contamination between food crops and pharmaceutical crops due to regulatory concerns. Variable weather patterns can lead to unpredictable harvests in outdoor crop cultivation, while extracting and purifying proteins from plant materials in subsequent processing stages presents both technical challenges and high costs. Nevertheless, regulatory policies in countries such as the United States, Canada, and Japan are evolving to support regulated and secure plant-based pharmaceutical production. Equitable distribution of plant-derived medicines represents a significant ethical challenge, especially for economically disadvantaged regions. Plant-based pharmaceutical production offers the possibility of making essential treatments more accessible by reducing costs and enabling distributed manufacturing. Still, the responsible implementation of this technology requires careful examination of biological safety risks, patent rights, and ecological consequences. The prospects for molecular farming appear extremely promising. Advances in synthetic biology, glycoengineering, and genome editing tools such as CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) now allow for exact plant modifications that enhance production capabilities. Hardy crops including sorghum and duckweed are becoming viable production systems that could support molecular farming in regions experiencing extreme weather conditions. Distributed manufacturing centers are also becoming more popular, where plant-based bioproduction facilities can operate independently from global supply chains and provide greater stability during pandemics or natural disasters. Combined systems that merge microbial or cell-free technologies with plant-based platforms may further expand the scope and efficiency of biomolecule production. Molecular farming has fundamentally transformed how pharmaceuticals, industrial enzymes, and specialized biomolecules are manufactured.

As healthcare needs expand, climate change disrupts conventional supply chains, and global population increases, plant-based biomanufacturing offers a sustainable, scalable, safe, and cost-effective solution. Given the field's rapid progress, molecular farming is anticipated to contribute significantly to future biotechnology sectors, public health programs, and worldwide sustainability initiatives. The foundations for the next biotechnology revolution are already established, positioning molecular farming to cultivate a future rich with potential.

References:-

- Bobo, J. (2024). *Molecular farming navigates a complex regulatory landscape*. *Frontiers in Plant Science*, **15**, Article 1411943. https://doi.org/10.3389/fpls.2024.1411943 Frontiers
- Shanmugaraj, B., & Hefferon, K. (2024). *Editorial: Plant molecular farming for the*

production of next-generation vaccines and biologics – prospects and challenges. *Frontiers in Plant Science*, **15**, Article 1381234. https://doi.org/10.3389/fpls.2024.1381234 Frontiers

- Venkataraman, S., Khan, I., Habibi, P., Le, M., Lippert, R., & Hefferon, K. (2023). *Recent advances in expression and purification strategies for plant-made vaccines*. *Frontiers in Plant Science*, **14**, Article 1273958. https://doi.org/10.3389/fpls.2023.1273958 Frontiers+1
- England, C., Trejo-Martinez, J., Perez-Sanchez, P., Karki, U., & Xu, J. (2023). *Plants as biofactories for therapeutic proteins and antiviral compounds to combat COVID-19*. *Life*, **13**(3), 617. https://doi.org/10.3390/life13030617 MDPI
- Venkataraman, S. (2022). *Plant molecular pharming and plant-derived compounds towards generation of vaccines and therapeutics against coronaviruses*. *Vaccines*, **10**(11), 1805. https://doi.org/10.3390/vaccines10111805 MDPI
- Adedeji, O. S., Adelodun, B., Odey, G., Pal, T., Ajibade, F. O., Silva, L. F. O., … Park, K. I. (2025). *Integrating molecular farming into sustainable plant biotechnology: A review of transgenic plants as biofactories for protein-based pharmaceutical production*. *Plant Cell, Tissue and Organ Culture*, **163**(2), Article 45. https://doi.org/10.1007/s11240-025-03247-4 Pure
- Liu, Z., & co-authors. (2023). *Synthetic biology for plant genetic engineering and molecular farming*. *Trends in Biotechnology*, (2023), (review). (Note: PubMed cites this as published in 2023.) PubMed
- Anonymous / The Good Food Institute. (2023). *Plant Molecular Farming Fact Sheet*. Good Food Institute. (Published April 2023) The Good Food Institute
- Anonymous / The Good Food Institute. (2025). *Plant molecular farming: Industry overview and developments*. Good Food Institute. (Published June 2025)

AGRICULTURE BULLETIN
ISSN: 3049-2289

Guava + Green Gram Agri-Horticulture for Productive Utilization of Degraded Lands

H.R. Meena[1], T.S. Chaithra[1], Meenakshi Meena[2], Kuldeep Kumar[1] and O.P. Meena[1]
[1]ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Kota, Rajasthan
[2]Ph.D. Scholar, Rajasthan College of Agriculture, Department of Horticulture, MPUAT, Udaipur, Rajasthan

Ensuring income in rainfed production systems of semi-arid regions continues to be a priority concern. The nature has options for sustainable production system. Agri-horticulture offers opportunity to enhance productivity by engaging natures's principles of diversity on the field. Growing of arable crops in association with fruit species is one of the viable approaches to sustain the crop production and stabilize the rural economy by enhancing the income. Apart from ensuring the efficient utilization of the natural resources, agri-horticulture systems can potentially be more productive than growing of pure crops. This article describes the package of practices along with production potential of agri-horticulture crops which is found to be quite promising under semi-arid conditions of South-eastern regions.

Introduction

Semi-arid region is characterized by sparse and highly variable rainfall, extreme variation of diurnal and annual temperature and high evaporation. Shortage of rainfall results partially or completely failure of the crop production. Crop production alone is inadequate to sustain the livelihood in the region. Integration of arable crop production with perennial components like fruit crops can play pivotal role to provide assured production and income. It is also largely attributes in the improvement of soil fertility, microclimate modernization and moisture availability to the inter spaced grown crops. In agri-horticulture system, trees and agricultural crops are combined together and they compete with each other for growth resources such as light, water and nutrients. The resource sharing in component crops may result in complementary or competitive effect depending upon nature of species involved in the system. Guava is proved as highly remunerative fruit crop for degraded lands of semi-arid region. Intercropping with guava is not only done for an extra profit generation but it also provides better land utilization technique through optimum production and along with maintains soil health by checking soil erosion. Guava + green gram agri-horticulture has been identified as an efficient agri-horticulture system for South-eastern eco-system of Rajasthan.

3. Potential of Guava and Green Gram Agri-Horticulture

Guava (*Psidium guajava*) is a drought hardy fruit crop which can be grown in poor alkaline or poorly drained soils. It can grow in soils with pH ranging from 4.5 to 7.5. Area under cultivation of guava is rapidly increasing in South-eastern Rajasthan due to its adoptability to stress conditions and good market value. Guava is a widely spaced crop and its growth rate in early stages is slow which offers an excellent opportunity for agri-horticulture of short duration, low growing legumes for resource conservation, weed control, insurance against crop failure and maximizing production. Unlike guava, green gram (Mung bean) is a fast growing (65-70 days duration) legume, which escapes competition with guava and is suited well for rainfed conditions.

4. Package of Practices for Agri-Horticulture System

4.1. Field Preparation

Plough the land 20 cm deep with mould board plough during pre-monsoon showers to control weed growth. Complete two operations with harrow / cultivator followed by planking to make smooth surface. Provide proper grade for drainage to avoid water logging.

ISSN: 3049-2289

4.2. Planting of Guava Sapling

Pit dig with one cubic meter sized uring first week of May. Spacing of pit is 6 x 6 m apart from plant to plant and row to row. Pit fills with mixture of soil, well rotten FYM @ 50 kg and 100 g of Fenvalerate dust (0.4%) per pit. Plant the guava (cv. L-49) saplings during month of July after onset of monsoon. Support the plant with bamboo stick to promote straight growth.

4.3. Sowing of Crops

Treat green gram seeds with Carbendazim @ 2 g/kg of seeds. Use 15 kg of green gram variety "MH1142" (65-70 days duration) for one-hectare agri-horticulture. Sow the inter crop immediately after first shower of the monsoon. To reduce erosion, sow green gram in rows across the slope i.e. 30 cm apart. Keep plant-to-plant distance in green gram as 10 cm.

4.4. Fertilizer Application

Apply 5 t/ha well rotten FYM in the field during land preparation. Apply fertilizer dose of 20 kg N, 30 kg P_2O_5 and 30 kg K_2O /ha as basal. Apply fertilizers to the guava plants on the basis of age. Fertilizers apply in circular trench along the periphery of the root zone. For the first four years FYM is applied in the month of June. Inorganic fertilizers are given in three split doses distributed equally in the months of July, September and February.

Table 1. Manure and fertilizer apply as per plant age

Age of plants (Years)	FYM (Kg)/plant	N (g)	P (g)	P (g)
1	5	100	50	50
2	10	200	100	100
3	20	300	150	150
4	30	400	200	200
5	40	600	300	300

4.5. Interculture Operations

First weeding should be completed within 25 days of sowing to keep the field weed free. Create dust mulch during dry spells to reduce moisture loss through evaporation. Regular, shallow hoeing is recommended in the basin of plant to remove weeds and break the soil capillaries, which helps conserve soil moisture. Manual weeding with a *khurpi* is the safest method for young guava plants.

4.6. Insect / Pest control

Dissolve 750 ml monocrotophos in 500 litre of water and spray in one hectare area for control of red hairy caterpillar, semilooper, tobacco caterpillar, capsule borer, and leaf hopper in castor. Repeat spray, if required, after a fortnight. Spray 75 g streptocyclin and 2 kg diathane Z – 78/ha for control of viral diseases in green gram. Apply carbofuran granules in soil before sowing @ 1 kg active ingradient /ha for control of thrips, stemfly, jassids and white fly in green gram. Spray malathion 50 EC @ 2 ml/L or dimethoate 30 EC @ 1 ml/L of water to control guava fruit fly. Spray 0.5% methyl parathion to control mealy bug in early instars. Scrape loose bark and swab the basal part of the trunk (up to 3 feet) with coal tar + kerosene (1: 2 ratio) to control bark eating caterpillar in guava plants.

5. Crop Harvesting

When 80% pods of green gram mature, picking should be done at regular intervals to avoid losses due to shattering. Fruit picking of guava start from November to December (winter crop) when they are fragrant, slightly yellow or light green, and give slightly under gentle pressure.

Photo . Guava fruit harvesting under agri-horticulture

ISSN: 3049-2289

6. Economics

- Total cost of system (including cost of green gram cultivation and guava plantation) is Rs. 59,000/ ha.
- Sole crop of green gram gives gross and net returns of Rs. 79,450/- and Rs. 56,850/ha, respectively.
- Guava + green gram system gives gross and net returns of Rs. 3,41,980/- and Rs. 2,82,980/ha, respectively.
- Benefit Cost Ratio of the agri-horticulture system is 4.79.

AGRICULTURE BULLETIN

ISSN: 3049-2289

Hydroponics Farming: The Soil-Less Revolution Feeding the Future

Dr. D. Dev Kumar[1*], Dr. K. Venkatakiran Reddy[2], Dr. T. Lokya[3], Ms. R. Divyalatha[4]

Hydroponics is a method of growing plants without soil, using mineral nutrient solutions dissolved in water instead. Plants can be grown with their roots exposed to the solution or supported by an inert medium like perlite, gravel, or rock wool. This technique uses less water than traditional farming and can result in faster growth and higher yields.

Nutrient delivery: Plants receive all necessary nutrients directly from the water, eliminating the need for soil.

Growth medium: While some systems have roots in water, others use an inactive medium to support the plants.

Water and nutrient management: The water is often recycled, and a balanced pH with the correct concentration of nutrients is maintained.

Benefits

1. **Water conservation:** Hydroponics can use as little as 10% of the water required for traditional farming.
2. **Faster growth:** Plants often grow faster, sometimes doubling or tripling the size and speed of growth compared to soil-based methods.
3. **Space-saving:** It is an efficient way to grow crops in a controlled environment, even in urban areas.
4. **Year-round production:** It allows for year-round growing, regardless of climate.
5. **Less waste:** It can reduce the use of pesticides and fertilizers, which can be harmful to the environment.

Applications

1. **Home and small-scale use:** It's popular for hobbyists and home gardening because it is a "cleaner" method that doesn't involve soil.
2. **Commercial farming:** It is used by commercial growers for various crops.
3. **Space exploration:** NASA uses hydroponic techniques for growing plants in space programs.
4. Not needed here, let's dive into hydroponics
5. You want to know more about hydroponics.

Solution:

Hydroponics is a soilless cultivation method where plants grow in a nutrient-rich solution rather than soil. Here are some key aspects:

Types of Hydroponic Systems: NFT (Nutrient Film Technique), DWC (Deep Water Culture), Ebb and Flow, Drip Irrigation, and Aeroponics.

Advantages: Water efficiency, increased crop yields, reduced land use, and less pesticide usage.

Common Plants: Lettuce, kale, spinach, tomatoes, cucumbers, and herbs like basil and mint thrive in hydroponics.

ISSN: 3049-2289

Hydroponics provides plants with precise nutrient control, optimal water supply, and often increased oxygen levels, promoting healthy growth.

Setting Up a Basic System:

1. Choose a system type (e.g., NFT or DWC).

2. Select a suitable location with adequate light.

3. Prepare the nutrient solution.

4. Plant your chosen crops.

5. Monitor pH and nutrient levels regularly.

Common Challenges:

- pH imbalance
- Nutrient deficiencies
- Pests and diseases

Tips for Success:

- Start small and scale up.
- Research specific plant needs.
- Monitor and adjust regularly.

Want to dive deeper into a specific aspect of hydroponics

Sounds like you're looking for more info on hydroponics! Here's some more:

- Hydroponic Nutrients: Plants need macro (N, P, K, Ca, Mg, S) and micro (Fe, Zn, Cu, Mn, B, Mo) nutrients. You can buy premixed solutions or create your own.
- pH Management: Hydroponic systems thrive between pH 5.5-6.5. Monitor regularly and adjust using pH up/down solutions.
- Lighting: LED grow lights are popular for hydroponics due to energy efficiency and customizable spectrum.

ISSN: 3049-2289

The Invisible Hands That Feed India: Why Farmers Deserve More Than One Day

Harithraadevi L., Research Scholar
Department of Postharvest Technology,
Horticultural College and Research Institute, TNAU, Periyakulam - 625604, Theni, India.

Before the rest of us have even opened our eyes, the day has already begun in the fields of India. Dew settles on tender leaves, bullocks stamp the cool soil, and farmers rise each day with steady resolve, carrying out the work that helps keep the entire nation fed and thriving. Every grain of rice, every slice of fruit, every vegetable on our plate carries the unseen fingerprints of these tireless hands.

On National Farmers' Day, or Kisan Diwas, observed on 23 December, the country pauses, even if only for a moment, to honour the people who live this reality every day. Farmers, revered as "Annadatas", do far more than grow crops; they nourish the nation, support the rural economy, and strengthen the food security of 1.469 billion people. Their work is continuous, their challenges are significant, and their contribution is beyond measure.

National Farmers Day 2025: Farming with Resilience in a Changing Climate

The theme for National Farmers Day 2025, *"Adapting to Climate Change"*, shines a spotlight on how farmers are innovating to meet the challenges of a shifting climate. From planting drought-tolerant crops and adjusting sowing schedules to improving soil and water management, farmers are embracing practical strategies and modern technologies to safeguard their harvests. These efforts not only help protect their livelihoods but also ensure the nation's food security, highlighting the resilience and ingenuity that drive India's agricultural sector forward despite increasingly unpredictable weather.

Kisan Diwas: More Than Just a Date

The day marks the birth anniversary of Shri Chaudhary Charan Singh, India's fifth Prime Minister, a statesman who championed farmers' rights with unmatched conviction. His legacy of compassion, policy reforms, and dedication to rural upliftment remains central to conversations on agricultural development even today.

Kisan Diwas is not merely a date on the calendar; it's a reminder. A reminder to recognise the resilience of those who work under open skies, through heat, rain, and uncertainty. A reminder to acknowledge the people whose hands fill our plates long before the food ever reaches our kitchens. And above all, a reminder that their contributions deserve not just celebration, but sustained respect and support throughout the year.

The Backbone of India's Food Security

India's farmers are much more than cultivators. They are the nation's guardians of food security. From Punjab's golden wheat belts to Tamil Nadu's lush paddy fields and the vegetable farms surrounding every growing city, farmers work from dawn to dusk to keep food moving through the supply chain. Their resilience fuels a country of more than 1.469 billion people.

Yet behind this strength lies a reality most consumers rarely witness, one shaped by uncertainty, hardship, and the constant need to adapt. Agriculture, employing nearly half of India's population, remains one of the strongest pillars of the economy and a major force in national development. It contributes significantly to the country's Gross Value Added, and with more than half of India's land under cultivation, farming continues to shape both rural livelihoods and the nation's overall prosperity.

Table 1. Estimated Foodgrain Production in India (2024–25)

ISSN: 3049-2289

Foodgrain	Production Estimate (2024–25)
Rice	1,501.84 lakh tonnes
Wheat	1,179.45 lakh tonnes
Nutri/Coarse Cereals	639.21 lakh tonnes
Maize	434.09 lakh tonnes
Total Pulses	256.83 lakh tonnes
Millet (Shri Anna)	185.92 lakh tonnes
Chickpea	111.14 lakh tonnes
Moong	42.44 lakh tonnes
Tur	36.24 lakh tonnes
Total Oilseeds	429.89 lakh tonnes
Soybean	152.68 lakh tonnes
Groundnut	119.42 lakh tonnes
Rapeseed & Mustard	126.67 lakh tonnes
Sugarcane	4,546.11 lakh tonnes
Cotton	297.24 lakh bales (170 kg each)
Jute & Mesta	88.02 lakh bales (180 kg each)
Total Foodgrains	**357.73 million tonnes**

The impact of farmers stretches far beyond producing crops. They build rural communities, nurture local economies, and ensure that every household has access to food. Their dedication is reflected in the nation's achievements, with India's foodgrain production projected to reach a record 357.73 million tonnes in 2024–25, marking a significant rise from the previous year. This milestone is not just a number; it is a tribute to the determination, innovation, and sacrifices of millions of farmers. Their work touches every corner of the country, quietly, consistently, and with unwavering commitment. Through their efforts, India remains nourished, resilient, and steadily moving forward.

The Quiet Burdens Farmers Carry

1. **Climate Uncertainty**: Unseasonal rains, heatwaves, and floods now disrupt every stage of cultivation, making each season unpredictable for smallholders across India.
2. **Low and Unstable Income**: Market price crashes, dependence on middlemen, and rising input costs often leave farmers with little reward for their hard work.
3. **Rising Production Costs**: Increasing prices of fuel, fertilisers, and labour force many small farmers to borrow heavily to start the season.
4. **Postharvest Losses**: With 10–30% of fruits and vegetables lost due to inadequate storage and weak supply chains, much of farmers' produce spoils before reaching consumers.

But Still, They Continue

On 27 September 2025, farmers from Tamil Nadu's Cauvery delta, especially around Thanjavur, sounded the alarm. Heavy and erratic rainfall has disrupted their paddy harvest and dried up their hopes.

On 7 March 2025, D. Prabhu, a tomato farmer from Thumpichipalayam near Kallimandayam in Dindigul (Tamil Nadu), opened up about his losses: "I spent over ₹5 lakh on fertilisers, pesticides and fencing … However, the huge arrival has caused a fall in prices to ₹4–6 per kg in the retail market." Despite investing heavily in his farm, Prabhu says the flood of tomatoes in the market has crushed his income, a bitter reminder that high production doesn't always mean high profits.

On 18 September 2025, Priya Ranjan, Joint Secretary (Horticulture), Ministry of Agriculture,

ISSN: 3049-2289

revealed that India loses nearly 15% of its horticultural produce after harvest, mainly due to gaps in storage, transport, and cold-chain facilities. Speaking at a national workshop, she noted that with horticulture production at around 365 million tonnes, the wastage is enormous, hurting both farmers and consumers. The government is now working to modernise the postharvest system through upgraded cold-chain standards, digital monitoring, and a nationwide infrastructure survey. The long-term goal is straightforward, bringing postharvest losses below 5% by 2047 and creating a food system that safeguards both farmer earnings and national food security.

Despite every obstacle, India's farmers wake before dawn, till their land, nurture their crops, and hope for a better tomorrow. Their perseverance keeps grains in our markets, fruits in our baskets, and vegetables on our plates. Their hands remain invisible to most of us, yet they carry the weight of an entire nation.

Government Initiatives for Farmer Welfare and Sustainable Agriculture

Figure 1. Major Agricultural Schemes and Initiatives Supporting Farmers

Acknowledging the essential contribution of farmers, the Government of India has introduced a range of programmes aimed at improving their socio-economic well-being and promoting sustainable agricultural development. Key initiatives such as the Pradhan Mantri Kisan Samman Nidhi (PM-KISAN), Pradhan Mantri Fasal Bima Yojana (PMFBY), and Pradhan Mantri Kisan Maandhan Yojana (PM-KMY) offer income support, crop insurance, and long-term social security. Complementary schemes, including the Modified Interest Subvention Scheme (MISS), Kisan Credit Card (KCC) scheme, and Agriculture Infrastructure Fund (AIF), provide affordable credit and strengthen agricultural infrastructure. Collectively, these programmes create a comprehensive support system that empowers farmers to adopt sustainable practices, enhance productivity, and achieve greater financial stability.

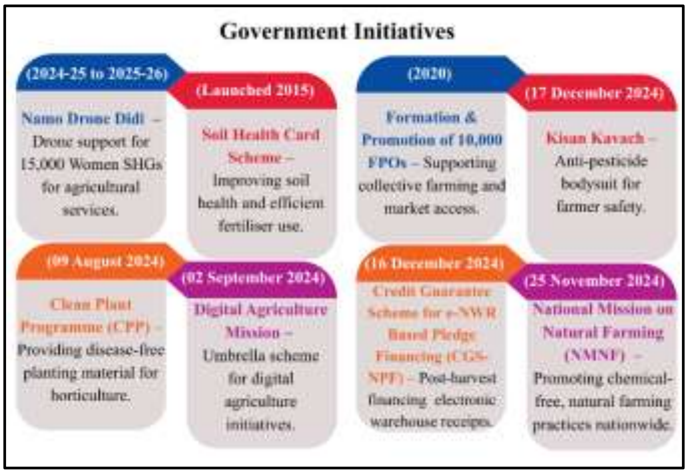


Figure 2. Other Notable Government Initiatives and Schemes Supporting Farmers

What Consumers Can Do

While policy changes and institutional support matter greatly, ordinary citizens can also make a difference. Consumers can play a vital role in supporting farmers beyond policy measures. Buying local and seasonal produce ensures fresher food while boosting rural incomes and reducing transport emissions. Minimising food waste honours the hard work behind every meal, and purchasing from Farmer Producer Organisations (FPOs) helps farmers secure fair prices and access better technology. Celebrating and acknowledging farmers' contributions shouldn't be limited to Kisan Diwas; sharing their stories, promoting sustainable choices, and supporting reforms can make a difference every day.

A Day Is Not Enough

Farmers never take a break. Their work goes on, day after day, and their dedication never falters.

Their commitment does not waver. Kisan Diwas is a reminder, but our gratitude must go beyond ritual. It calls for awareness, action, and genuine appreciation, because the invisible hands that feed India deserve far more than one day of recognition. They deserve respect every day of the year. Happy Farmers' Day to the Invisible Hands! Let us always appreciate and thank our farmers for their tireless hard work and for putting food on our plates every day.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Impact of Crop Residue Burning on Climate Change

Meka Shivaram Reddy[1*], Peram Nagaseshi Reddy,[1] Chinthala Mounika[2], N. Vikram[3], P.V.S. Naidu[1]
[1]Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India – 848125
[2]ICAR-Indian Agricultural Research Institute, New Delhi, India – 110012
[3]Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana

Crop residue burning is a widespread practice in northern India, where farmers burn large volumes of rice–wheat residues to quickly prepare fields for the next crop. Although inexpensive and time-efficient, this practice releases dense smoke plumes containing particulate matter, carbon dioxide, methane, carbon monoxide, and black carbon, which significantly contribute to post-monsoon air pollution and the formation of the Asian Brown Cloud. These emissions degrade air quality, accelerate climate change, reduce visibility, and pose severe health risks, including increased respiratory and cardiovascular diseases. Burning also results in major nutrient losses, particularly nitrogen, phosphorus, potassium, and organic carbon leading to long-term soil degradation, lower fertility, and reduced crop productivity. Consequently, farmers face higher production costs due to greater fertilizer and irrigation needs. Despite its negative impacts, burning persists because of short turnaround times between rice harvest and wheat sowing, reduced straw demand, slow decomposition rates, and the higher costs associated with mechanical or biological alternatives. Sustainable solutions such as the Happy Seeder, Super SMS, Pusa Decomposer, residue-based bioenergy, composting, supportive policies, and farmer awareness programs offer effective pathways to reduce burning. Widespread adoption of these practices is essential for improving air quality, restoring soil health, and promoting climate-resilient agriculture.

Introduction

Each year after harvest, vast fields across northern India and Pakistan are set aflame to quickly clear leftover crop residues. This practice though convenient and inexpensive produces dense smoke clouds that travel thousands of kilometres, severely degrading air quality and contributing to climate change. With India generating about 625 million tonnes of crop residues annually, of which 92 million tonnes are burned, the nation faces a serious open-field residue burning crisis (Gatka *et al.*, 2024). Cereal crops alone contribute 70% of total residues, making rice–wheat systems the major source.

The Asian Brown Cloud: A Regional Climate Threat

A major transboundary air pollution layer, termed the "Asian Brown Cloud," forms over South Asia from October to February. This thick haze, visible even from satellites, results largely from stubble burning across northwestern India and eastern Pakistan. Studies show that crop residue burning contributes up to 60% of pollution in northern India and Pakistan during the post-monsoon season (Gatka *et al.*, 2024). This mixture of carbon soot, aerosols, and gases traps heat in the lower atmosphere, disrupting monsoon patterns, reducing solar radiation reaching the surface, and accelerating regional climate change.

In 2024, over 37,602 paddy stubble fire incidents were reported across six Indian states:

S.no	State	No. of Burning Incidents
1.	Madhya Pradesh	16,360 (44% of total)
2.	Punjab	10,909
3.	Uttar Pradesh	3,308
4.	Rajasthan	2,269
5.	Haryana	1,153

These widespread fires together create the seasonal brown haze that blankets South Asia each winter, with severe public health and climatic consequences.

Composition of Emissions

Burning 1 tonne of paddy residue releases several harmful compounds into the atmosphere (Ghanghas *et al*., 2023)

Compound	Quantity released (per tonne)
Particular matter	3 kg
Carbon dioxide (CO_2)	60 kg
Sulphur dioxide (SO_2)	2 kg
Ash	199 kg

Besides these, significant amounts of methane (CH_4) and carbon monoxide (CO) are also emitted, both of which have high global warming potential. Such emissions collectively contribute to 60 % of post-monsoon air pollution episodes across northern India and Pakistan.

Loss of Valuable Nutrients

Crop residue burning not only pollutes the air but also strips the soil of essential nutrients. According to Misra (2022), in Punjab:

Nutrient	Loss due to burning (%)	Amount lost (kg/ha)
Nitrogen (N)	90 %	35
Phosphorus (P)	25 %	3.2
Potassium (K)	20 %	21
Carbon (C)	100 %	2400

This nutrient loss severely reduces soil fertility and organic carbon content, forcing farmers to depend more on costly chemical fertilizers—an economically and ecologically unsustainable cycle.

Multifaceted Impacts of Crop Residue Burning

1. Atmospheric Impacts

The open-field burning of crop residues releases significant quantities of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) all of which contribute directly to global warming and climate change. Beyond these gaseous emissions, stubble burning produces vast amounts of fine particulate matter ($PM_{2.5}$) and smog, which severely deteriorate air quality and visibility across the Indo-Gangetic plains. Prolonged exposure to these pollutants has serious health implications; according to the World Health Organization (2024), the average life expectancy in Delhi has decreased by up to 12 years due to chronic exposure to high levels of air pollution. Furthermore, the black carbon generated during residue burning settles on the Himalayan glaciers, reducing their albedo (reflective capacity). This accelerates glacial melting, disrupts regional hydrology, and poses long-term threats to water security and climate stability across South Asia.

2. Soil Impacts

Crop residue burning has profound and long-lasting effects on soil health and productivity. The intense heat generated during burning leads to a substantial loss of soil organic carbon and microbial biomass, which are vital for maintaining soil structure and fertility. This destruction of beneficial microorganisms causes a sharp decline in soil biodiversity and nutrient cycling, disrupting the natural processes that convert organic matter into plant-available nutrients. As a result, soils become biologically inactive, less porous, and structurally degraded. The reduction in organic matter also diminishes the soil's moisture retention capacity, making it more prone to drying, erosion, and nutrient leaching. Collectively, these impacts culminate in reduced soil fertility and declining crop productivity, threatening the long-term sustainability of agricultural systems

ISSN: 3049-2289

3. Health Impacts

The fine particulate matter ($PM_{2.5}$ and PM_{10}) released during crop residue burning poses a serious public health hazard. These ultrafine particles are small enough to penetrate deep into the lungs and even enter the bloodstream, triggering inflammation and oxidative stress in vital organs. Continuous exposure to such polluted air impairs respiratory and cardiovascular functions, leading to a rise in chronic pulmonary diseases, asthma, bronchitis, and heart ailments. Vulnerable groups especially children, the elderly, and individuals with pre-existing respiratory conditions are disproportionately affected. Over time, the cumulative impact of breathing polluted air contributes to declining lung function and reduced life expectancy, making residue burning not just an environmental issue but a major public health crisis in agrarian regions.

4. Economic Impacts

The decline in soil fertility resulting from residue burning has serious economic repercussions for farmers and rural communities. As nutrient-rich topsoil and organic matter are lost, crop yields gradually decrease, directly reducing farm income and profitability. To compensate for diminished fertility, farmers are compelled to apply higher doses of fertilizers and increase irrigation, which significantly raises input costs and reduces net returns. Over time, this cycle of soil degradation and rising production expenses undermines the economic viability of farming. At a broader scale, regional economies suffer as reduced agricultural output lowers market supply, while escalating healthcare costs from pollution-related illnesses place additional financial burdens on society. Thus, residue burning not only erodes the soil's productivity but also weakens the economic resilience of entire farming communities.

Why Farmers Still Burn Residues

Despite awareness and penalties, burning persists because of economic and time pressures:

- Short window between harvest of *kharif* rice and sowing of *rabi* wheat forces rapid clearance.
- Shrinking livestock populations have reduced straw demand as fodder.
- Lengthy composting periods discourage biological recycling.
- Most critically, burning is cheaper—farmers incur a penalty of around ₹2,500 per acre, while mechanical or compost-based disposal costs ₹6,000–₹7,000 per acre. Hence, for many smallholders, burning remains a less expensive alternative

Sustainable Alternatives and Policy Measures

Addressing the problem of crop residue burning requires a multi-pronged approach that integrates technological innovations, policy support, and behavioural change among farmers. Several sustainable alternatives and policy measures have been developed to convert residues from an environmental liability into an agricultural asset.

1. In-situ Residue Management

In-situ management focuses on using residues within the field itself, allowing them to decompose and enrich the soil:

- Happy Seeder: Enables direct sowing of wheat into standing rice stubbles without burning, saving time and conserving moisture.
- Super Straw Management System (Super SMS): Attached to combine harvesters to finely chop and spread residues evenly, facilitating their decomposition.
- Rotavators, mulchers, and zero-till drills: Help in incorporating residues into the soil, improving organic matter and microbial activity.
- Pusa Decomposer (IARI): A microbial consortium that decomposes paddy straw within 20–25 days, turning residue into humus and enhancing nutrient availability.

ISSN: 3049-2289

2. Ex-situ Utilization of Crop Residues

When residues cannot be managed in-situ, they can serve as valuable raw material for various industries:

- Bioenergy production: Residues are used in biogas, bioethanol, and biomass power plants, contributing to renewable energy generation.
- Industrial applications: Straw is used for paper, cardboard, packaging, and biochar production, providing farmers with an additional income source.
- Animal feed and bedding: Paddy and wheat straw can be treated (e.g., urea treatment) and used as nutritive fodder in regions facing feed scarcity.
- Composting and vermicomposting: Residues can be transformed into organic manure to restore soil fertility and reduce chemical fertilizer dependency.

3. Policy and Institutional Support

The Government of India has implemented multiple schemes and policies to promote residue management:

- National Policy for Management of Crop Residue (NPMCR, 2014): Encourages both in-situ and ex-situ management practices.
- Central Sector Scheme on Promotion of Agricultural Mechanization (2018): Provides financial assistance up to 80% for machinery purchase and promotes Custom Hiring Centres (CHCs) for smallholders.
- National Clean Air Programme (NCAP) and Commission for Air Quality Management (CAQM): Focus on reducing crop burning emissions in northern India.
- Subsidies and incentives: Farmers are given direct financial support and awareness-based incentives for adopting residue management technologies.
- State-level initiatives: Punjab, Haryana, and Uttar Pradesh have launched "Zero Stubble Burning Villages" and eco-club programs to engage communities and youth.

4. Technological Innovations and Research

- Development of straw-collecting drones, baling units, and palletisation machines for easy collection and transport.
- Biochar production technologies that convert residue into a stable form of carbon, improving soil fertility while sequestering carbon.
- Digital monitoring and satellite-based detection systems by ICAR–CREMS and ISRO to track stubble fires and plan interventions.
- Research on microbial consortia and enzymatic accelerators to enhance the rate of residue decomposition under diverse agro-climatic zones.

5. Behavioural and Educational Interventions

- Farmer field schools and demonstrations highlighting the benefits of residue retention and decomposition.
- Integration of residue management into agricultural curricula and extension training.
- Community-led residue management cooperatives, where machinery and composting units are shared to reduce costs.
- Reward and recognition programs for villages or panchayats achieving "zero-burning" status.

6. Long-term Strategic Approaches

- Crop diversification toward less residue-generating crops (e.g., maize, pulses, and oilseeds) in rice-dominated areas.
- Incentive-based carbon farming programs, providing carbon credits or payments for ecosystem services to farmers adopting sustainable practices.

- Integration of residue management with conservation agriculture, promoting minimum tillage, residue retention, and crop rotation.
- Strengthening public–private partnerships (PPP) for large-scale biomass collection, storage, and utilization.

Conclusion

Crop residue burning is a pressing environmental, health, and climate crisis. Each plume of smoke released from a burning field carries not only lost nutrients but also lost opportunities for sustainable farming. By replacing the matchstick with microbial and mechanical innovation, India can transform crop residues from pollutants into valuable resources, ensuring cleaner air, fertile soil, and a resilient climate.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Role of Artificial Intelligence and Machine Learning in Agriculture 5.0

Pradyumna Pratap Harichandan, Anup Behera and Anjali Khuntia
College of Agricultural Engineering and Technology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha

The world's population has soared to approximately 8.2 billion in 2025 and is projected to approach 10 billion by 2050 (Suzuki and Pirlea, 2025), a growth fuelled by advances in public health, sanitation, and life expectancy (Maja and Ayano, 2021). As this demographic expansion continues, there is mounting pressure on core resources such as land, water, and energy intensifying already urgent challenges in food security, climate adaptation, and resource sustainability. In parallel, population growth is coupled with the migration of workers to other industries and a steadily rising average age among farmers, contributing to labour shortages and greater urgency for innovation within agriculture. These challenges expose the limitations of conventional farming systems and necessitate a fundamental transformation towards more intelligent, resilient, and sustainable production paradigms. In response, the agricultural domain has undergone a rapid digital evolution, progressing from the site-specific management of Precision Agriculture (PA) to the data-driven approach of Smart Farming, and now towards the integrated, human-centric vision of Agriculture 5.0.

1.1 The Evolutionary Journey of Farming

Agriculture has evolved significantly over time, progressing through five major stages shaped by technological innovation. It began with the pre-industrial era (Agriculture 1.0), when farming was largely subsistence-based and depended heavily on human and animal labour using basic tools. The Industrial Revolution (Agriculture 2.0) marked a turning point, introducing mechanization and scientific farming practices that enabled large-scale production. This growth accelerated during the Green Revolution (Agriculture 3.0) in the mid-20th century, which increased yields through the use of chemical inputs, improved crop varieties, and early digital technologies. Building on this momentum, the onset of Agriculture 4.0 ushered in advanced digital systems including the Internet of Things, artificial intelligence, and precision farming techniques allowing data-driven decision-making and greater efficiency. Today, agriculture is moving toward Agriculture 5.0, a future where cutting-edge technologies are combined with sustainability, resilience, and ethical food production to address global food security and environmental challenges (Fig. 1).

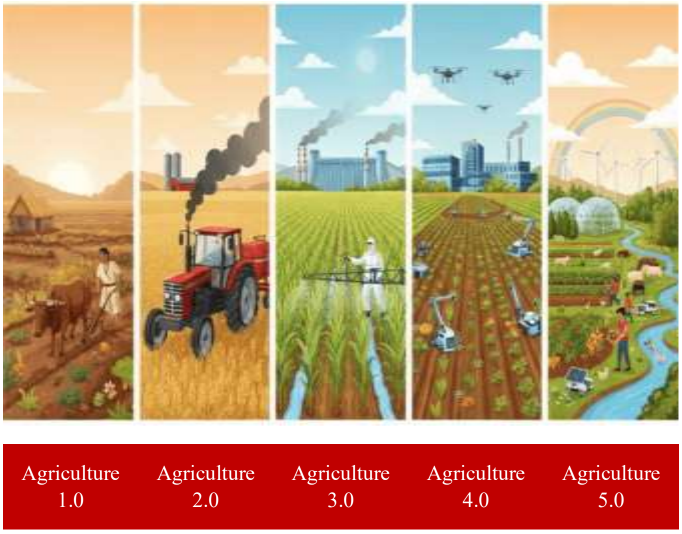


Fig. 1 Evolution of Agriculture

1.2 AI is the brain of Agriculture 5.0

In the emerging landscape of Agriculture 5.0, numerous advanced technologies including the Internet of Things (IoT), collaborative robotics, digital twins, and blockchain come together to form an interconnected technological ecosystem. Within this system, each component plays an important role in sensing, storing, and executing agricultural processes. However, if this network represents the body of Agriculture 5.0, then Artificial Intelligence (AI) can be seen as its central brain the element responsible for interpreting information, learning from it, and enabling intelligent action. While technologies such as IoT and robotics generate and transmit vast amounts of operational data, it is AI that transforms this data into meaningful insights. For example, IoT devices continuously monitor soil moisture, temperature, nutrient levels, and crop health, but it is AI-driven analytics that identifies trends, detects anomalies, and interprets these measurements into practical recommendations such as diagnosing diseases, detecting nutrient deficiencies, or predicting irrigation needs. Similarly, digital twins provide virtual representations of farm systems, integrating environmental, biological, and operational data. Yet, the true value of these digital replicas is realized through AI, which conducts simulations, evaluates possible scenarios, and delivers data-backed guidance to improve decision-making and resource use. The same dependency applies to automation: collaborative robots and autonomous machinery rely on AI-powered capabilities such as machine learning, computer vision, and navigation algorithms to perform tasks like selective harvesting, weeding, or autonomous movement within fields. In this way, AI functions not merely as another tool within the technological stack but as the integrative and decision-making engine that enables Agriculture 5.0 to operate intelligently. Without AI, the system would resemble a body with sensory organs but no cognitive capacity able to collect data but unable to interpret or respond effectively. It is this unique ability to learn, reason, predict, and adapt that establishes AI as the foundational element driving the sustainable, efficient, and resilient vision of Agriculture 5.0 (Taha et al., 2025).

1.3 Architecture of smart agriculture

The smart agriculture architecture illustrated in Fig. 2 can be understood as a vertically integrated, multilayered system in which data are systematically acquired, transmitted, stored, analysed, and ultimately transformed into intelligent actions that support decision-making in the field. At the foundation lies the sensing layer, comprising heterogeneous devices such as in situ sensors, drones, IoT nodes, weather stations, and cameras, which continuously monitor soil properties, plant physiology, microclimatic conditions, and machinery status (Guevara et al., 2024). The vast streams of raw data generated at this level are then conveyed through the transmission layer, where gateways and communication infrastructures (e.g., cellular, LPWAN, or satellite networks) ensure reliable, real-time and often bidirectional connectivity between the field and higher-level platforms (Hashmi et al.,2024). These data are aggregated in the storage layer, which relies on cloud servers, local edge servers, and relational or NoSQL databases to provide scalable, secure, and structured repositories capable of handling high-volume, high-velocity agricultural data (Kalyani et al., 2024). Building on this foundation, the analysis layer performs data preprocessing, feature extraction, and advanced analytics, leveraging machine learning and deep learning models to detect patterns, generate predictions, and derive diagnostic or prescriptive insights related to crop health, yield, resource use, and operational efficiency (Zhu and Palaoag, 2023). At the top of the architecture, the application layer exposes these AI-driven insights through user-facing decision-support systems, mobile and web dashboards, automated control interfaces, and farm management platforms, enabling precise interventions such as variable-rate irrigation or fertilization, early disease control, and optimized harvest planning (Fig. 2). In this hierarchical framework, AI constitutes the central cognitive component: while the lower layers provide sensing, communication, and storage capabilities, it is the analytical intelligence embedded in the upper layers that interprets data, orchestrates system responses, and effectively transforms a network of devices into an integrated, smart, and adaptive agricultural ecosystem (Shukla et al., 2023).

ISSN: 3049-2289

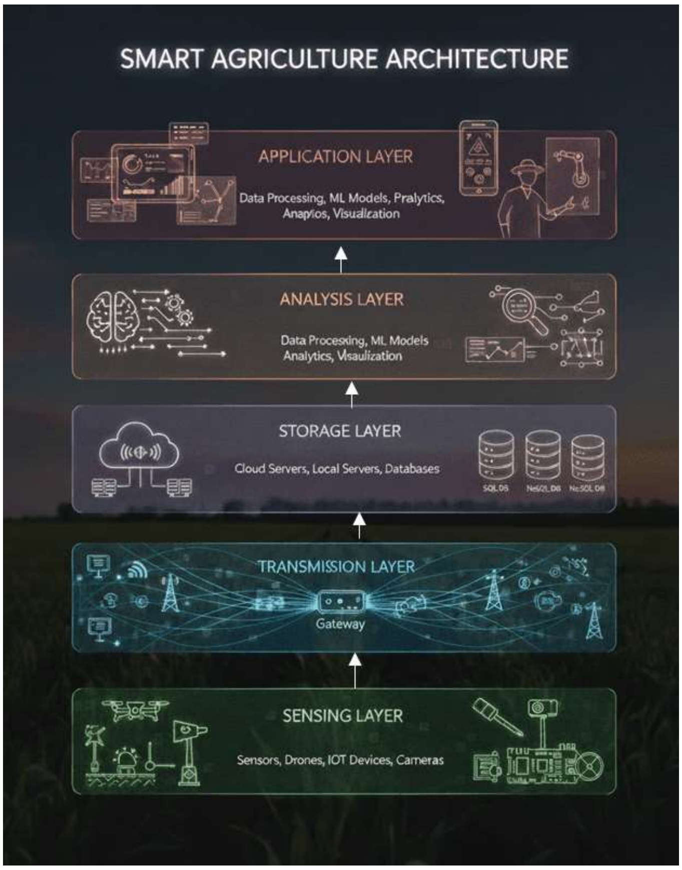


Fig.2 Architecture of smart agriculture

2. AI Technologies Reshaping the Farm

2.1 Computer Vision and Drone Intelligence

Computer vision and drone intelligence have revolutionized modern agriculture by providing farmers with unprecedented insights into crop health and field conditions, effectively becoming "the farmer's new eyes" (Zhang and Kovacs, 2012). Using high-resolution imagery captured by drones equipped with multispectral and hyperspectral sensors, combined with machine learning algorithms, farmers can perform detailed analyses of plant growth, detect early symptoms of disease and pest infestations (Fig. 3), and monitor soil moisture levels with high precision. This technology enables targeted interventions, such as precise irrigation and pesticide application, which optimize resource use, reduce costs, and improve yield quality. Recent research emphasizes that drone-based computer vision systems enhance decision-making speed and accuracy, offering scalable solutions for both smallholders and large commercial farms, and thus embody a critical component of Agriculture 5.0's intelligent farming ecosystem (Guebsi et al., 2023).

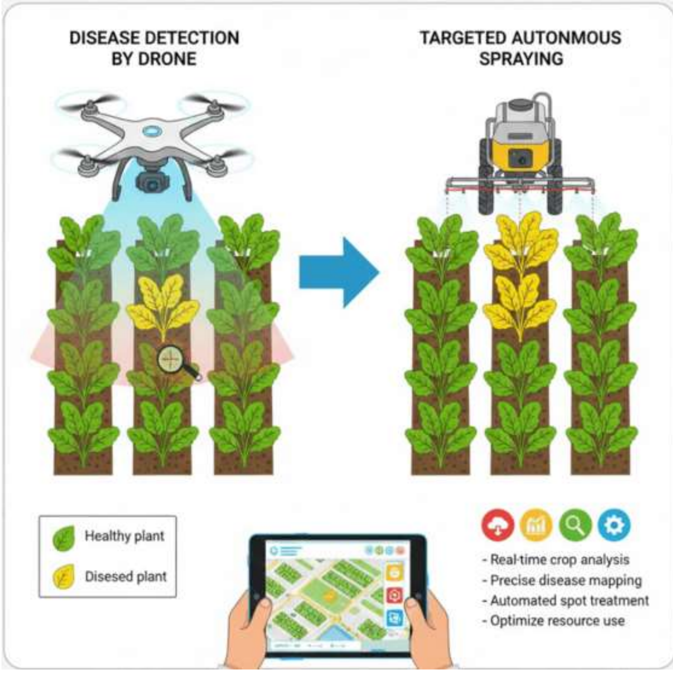


Fig. 3 Disease detection using drone and computer vision

2.2 Weather forecasting using AI

Artificial intelligence (AI) has significantly enhanced the predictive capabilities in agriculture, particularly in weather forecasting and crop yield estimation, which are crucial for optimizing farm management and ensuring food security. By integrating vast datasets from satellites, weather stations, and ground sensors, AI models, especially those based on machine learning and deep learning techniques, can accurately predict weather patterns (Fig. 4), detect early climatic anomalies, and forecast crop yields with high precision. These predictions empower farmers to make informed decisions on planting schedules, irrigation, fertilization, and harvest timing, thereby minimizing risks associated with weather variability and maximizing productivity (Nyakuri et al., 2023). Recent studies report that AI-driven weather and yield forecasting systems have improved accuracy by up to 30% compared to traditional methods, offering scalable solutions for managing agricultural uncertainty under climate change pressures.

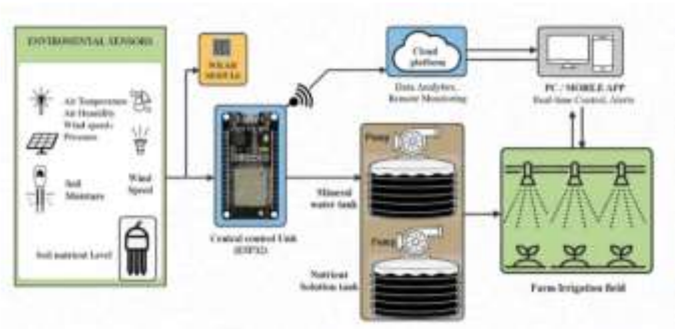


Fig. 4 Irrigation based on weather prediction

2.3 Autonomous tractors and harvesters

Robotics equipped with artificial intelligence have redefined modern agriculture by introducing autonomous tractors and smart harvesters that operate with minimal human intervention. These intelligent machines combine advanced sensors, GPS, machine learning, and computer vision to navigate fields precisely, avoid obstacles, and perform tasks such as planting, tilling, and harvesting with high accuracy and efficiency (Fig. 5). Autonomous tractors optimize fuel consumption and soil compaction by following the most efficient routes, while smart harvesters employ real-time crop monitoring to selectively harvest only mature produce, thus minimizing losses and labour costs. Research indicates that these AI-enabled robotic systems significantly improve operational efficiency, reduce human labour dependency, and contribute to sustainable practices by enabling precise resource application and minimizing environmental impact, making them a cornerstone technology of Agriculture 5.0 (Bechar and Vigneault, 2016).

Fig. 5 Field robotics using data intelligence and cloud platform

2.4 The Internet of Things (IoT) and AI

The integration of Internet of Things (IoT) and artificial intelligence (AI) is transforming agriculture into a highly connected, intelligent system capable of real-time monitoring and adaptive management. IoT devices such as soil sensors, weather stations, drones, and automated machinery continuously capture vast amounts of data from the field, including moisture levels, nutrient content, temperature, and crop health indicators (Fig. 6). AI analyses this data using machine learning models to generate actionable insights that enable precision farming practices such as optimized irrigation, fertilization, and pest control tailored to the specific needs of each crop and location (Wolfert et al., 2027). This synergy between IoT and AI not only increases operational efficiency and resource use but also enhances sustainability by reducing waste and environmental impacts. Recent research underscores that farms leveraging IoT-AI frameworks achieve significant improvements in productivity, cost savings, and resilience against climate variability, embodying the core technological foundation of Agriculture 5.0.

Fig. 6 IOT based sensing, analysis, control and execution

3. Conclusion

Artificial Intelligence (AI) and Machine Learning (ML) are pivotal in advancing Agriculture 5.0 by revolutionizing sustainable farming through enhanced decision-making, optimized resource use, and increased productivity. AI-powered systems enable the collection, processing, and analysis of extensive data—from weather patterns and soil health to crop monitoring and market trends—allowing farmers to make precise, real-time decisions that mitigate risks and maximize yields. These technologies facilitate precision agriculture by enabling targeted application of irrigation, fertilizers, and pesticides, reducing waste and environmental impact. Moreover, integration with autonomous machinery streamlines labour-intensive operations, improving efficiency and profitability while addressing the shortage of agricultural labour. Despite challenges related to data privacy, connectivity, and equitable access, continued innovations and collaborative frameworks are crucial to overcoming these barriers. Overall, AI and ML are indispensable tools shaping a resilient and sustainable agricultural future, empowering stakeholders to meet global food security challenges and nurturing environmental care.

References

Ali, G., Maad, M., Bosco, B., Mostafa, A., & Ioannis, A. (2024). *A survey on artificial intelligence in cybersecurity for smart agriculture: State-of-the-art, cyber threats, artificial intelligence applications, and ethical concerns.* Mesopotamian Journal of Computer Science, 2024, 71–121. https://doi.org/10.58496/MJCSC/2024/007

Bechar, A., & Vigneault, C. (2016). Agricultural robots for field operations: Concepts and components.Biosystems Engineering, 149, 94-111. https://doi.org/10.1016/j.biosystemseng.2016.07.010

Guebsi, R., Mami, S., & Chokmani, K. (2024). Drones in Precision Agriculture: A Comprehensive Review of Applications, Technologies, and Challenges. *Drones*, *8*(11), 686. https://doi.org/10.3390/drones8110686

Guevara, I., Ryan, S., Singh, A., Brandon, C., & Margaria, T. (2024). *Edge IoT prototyping using model-driven representations: A use case for smart agriculture.* Sensors, 24(2), 1–20. https://doi.org/10.3390/s24020495

Hashmi, A., Mir, G. U., Sattar, K., Ullah, S. S., Alroobaea, R., Iqbal, J., & Hussain, S. (2024). *Effects of IoT communication protocols for precision agriculture in outdoor environments*. IEEE Access, 12, 46410–46421. https://doi.org/10.1109/access.2024.3381522

https://www.worldometers.info/world-population/

Jeong, J. H., et al. (2016). Random forests for global and regional crop yield predictions. PLOS ONE, 11(6), e0156571. https://doi.org/10.1371/journal.pone.0156571

Kalyani, Y., Vorster, L., Whetton, R., & Collier, R. (2024). Application scenarios of digital twins for smart crop farming through cloud–fog–edge infrastructure. Future Internet, 16(3), 1–16. https://doi.org/10.3390/fi16030100

Maja, M.M.; Ayano, S.F. The Impact of Population Growth on Natural Resources and Farmers' Capacity to Adapt to Climate Change in Low-Income Countries. Earth Syst. Environ. 2021, 5, 271–283.

Nyakuri, J., Ishimwe, P., Jean, V., Irakora, L., Bakunzi, S., Nshimyumuremyi, E., Ntawukuriryayo, S., Karanguza, A., Habiyaremye, F., & Theogene. (2023). *AI-based real-time weather condition prediction with optimized agricultural resources.* **European Journal of Technology, 7**. https://doi.org/10.47672/ejt.1496

Shukla, B. K., Maurya, N., & Sharma, M. (2023). *Advancements in sensor-based technologies for precision agriculture: An exploration of interoperability, analytics and deployment strategies.* Engineering Proceedings, 58(1), 1–6. https://doi.org/10.3390/ecsa-10-16051

Suzuki, E.; Pirlea, A.F. World Population Day: Trends and Demographic Changes, World Bank Blog- https://blogs.worldbank.org/en/opendata/world-population-day--trends-and-demographic-changes

AGRICULTURE BULLETIN
ISSN: 3049-2289

The Biopesticidal Buzz: A Safer Choice for Bees, or a Hidden Threat?

Soujanya, N[1*]., and Venu, H.S[2]
[1*]Ph.D Scholar, Department of Microbiology, Jain University, Bengaluru
[2]Junior Research fellow, ICAR-NBAIR, Bengaluru

The global decline of honeybee populations poses a significant threat to agricultural productivity and ecosystem health, with synthetic chemical pesticides identified as a major culprit. In response, biopesticides derived from natural materials like plants, bacteria, and minerals are being hailed as a safer, eco-friendly alternative. However, the assumption that "natural" automatically means "safe for bees" is being challenged by emerging science. This article explores the complex relationship between honeybees and these new-generation pest controls. While many biopesticides, such as certain bacterial and fungal strains, do indeed demonstrate low toxicity to bees, others, particularly botanical extracts like neem oil and pyrethrins, can be harmful at certain concentrations or when combined with other stressors. The key finding is that the safety of a biopesticide is not guaranteed by its origin but by its specific mode of action, formulation, and application context. Research reveals that even non-lethal exposures can impair honeybee navigation, foraging efficiency, and larval development, ultimately weakening the entire hive. Therefore, the shift to biopesticides is a positive step, but it requires careful management and continued research to ensure these tools truly protect our vital pollinators.

Pollination is one of the most essential natural activity for global food production, significantly enhancing yield and quality of crops such as fruits, vegetables, nuts, legumes, and oilseeds. Khalifa et al. (2021) highlighted that achieving food security in present world is highly challenging due to various factors, including climate change, fragmentation, and a rapidly growing human population. Without pollination, global food production could decrease by about 5-8%. Additionally, pollination helps in maintaining biodiversity and promotes sustainability within the agricultural sector by supporting natural ecosystems.

Among all pollinators, honey bees are recognized as the most efficient and reliable. These fascinating social insects thrive in organized colonies, where each bee performs specific duties for the survival of the entire colony. They work together to defend their nests and produce honey. By collecting nectar and pollen from flowers, honey bees facilitate pollen transfer between blossoms, enabling plants to produce seeds and fruits.

In the fight to protect our crops from pests, farmers have long relied on powerful chemical pesticides. But over the last decade, a shadow has fallen over our fields and orchards—the alarming decline of honeybee populations. As headlines blared about the dangers of neonicotinoids and other synthetic chemicals, a quiet revolution has been brewing: the rise of biopesticides.

Touted as a more natural and eco-friendly alternative, biopesticides are derived from living organisms like bacteria, fungi, and minerals. biopesticides considered as the "special forces" in pest control. Instead of the broad-spectrum "scorched earth" approach of some synthetic chemicals, they are often highly specific, targeting only a particular pest or a few related species.

The most famous example is Bt (*Bacillus thuringiensis*)**,** a soil bacterium used for decades. It produces spores and crystal proteins that are toxic only to specific insect larvae, like caterpillars and mosquitoes, but are harmless to humans, wildlife, and crucially, bees.

Other types include:

- **Plant-Incorporated Protectants (PIPs)**: Genes from Bt, for example, are inserted into corn or cotton, making the plant itself produce the pest-killing protein.

- **Fungal and Bacterial Insecticides**: Fungi like *Beauveria bassiana* that infect and kill specific insects.
- **Botanical Oils and Extracts**: Neem oil, pyrethrin (from chrysanthemums), and essential oils.

The clear path

The primary advantage of biopesticides for bees is their specificity. A pesticide designed to disrupt the gut of a leaf-eating caterpillar likely won't affect a bee, which has a completely different biology and diet. This is a monumental shift from systemic neonicotinoids, which are absorbed by the plant and can end up in its pollen and nectar, exposing bees for weeks. Studies have shown that many popular biopesticides, like certain Bt strains, have least to no direct toxicity to adult honeybees.

Biopesticides represent a significant step in the right direction. They are a powerful tool in the Integrated Pest Management (IPM) toolbox, allowing for targeted control that drastically reduces widespread bee poisoning.

The relationship between biopesticides and honeybees is one of promising potential, tempered by the need for careful stewardship. While they are far from the primary driver of bee declines and are a massive improvement over the most harmful synthetic chemicals, they are not risk-free. The buzz is that by continuing to research, regulate, and apply these tools wisely, we can cultivate a future where both our crops and our precious pollinators can thrive.

References

Khalifa, S. A., Elshafiey, E. H., Shetaia, A. A., El-Wahed, A. A. A., Algethami, A. F., Musharraf, S. G., & El-Seedi, H. R. (2021). Overview of bee pollination and its economic value for crop production. *Insects*, *12*(8), 688.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Precision Breeding for Allergen-Free crop

Lalchand[1,2*], Ritabrata Sarkar[1,2], Pramod Kumar Meghwal[1,2]
Anurag Kumar[1,2] and Sudhir Kumar[1]
[1]*ICAR–Indian Institute of Agricultural Biotechnology, Ranchi 834003, Jharkhand, India.*
[2]*ICAR-Indian Agricultural Research Institute, Pusa, New Delhi 110012 India.*

Using highly targeted genome-editing techniques like CRISPR/Cas9 and RNA interference (RNAi) to accurately modify or remove specific genes without introducing foreign DNA, precision breeding is a revolutionary development in contemporary genetic engineering. By directly targeting and silencing allergen genes, this method reduces or eliminates allergenic proteins at their source, making it possible to generate hypoallergenic crop kinds. Precision breeding has enormous promise to improve food safety and consumer health since it offers unmatched accuracy, efficiency, and a lower chance of unwanted effects when compared to conventional genetic manipulation.

What is Precision Breeding

precision breeding is a modern and highly targeted approach to genetic modification, primarily accomplished through techniques known as genome editing or gene editing. CRISPR (clustered regularly interspaced short palindromic repeats)/Cas9 system most widely used tool in this technology. In simple terms, gene editing is the process of adding or removing nucleotides at specific, specific genes or regions inside an organism's genome. CRISPR enables direct editing or removal of individual targeted nucleotides, which allows the development of hybrid crops with desired features, in contrast to earlier transgenic techniques that introduce foreign genes., The editing efficiency, throughput, and precision of CRISPR-based breeding have significantly improved when compared with less specific gene editing methods. This capability is being employed to address issues like food allergies, as it can be used for the precise regulation of gene activity and unequivocally knocking out allergen genes from the source. Other similar approaches/methods, such as Site-Directed Nuclease (SDN), also use precise cleavage for achieving genetic changes.

Success Story: Allergen-Free Foods

Allergen-free foods have been developed, with much success, by the application of highly specific gene-editing technologies such as RNA interference (RNAi) and CRISPR/cas9, to remove or suppress the expression of allergic proteins at their synthesis point. A prime successful story is that of peanuts (Arachis hypogaea), which is one of the major allergens causing serious food allergies. Using the RNAi technology, scientists were able to attempt silence of the genes of Ara h 2 and Ara h 6, which are immunodominant allergens. This strategy resulted in the reduction of IgE binding on the peanuts significantly, and lines with repressed protein expression did not further reduce seed germination or natural defences even after multiple generations.

Other major food crops have also made the same advancement, with the application of gene editing to deal with the baker asthma that was caused by amylase/trypsin inhibitor (ATIs), which is seen in wheat (Triticum aestivum). Researchers were able to knock down two ATI subunits concurrently using CRISPR technology resulting in a reduction in the expression of both subunits. In soybeans (Glycine max), a significant source of allergens, gene editing has shown positive results. Soybeans have their major allergen Gly m Bd 30 K removed successfully using specific techniques. In addition, gene editing of several loci in the target resulted in frame-shift mutation of second and third generation soybean seeds, which showed successful reduction in the accumulation and expression of allergen proteins.

ISSN: 3049-2289

The success of these studies points to the need to develop modified food allergens that are safer and hypoallergenic to treat the needs of people with food allergies.

How Does It Work

Precision breeding is primarily done using CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats) to use advanced genome engineering methods to target the genome of an organism in a very precise manner. This is a technology which makes it possible to directly edit or delete specific nucleotides within specific genome, unlike previously when transgenic methods often involved the insertion of foreign genes. The two key components of the CRISPR/Cas9 system include a guide RNA and Cas9 endonuclease. SgRNA is a short, editable sequence of RNA, and it is expected to complete a target sequence within a target gene. The Cas9 protein is programmable and acts as two molecular scissors by generating a site-specific double-stranded break (DSB) in the DNA when this sgRNA complexes with the Cas9 protein and directs it to the specific spot in the DNA. To introduce the gene into the genome into an inactivated state (a knockout) or to alter the target gene to obtain a desired phenotype, researchers can insert, delete, or modify nucleotides following this precise disruption of the targeted target region of the genome to produce cell regeneration processes. To produce designer crops with superior characters, including this reduced allergenicity, this innovative method makes it possible to target specific genes, including the elimination of allergen genes in edible foodstuffs like wheat and peanuts.

Advantages and Impact

By enabling the unambiguous deletion of the allergen genes in the genome or their targeted and specific alteration, precision breeding, mainly with the use of gene-editing technologies, such as CRISPR/Cas9, is highly beneficial and has great implications in the creation of allergen-free and allergen depleted food crops. One of the main strengths of the new technology is that it is more precise with editing ability like none the world has seen before than other methods of genetic editing; Compared to the transgenic approach, CRISPR means that one can now directly edit or silence specific nucleotides without introducing foreign DNA, minimizing the risk of unintended consequences such as the appearance of new allergies. The overall effect on the health and food safety of the world is great since this is an appealing method of improving food safety and protecting consumer health against the harmful, and often deadly, effects of food allergies. It has demonstrated viable effectiveness in reducing the expression of alpha-amylase/trypsin inhibitors (ATIs) in plants, such as wheat, and in remarkably lowering the expression of potent allergens (such as Ara h 2 and Ara h 6) in peanuts and soybeans with no negative impact on important plant phenotypes such as seed germination or resistance to fungal infection. Socially, the produced allergen-free products can enhance food safety as they can be returned into society appropriately, such as daycare and schools, and increase consumer confidence and satisfy the growing demand of healthy and safe alternatives. This innovation will result in a completely new market of previously prohibited food products and help to increase agricultural value economically. Moreover, the accuracy of the CRISPR technology, which may accelerate its further adoption in treating allergy-related illnesses and changing the path of disease management, appears to be less of a concern to the masses and regulators compared to the traditional GM. Moreover, the accuracy of the CRISPR technology, which may accelerate its further adoption in treating allergy-related illnesses and changing the path of disease management, appears to be less of a concern to the masses and regulators compared to the traditional GM.

Challenges

The issues related to the breeding of allergen-free crops are complex in nature, which is mostly due to the fact that the targeted plant proteins are complicated in their structure. The complex problem is that not all the time it is possible to directly attack the allergy genes to prevent their expression in the plant due to the fact that some of the allergens are vital to the physiological processes of the plant

ISSN: 3049-2289

including biotic and abiotic stress reduction. The elimination or modification of these allergenic proteins is very difficult to do without losing other beneficials peanut attributes, like taste or nutritional content. Moreover, the problem of allelic protein profiles is also a major challenge and in the case of certain crops such as peanuts, limited genetic variation also inhibits breeding initiatives. Finally, the realization of totally allergen-free crop varieties appears to be extremely hard, and there are still fears that there is the necessity to stabilize the epigenetic changes and to know their long-term impacts on human health and the environment fully.

Future Prospects

The future outlook of precision breeding of allergen-free food is very bright and it will have a tremendous implication in world health, food safety and economy. Since CRISPR/Cas9 provides unprecedented accuracy, efficiency and throughput, the technology is set to be used extensively and be successful in creating new hypoallergenic crop varieties. On a social level, the resulting allergen-free products are likely to enhance food safety by being safely reintroduced into the general community such as daycare centers and schools to increase consumer confidence and meet the increasing demand of healthy, safe alternatives. The economic impact of this innovation is expected to create an entirely new market to previously limited foodstuff products and play a key role in the further value formation of agriculture, which will eventually lead to the success of addressing allergic diseases and form the future of the development of the entire pharmaceutical field throughout the globe.

Conclusion

The use of CRISPR/Cas9 gene-editing technology in the process of precision breeding is an exceptional change to the older transgenic technology; it provides a more accurate and effective means of overcoming food allergies than it has ever been before. This method directly and unambiguously alters or removes the genes of the concrete allergen (such as Ara h 2/ Aar h 6 in peanuts or ATIs in wheat) at their origin, bypassing the shortcomings of traditional breeding. Its promising potential to produce stable and hypoallergenic form of crops without disrupting the important plant attributes is demonstrated by the successful results that it has been producing in wheat, peanuts and soybeans. The end effect of this innovation is far-reaching, and it provides a potential solution to increase food safety and safeguard the health of consumers and open up new economic and social possibilities due to reintroducing safe, nutritious foods to the market.

References

Brackett, N. F., Pomés, A., & Chapman, M. D. (2022). New frontiers: Precise editing of allergen genes using CRISPR. *Frontiers in Allergy*, *2*, Article 821107. https://doi.org/10.3389/falgy.2021.821107

Chakraborty, A., & Wylie, S. J. (2024). Gene editing for allergen amelioration in plants – A review. *Plant Gene*, *40*, Article 100476. https://doi.org/10.1016/j.plgene.2024.100476

Gelaye, Y., & Luo, H. (2025). Application of epigenetics for allergen-free peanut production: a comprehensive review. *Epigenetics Insights*, *18*, Article e006. https://doi.org/10.48130/epi-0025-0006

Vadthya, L., Parmar, S., Huai, D., Karpinska, B., Chen, X., Bera, S. K., Pandey, M. K., Pandey, A. K., Sudini, H. K., Ozias-Akins, P., Foyer, C. H., Nwosu, C. V., Baker, A., Xu, P., Liao, B., Mir, R. R., Guo, B., Nguyen, H. T., Kumar, R., ... Varshney, R. K. (2023). Prospects for developing allergen-depleted food crops. *The Plant Genome*, *16*(2), Article e20375. https://doi.org/10.1002/tpg2.20375

AGRICULTURE BULLETIN
ISSN: 3049-2289

Diversity and Distribution of Trichogrammatid Species in India: Morphological, Behavioral Differences and Their Role in Crop Pest Management

Sumit Mehla*[1], B.L. Sharma[1a], Deepika Kalkal[1a], Palvi Thakur[1] and Raj Kumar[1]
[1] PhD Scholar, [1a] Assistant Scientist,
Department of Entomology, CCS Haryana Agricultural University, Hisar, Haryana

Trichogramma species are minute egg parasitoids widely used in India for biological control of Lepidopteran pests. Morphologically, they are distinguished by subtle variations in body size, antennal hair length, wing setae and male genitalia structure. Behaviourally, species differ in host specificity, oviposition timing and dispersal ability, adapting to crop and pest cycles. Temperature tolerance varies: *T. chilonis* thrives in warm, humid regions while others like *T. japonicum* prefer cooler, moist lowlands. Their distribution spans major agricultural rice belts in eastern and southern India, sugarcane areas in the northeast and vegetable/cotton zones in Punjab, Haryana, Madhya Pradesh and other states.

Introduction

Different species of *Trichogramma* (*trichogrammatids*) are widely used in India as effective biological control agents targeting the egg stages of various insect pests, mainly Lepidopteran species, to manage crop pests sustainably. These tiny egg parasitoid wasps belong to the family *Trichogrammatidae* and are integral to integrated pest management (IPM) programs in Indian agriculture. Here is a comprehensive, original article on the major *Trichogramma* species used in India, their specific crop and pest associations, and their contributions to pest management.

Trichogramma Species Used in India and Their Role in Crop and Pest Management:-

Trichogramma are minute egg parasitoids (0.2–1 mm) that lay their eggs inside the eggs of insect pests, primarily Lepidoptera, interrupting pest development before larval stages occur. Their parasitoid activity reduces pest populations and damages caused by insects, enabling better crop health and yields. *Trichogramma* species have been extensively studied and deployed in India for managing pests in important crops such as rice, sugarcane, cotton, vegetables, and fruit crops.

Diversity of *Trichogramma* in India:-

Globally, approximately 210 species of *Trichogramma* have been identified. In India, about 30 species have been documented, but only around a dozen species have been effectively employed in pest management programs. The major species used commercially and experimentally include:

- *Trichogramma chilonis Ishii*
- *Trichogramma japonicum Ashmead*
- *Trichogramma pretiosum Riley*
- *Trichogramma achaeae Nagaraja*
- *Trichogramma brassicae Bezdenko*

Among these, *T. chilonis* is the most widely studied and utilized species across diverse agricultural ecosystems due to its adaptability and broad host range.

A. *T. japonicum* **B.** *T. achaeae* **C.** *T. pretiosum* **D.** *T. chilonis*

ISSN: 3049-2289

Table 1: Key Trichogramma Species in India with Morphological and Behavioral Differences

Species	Morphological Characteristics	Behavioral Traits	Dominant Crops and Target Pests	Dominant Growing Regions / Distribution in India
Trichogramma chilonis Ishii	- Body length ~0.5mm. - Males yellow with black sides on pronotum, mesonotum, and hind legs. - Antennae with long hairs (~2.5x flagellum width). - Male genitalia with distinct dorsal gonobase expansion and chitinized structures.	- Adaptable to diverse hosts. - Parasitizes eggs of sugarcane borers, rice stem borers. - Active in warm and humid climates. - Releases synchronized with pest oviposition.	- Sugarcane: borers like *Chilo infuscatellus, C. sacchariphagus indicus.* - Rice: stem borers *(Scirpophaga incertulas, C. partellus).* - Cotton, vegetables (fruit borers).	Widely distributed across India, including Punjab, Maharashtra, Andhra Pradesh, Tamil Nadu, West Bengal.
Trichogramma japonicum Ashmead	- Males dull yellow with black thorax and abdomen tergites. - Antennal hairs long and sharply tapering (~3.5x flagellum width). - Male genitalia highly sclerotized, horseshoe shaped.	- Prefers lowland rice and sugarcane environments. - Efficient against rice stem borers. - Exhibits host-seeking behavior linked to volatiles from infested plants.	- Lowland rice: control of yellow stem borer (*Scirpophaga incertulas*). - Sugarcane stem borers.	Prominent in rice-growing regions: Eastern Uttar Pradesh, Haryana, West Bengal, Kerala, Tamil Nadu.
Trichogramma pretiosum Riley	- Males yellow with blackish mesoscutum and abdomen. - Antennal hairs finely tapering (~2.5x flagellum width). - Genitalia with triangular dorsal expansions.	- Used in vegetables and cotton. - Parasitizes a wide array of Lepidopteran eggs. - Can withstand moderately variable climatic conditions.	- Vegetables: tomatoes, cabbage (fruit borers). - Cotton bollworms.	Found mainly in northern and central Indian vegetable-growing belts such as Punjab, Haryana, Madhya Pradesh.
Trichogramma achaeae Nagaraja & Nagarkatti	- Adults ~0.5 mm long. - Males yellow with blackish sides on pronotum and abdomen.	- Found mostly in orchards and horticultural crops. - Parasitizes eggs of	- Orchards: mango, citrus. - Vegetables with Lepidopteran pests.	Widely distributed, recorded in southern and

ISSN: 3049-2289

	- Antennal flagellum with long hairs (>2.5x width). - Male genitalia with distinct chelate structures.	Lepidoptera in fruit crops. - Exhibits good host fidelity.		northeastern India.
Trichogramma chilotraeae *Nagaraja & Nagarkatti*	- Males ~0.51 mm long with yellow and black patterning on pronotum and abdomen. - Antennal flagellum unsegmented with very long hairs (>3x width). - Genitalia have a triangular dorsal expansion but with tapering apex.	- More specific to certain sugarcane borers. - Active in mid-higher elevation or humid areas.	- Sugarcane: *Chilo infuscatellus* primarily.	Localized mainly in West Bengal and eastern India sugarcane belts.

Mechanisms and Advantages of Using Trichogramma in Pest Management

Trichogramma attack insect eggs by laying their eggs inside them; the developing wasp larvae consume the host egg contents, preventing pest hatching and further crop damage. Their advantages include:

- Eco-friendly pest control: Reduces chemical pesticide use, preserving beneficial insects and soil health.
- Early pest suppression: Targets the pest egg stage, stopping pest outbreaks before larval damage occurs.
- Wide host range: Effective against numerous Lepidopteran pests.
- Compatibility: Can be integrated with other IPM tools including resistant varieties, biopesticides, and cultural practices.
- Cost-effective: Mass-rearing techniques, such as rearing on alternative host eggs (like *Corcyra cephalonica*), allow large-scale field application.

Release Strategies and Field Applications:-

Two main methods of deploying *Trichogramma* in Indian agriculture are common:

1. **Inundative releases**: Releasing large numbers of adults during pest egg-laying periods for immediate pest suppression.
2. **Augmentative releases**: Periodic releases throughout the crop cycle, synchronized with pest activity for sustained control.

Challenges and Future Directions:

Despite successes, several challenges remain:

- **Pesticide incompatibility**: Some chemical insecticides can reduce *Trichogramma* effectiveness by lowering parasitism rates.
- **Field persistence**: Environmental factors can affect survival and activity.
- **Strain specificity:** Matching parasitoid strain with local pest and agro-ecological conditions is important for efficacy.
- **Mass culture consistency**: Sustainable and economically viable production systems must be maintained.

ISSN: 3049-2289

Efficiency of Major *Trichogramma* Species

Trichogramma chilonis and *T. japonicum* are extensively documented for their successful control of stem borers and bollworms in India, showing high parasitization rates when released at optimal densities. Field and laboratory tests on *T. japonicum* have demonstrated strong performance in suppressing pests like the rice yellow stem borer, with efficiency affected by host selection and mass-rearing conditions. Studies suggest that indigenous *Trichogramma* strains tend to be more effective due to greater adaptation to local climatic stresses.

Trichogramma pretiosum has also been recognized for its significant parasitization efficiency against pests such as *Helicoverpa armigera*, often outperforming other species under controlled temperatures typical in continental India. *T. embryophagum* and *T. evanescens* exhibit considerable efficiency on specific hosts, with emergence rates and survival optimized at temperatures around 30°C–32°C which aligns with many Indian cropping seasons.

Adaptations in Indian Continental Climate

Continuous rearing and selection have led to strains of *Trichogramma* species with enhanced tolerance to temperature extremes, supporting their expansive field use. For instance, the development of high-temperature tolerant *T. chilonis* in New Delhi improved its effectiveness during Indian summers. Similarly, low-temperature adapted strains of *T. chilonis* maintain performance during cooler periods, ensuring versatility.

Egg parasitoids may also enter diapause or quiescence within host eggs, a trait that enables them to withstand fluctuations in environmental conditions and synchronize emergence with pest egg availability. Indigenous species often display superior reproductive success, longevity, and parasitism rates due to selection pressures encountered in their native environments.

Conclusion

Across India's continental climates, *Trichogramma* species demonstrate significant differences in efficiency and climate adaptability. Native strains are generally more effective due to their evolutionary adaptation to local stress factors like high temperature and humidity variations. The continual development of climate-resilient strains, as well as judicious species selection based on crop and region, is essential for maximizing biological control success and reducing chemical pesticide use. The strategic deployment of locally adapted *Trichogramma* lines ensures reliable pest suppression, economic benefits for farmers, and sustainability within Indian agricultural systems.

Reference:-

Kfir, R., Overholt, W. A., Khan, Z. R., & Polaszek, A. (2002). Biology and management of economically important lepidopteran cereal stem borers in Africa. *Annual review of entomology*, **47** (1), 701-731.

Khan, Z. R., Pickett, J. A., Berg, J. V. D., Wadhams, L. J., & Woodcock, C. M. (2000). Exploiting chemical ecology and species diversity: stem borer and striga control for maize and sorghum in Africa. *Pest Management Science: Formerly Pesticide Science*, **56** (11), 957-962.

Okosun, O. O., Allen, K. C., Glover, J. P., & Reddy, G. V. (2021). Biology, ecology, and management of key sorghum insect pests. *Journal of Integrated Pest Management*, **12** (1), 4.

Patel, C. T., Patel, C. C., & Varma, C. B. (2021). Biochemical basis of resistance to stem borer, *Chilo partellus* (Swinhoe) infesting forage sorghum, *Sorghum bicolour* (L.) Moench. *Journal of Entomology and Zoology Studies*, **9**(1), 834-839.

Radadiya, N. V., Davda, B. K., Ghevariya, T. V., Kanzariya, K. G., Der, H. N., & Varma, A. D. (2023). Evaluation of insecticide and botanical combination for management of sorghum shoot fly and stem borer.

Ramesh, S., Maheswaramma, S., Prasad, G. S., Shankar, M., & Kumar, M. P. (2023). Efficacy of granular insecticides against sorghum stem borer, *Chilo Partellus* (Swinhoe) in Sorghum. *Journal of Entomological Research*, **47,** 926-929.

Kalkal, D., Yadav, K., Mehla, S., Bhall, R., Saini, A., & Godara, M. (2024). Population Dynamics and Ecological Role of *Chrysoperla* spp. In Major Agricultural crops: A Review. *Journal of Scientific Research and Reports*, **30**(9), 850-857.

Raypuriya, N., Ghanghas, R., Das, A., Priyadarshini, P., Yadav, S., Dose, J. G., & Maheshwari, S. (2025). Advances in Biological Control of Crop Pests through Entomopathogenic Nematodes: A Review. *UTTAR PRADESH JOURNAL OF ZOOLOGY*, **46**(17), 8-22.

Kumar, R., Rana, A., Yadav, P., & Mehla, S. Escalating Resistance of Pink Bollworm in Bt Cotton Across Northern India and Its Strategic Management.

Thakur, P., Kumar, D., & Mehla, S. Sublethal and Chronic Effects of Insecticide Residues.

****

ISSN: 3049-2289

From Cities to Soil: Rediscovering Rural India Through Agro-Tourism

Dhiraj Kumar
Chief Manager & Faculty,
State Bank Institute Rural Development, Hyderabad

1. Introduction

In the fast-paced urban world dominated by concrete structures, digital lifestyles, and the relentless pursuit of material success, a growing number of people are experiencing what can be termed as a "rural disconnect. Agro-tourism can help bridge that reconnects, between city folks and the soil—the essence of India's agrarian roots.

Agro-tourism, also known as Agri-tourism, involves visiting active farms, plantations, or agricultural enterprises to engage in recreational, educational, or hands-on farming experiences. In India, where more than 60% of the population is still engaged in agriculture, agro-tourism holds immense potential—not just for cultural exchange, but also for rural development, sustainable livelihoods, and alternative income generation for farmers.

2. The Rise of Agro-Tourism in India

Agro tourism in India is an old concept. Traditionally, visits to ancestral villages during summer vacations were common, offering an informal peek into rural life. However, organized agro tourism as a commercial activity began gaining momentum in the early 2000s. States like Maharashtra, Kerala, Punjab, and Himachal Pradesh pioneered this model with strong support from tourism and agriculture departments.

Maharashtra was the first Indian state to frame a formal agro-tourism policy in 2010, enabling farmers to develop tourism infrastructure on their land with financial support and regulatory facilitation. The Maharashtra State Agro-Tourism Development Corporation has been instrumental in creating awareness and setting up agro-tourism centres that now attract thousands of visitors annually.

3.What Makes Agro-Tourism Appealing?

3.1. Authentic Experiences

Unlike traditional tourism that revolves around sightseeing or luxury stays, agro tourism offers immersive experiences. From ploughing fields, milking cows, harvesting fruits, cooking on a chulha (mud stove), to sleeping under the stars in a mud house—visitors get to live a day in the life of a rural household.

3.2. Eco-Friendly and Sustainable

Agro-tourism is inherently low-impact. It encourages sustainable travel practices, supports local economies, and promotes eco-friendly living. The absence of pollution, organic farming practices, and green landscapes makes it a wellness retreat for many.

3.3. Educational Value

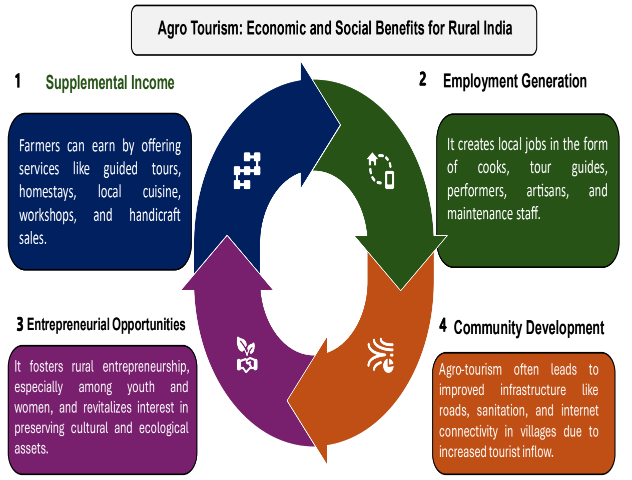
Urban children and youth benefit immensely from agro tourism. They Understand the farm-to-fork journey while interacting with animals, and also learn about plants and biodiversity, which promote environmental consciousness and respect for farmers.

3.4. Cultural Connection

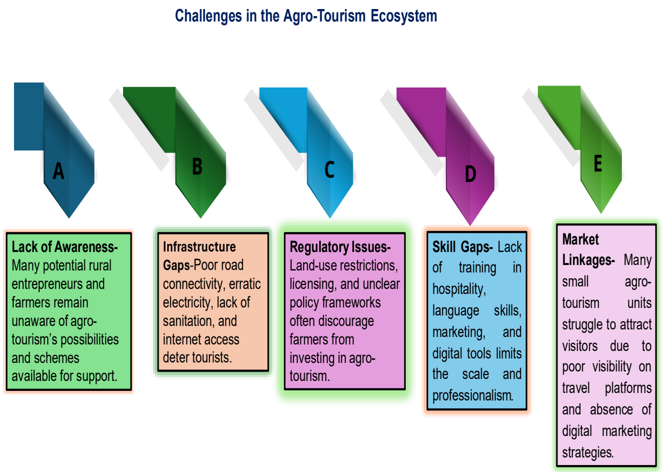
Agro-tourism opens the door to conserve rich rural traditions like folk music, art, dance, crafts, and local cuisines and foster cultural empathy and appreciation for India's diverse heritage.

ISSN: 3049-2289

4.Economic and Social Benefits for Rural India



5.Challenges in the Agro-Tourism Ecosystem



6.Policy Support and the Way Forward

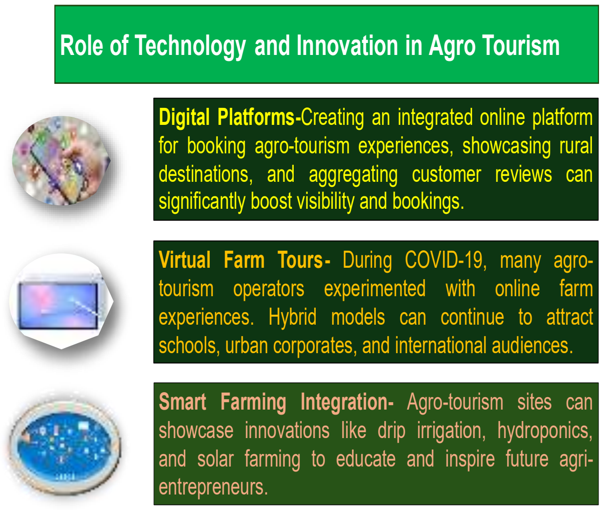
Recognizing its potential, several government schemes and initiatives are now aimed at promoting agro tourism:

- Scheme from MIDH- Mission for Integrated Development of Horticulture.
- Rural Tourism schemes under Ministry of Tourism provide financial support for capacity building and promotion.
- Start-Up India and Skill India missions are relevant for grooming rural tourism entrepreneurs.

However, a more cohesive and cluster-based approach is required. States should identify potential agro-tourism clusters and develop them with proper branding, convergence of schemes, and public-private partnerships.

Banks and NBFCs should design agro-tourism-specific credit products. Support from NGOs and FPOs in hand-holding farmers through planning, training, and digital marketing may also be explored.

7. Role of Technology and Innovation



8. Case Studies: Models That Work: The Goat Village, Uttarakhand

In the aftermath of the devastating Kedarnath floods of 2013, while much of the nation watched in sorrow, one man decided to stay back—and sow the seeds of rural transformation.

That man was Mr. Roopesh Rai, a high-flying marketing professional with elite stints at the Taj Group and Thomas Cook. What began as a humanitarian relief visit to Uttarakhand turned into a personal awakening. Witnessing the widespread displacement and crumbling of fragile Himalayan livelihoods, Roopesh found himself questioning the purpose of his corporate career. The bustling cities he once loved felt far removed from the dignity and resilience of rural India he had just encountered.

By 2015, Roopesh Rai, along with 02 other persons founded Green People.

Their flagship project? The Goat Village—an idea designed to revive abandoned mountain villages

ISSN: 3049-2289

through a unique fusion of eco-tourism, goat-based farming, and cultural conservation.

The Goat Village: A Dream Built in Stone and Soil

Source: https://thegoatvillages.com/

Location: Garhwal region, Nag Tibba and other locations
Model: Community-Based Rural Agro-Tourism

The first Goat Village, nestled in the hills of Nag Tibba, was more than just a tourism initiative—it marked the beginning of a grassroots movement for rural revival. Built using traditional Koti Banal architecture—stone-and-wood houses that naturally withstand the elements—the village invited urban guests to unplug from the digital world and reconnect with nature. There were no TVs, no Wi-Fi routers, and certainly no room service. Instead, guests got piping-hot mandua (millet) rotis cooked on wood stoves, trails through deodar forests, and early morning goat-milking routines.

It was luxury in simplicity. And it clicked. What started with just a trickle of 1,200 visitors annually soon swelled to over 90,000 guests a year. As word spread, Green People opened new Goat Village sites across Uttarakhand—from the alpine meadows of Dayara Bugyal, to the birdwatcher's paradise of Pangot, to the scenic hamlets of Kumali.

A unique model by Green People (a social enterprise), The Goat Village offers curated agro-tourism experiences in Himalayan villages. Tourists are provided shelters in traditional stone huts, they eat local Garhwali food, and also explore goat rearing and terrace farming.

8.1 More Than Tourism: A Model for Rural Renaissance

Behind the picturesque homestays and Instagrammable landscapes was a serious social mission: reverse migration.

For years, Uttarakhand's Mountain villages have faced silent collapse. Young people moved away due to lack of jobs. Fields lay fallow. Homes were abandoned. Green People sought to reverse this trend by bringing livelihoods back to the mountains.

Locals were trained in hospitality, organic farming, and goat-rearing. Women's SHGs started producing jams, pickles, and handicrafts. Youth who once migrated for odd jobs in cities were now running village homestays with pride. Every visitor who booked a room contributed not just to the local economy, but to a story of rural self-reliance.

8.2 Recognition and Ripple Effects

By 2019, The Goat Village had grown from a social experiment into a nationally recognized success story. It was awarded the **Gold Prize at the Indian Responsible Tourism Awards** and also bagged honors at the **World Responsible Tourism Awards**, rubbing shoulders with international pioneers in ethical travel.

But the true reward was what bloomed silently across the Himalayan slopes:

- Fields once barren turned green.
- Children who once walked miles to school returned to homes with income.
- Village temples, previously echoing with absence, now rang with the laughter of guests and hosts alike.

9. Way forward

Agro-tourism is not merely about rural travel—it is a cultural movement, a sustainability solution, and a developmental catalyst. It brings together the best of both worlds: the wisdom of rural India and the curiosity of urban India.

As India marches ahead in the digital age, it must not leave its roots behind. Reconnecting cities with soil

ISSN: 3049-2289

will not only revive forgotten values and practices but also empower millions of farmers and rural families with dignity, pride, and prosperity.

Agro-tourism, if nurtured well, can become the "green gold" that cultivates a more inclusive, connected, and grounded India.

"What if we returned to where we began?" A thought for the readers.

Reference: https://thegoatvillages.com/

AGRICULTURE BULLETIN
ISSN: 3049-2289

Soil Ecoacoustics: The Science of Hearing a Living Earth

Aparna Mohan
PG Scholar, Department of Soil science and Agricultural Chemistry, Kerala Agriculture University

Soil ecoacoustics is an innovative field that uses sound recording and analysis to study activity and diversity within soil ecosystems. By interpreting acoustic signals from organisms, physical processes, and human influences underground, researchers can non-invasively assess soil health, biodiversity, and environmental changes using specialized sensors and analytics. This approach supports sustainable land management and precision agriculture.

What is Soil Ecoacoustics?

Soil ecoacoustics is an emerging field where researchers record and analyze sounds produced by organisms and processes within the soil crackles, clicks, pops, and rustling noises that reveal the presence and activity of invertebrates, insects, and even small mammals. Using specialized microphones and probes, scientists can pick up minute vibrations and interpret them to assess soil biodiversity and health.

Types of Soil Ecoacoustics Measurements

Biophonic Sounds: These are the sound generated by microorganisms within the soil. Tiny creatures like ants, beetles, and earthworms create faint noises as they move, dig, or feed. Even plant roots make gentle sounds while growing and absorbing water. These sounds reflect the soil's biological activity and overall health.

Geophonic Sounds: These include natural, non-biological noises, such as those produced by water moving through soil, shifting rocks, or physical disturbances.

Anthrophony: includes all human-generated sounds that penetrate the soil environment. Examples include vibrations from machinery, footsteps, or construction, which can interfere with ecological acoustic measurements.

How does monitoring works?

Special contact microphones or accelerometer were inserted into the soil which is attached to metal probes that transmit sound efficiently. These sensors detect minute vibrations from soil organisms moving, feeding or burrowing. The recorded data are then analysed using computer software that visualizes and distinguishes different sources of noise. Each organism or process often has a unique acoustic signature, a kind of sound fingerprint.

Applications of Soil Ecoacoustics

- **Biodiversity Monitoring:** Acoustic sensors can reveal the richness of below ground fauna without digging or disturbing soil structure.
- **Soil health assessment:** The intensity and diversity of biophonic sounds indicate microbial and fauna activity which is a direct measurement of ecosystem vitality.
- **Climate and environmental research:** Soil acoustic data reflect responses of soil organisms to temperature, moisture and land use changes helping assess the effects of climate change.
- **Technological innovation:** With the integration of IoT based sensors, ecoacoustic monitoring can become automated, offering real time updates from the field.

Ecoacoustics in Agriculture

In agriculture, soil ecoacoustics offers sustainable, non-invasive method for monitoring soil vitality and biodiversity. By distinguishing biological sounds from natural and human noise, acoustic sensors can accurately represent underground activity levels. This technique helps farmers and researchers detect early signs of soil degradation like compaction or drought stress and assess the success of soil restoration efforts. As a complementary tool to

ISSN: 3049-2289

traditional soil testing and remote sensing, ecoacoustic provides real-time, ecosystem sensitive insights that can guide more sustainable and resilient farming practices.

Conclusion

Soil ecoacoustics opens a new window into the hidden life beneath our feet, allowing scientists and farmers to listen to the rhythms of living soils. By analyzing the natural sounds produced by organisms and physical processes underground, it provides a powerful, non-invasive way to assess biodiversity, soil health, and environmental change. As technology advances, integrating acoustic monitoring with smart sensors and data analytics will make real-time soil observation more accessible. This innovative approach not only enhances ecological understanding but also supports sustainable land management and climate resilient agriculture, turning the silent earth into a living source of information.

References

- Gitau, C., Kettel, E., Abrahams, C., Webala, P.W. and Uzal, A. 2025. The role of ecoacoustics in monitoring ecosystem degradation and restoration. *Restor. Ecol.* 70168.
- Robinson, J.M., Breed, M.F. and Abrahams, C., 2023. The sound of restored soil: using ecoacoustics to measure soil biodiversity in a temperate forest restoration context. *Restor. Ecol. 31*(5):13934.
- Robinson, J.M., Annells, A., Cavagnaro, T.R., Liddicoat, C., Rogers, H., Taylor, A. and Breed, M.F., 2024. Monitoring soil fauna with ecoacoustics. *Proc. R. Soc. B. 291*(2030):20241595.
- Metcalf, O.C., Nunes, C.A., Abrahams, C., Baccaro, F.B., Bradfer-Lawrence, T., Lees, A.C., Vale, E.M. and Barlow, J., 2024. The efficacy of acoustic indices for monitoring abundance and diversity in soil soundscapes. *Ecol. Indic. 169*, p.112954.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Climate-Smart Plant Breeding: A Lifeline for the North-East Hill Region

S MD Basid Ali
PhD Scholar, Department of Genetics & Plant Breeding
Central Agricultural University, Imphal, Meghalaya

Climate change is making once-familiar hills unpredictable. In the North-East Hill (NEH) region, where farms lie on steep slopes and rain can swing between deluge and drought agriculture is already on the front lines. For small farmers in this region, every growing season feels riskier: sudden floods, dry spells, and unseasonal temperatures threaten not just yield, but livelihoods. Addressing this requires more than better farming practices as it demands climate-smart plant breeding (CSPB), combining modern genetics with traditional wisdom to build crops that withstand the changing climate.

Why Climate-Smart Breeding Is Urgent for the NEH Region

1. High Climate Sensitivity of Hill Farming

The NEH region's terrain makes it uniquely vulnerable. Sloping fields suffer soil erosion during heavy rains; terrace plots may dry out quickly in droughts. Traditional varieties of crops such as upland rice, millets, and pulses, though well adapted to local culture, are often genetically fragile under extreme or erratic stress. Without improved genetic resilience, farmers face increasing crop failure risk.

2. Rich but Underutilized Genetic Diversity

One of NEH's greatest strengths is its biodiversity. Landraces (traditional varieties) of rice from this region contain valuable, stress-tolerance genes, particularly against diseases like blast (Magnaporthe) as well as varied abiotic stress-coping mechanisms (Subramanian et al., 2025). Such local genetic resources are a goldmine for breeders, but they must be tapped using modern tools.

3. Constraints on External Inputs

Compared to lowland or irrigated plains, NEH farmers have limited access to expensive inputs like synthetic fertilizers or irrigation. Climate-smart varieties that perform well under nutrient-poor or water-limited conditions can ease the burden on farmers while helping maintain productivity.

4. Food and Nutritional Security

Many NEH households rely on pulses and cereals for both food and income. Climate-smart breeding of pulses (like pigeon pea, chickpea, or mung bean) to tolerate heat, erratic moisture, or pests can directly improve protein security in a region where access to animal protein may be limited (Jitendra Kumar et al., 2019).

What Exactly Is Climate-Smart Plant Breeding?

Climate-smart plant breeding refers to using advanced breeding techniques to create varieties that are **resilient** (able to survive stress), **adaptive** (able to perform across environments), and **productive** (maintaining yield). Key approaches include:

1. **Genomic Selection (GS):**
   This technique uses genome-wide marker data to predict which breeding lines are likely to perform well under stress, even before they are fully grown. GS accelerates breeding cycles, which is critical in a changing climate because breeders need to keep up with evolving stresses (Budhlakoti et al., 2022).
2. **Marker-Assisted Selection (MAS) & Genome Editing:**
   MAS targets specific genes/QTLs known to influence stress tolerance. Genome-editing (e.g. CRISPR-Cas) goes a step further by precisely modifying stress-related genes, such as those involved in drought response or heat tolerance. Indian researchers have highlighted genome-editing as a potent tool for making crops more

ISSN: 3049-2289

resilient without introducing foreign DNA (Mann et al. 2025).

3. **Integrated Genomic Breeding Pipelines:** By combining GS, MAS, high-throughput phenotyping, and even *speed-breeding*, breeders can efficiently stack resilience traits. Integrated genomic selection (IGS) has been proposed to make breeding more predictive and climate-aware, especially for cereals (Sinha et al., 2023).
4. **Adaptive Trait Mining in Pulses:** For pulses, important climate-resilient traits might include early flowering, root architecture flexibility, or tolerance to soil moisture extremes. Research suggests that exploiting these traits via molecular breeding and genome editing can dramatically improve pulse resilience (Jitendra Kumar et al., 2019).
5. **Predictive Analytics and AI:** Machine learning models now help breeders simulate how different genotypes will perform under future climate scenarios. Such predictive breeding can identify which lines are most likely to succeed in NEH's variable climate (Khan et al., 2022).

Relevance to the NEH Region: Specific Advantages

A. Leveraging Local Genetic Wealth

NEH's traditional landraces aren't just relics — they carry adaptive wisdom. By integrating this local biodiversity with genomic tools, breeders can develop region-specific, climate-resilient cultivars. This preserves heritage while building future-ready crops.

B. Resilient Pulses for Food & Income

Pulses are culturally and nutritionally important in NEH diets. Developing heat-tolerant or drought-resilient pulses ensures that farmers' staple crops remain productive even under stress. Such varieties also contribute to soil health through nitrogen fixation, creating a virtuous cycle.

C. Stabilising Livelihoods for Fragile Farms

Because many NEH farms are small and on difficult terrain, climate-smart varieties that reduce yield risk make farming more viable. Even if climate extremes hit, resilient varieties give farmers a fighting chance — reducing the likelihood of total crop loss.

D. Low-Input Farming Compatibility

Resilient varieties reduce the need for irrigation, synthetic fertilizer or repeated replanting. This aligns very well with NEH's resource constraints and traditional ecological farming practices.

E. Bridging the Knowledge Gap

To make climate-smart breeding effective, regional breeding stations and local farmers must be involved. Participatory breeding (in which farmers help select new lines) ensures that resilience is built for real-world conditions, not just lab environments.

Challenges to Implementing Climate-Smart Breeding in NEH

1. **Infrastructure and Technical Capacity**

   Advanced tools like GS, genome editing, or phenomics require labs, skilled staff, and funding. Many NEH research stations may lack these.

2. **Seed Multiplication and Distribution**

   Once climate-smart varieties are developed, these need to be multiplied and distributed through local seed systems. Without this, farmer adoption will remain low.

3. **Adoption by Farmers**

   New varieties—even climate-smart ones—must be acceptable in terms of yield, taste, cooking quality, maturity time, and risk profile. Breeders must work closely with farmers to ensure adoption.

4. **Regulatory Challenges**

   Genome-edited crops face regulatory scrutiny, awareness issues, and sometimes public skepticism. These must be addressed for broad deployment.

5. **Long-Term Funding**

   Climate-smart breeding is a long-term investment. It requires sustained research funding, especially for region-specific challenges like those in NEH.

Recommendations for Policy and Practice

- **Strengthen Regional Breeding Programs:** Establish and fund regional breeding hubs in the NEH region, equipped for genomics, phenotyping, and participatory research.
- **Promote Participatory Breeding:** Engage local farmers directly in selection — their knowledge of micro-climates and traditional crops is invaluable.
- **Build Climate-Smart Seed Systems:** Work with cooperatives, KVKs, seed enterprises to multiply and distribute resilient varieties.
- **Train and Empower:** Provide training to local breeders, extension workers, and farmers on climate-smart methods, genomics, and future-weather forecasting.
- **Integrate with Ecological Practices:** Combine CSPB with soil conservation, agroforestry, contour farming, and organic matter management to maximize resilience.
- **Support Regulatory Clarity:** Advocate for clear, science-based regulatory guidelines for genome-edited crops so that breeders can deploy climate-smart varieties safely and quickly.

Conclusion

For the North-East Hill region, climate-smart plant breeding isn't just a scientific luxury — it's a lifeline. As climate uncertainty deepens, the region needs crop varieties that are resilient, productive, and adaptive. By combining its rich genetic heritage with cutting-edge breeding technologies, NEH can secure its agricultural future. This isn't just about building better crops — it's about empowering farmers, preserving biodiversity, and ensuring food and livelihood security in the face of a changing climate.

References

1. Budhlakoti, N., Kushwaha, A. K., Rai, A., Chaturvedi, K. K., Kumar, A., Pradhan, A. K., … & Kumar, S. (2022). Genomic Selection: A Tool for Accelerating the Efficiency of Molecular Breeding for Development of Climate-Resilient Crops. *Frontiers in Genetics*, 13, 832153.
2. Sinha, D., Maurya, A. K., Abdi, G., Majeed, M., Agarwal, R., Mukherjee, R., … et al. (2023). Integrated Genomic Selection for Accelerating Breeding Programs of Climate-Smart Cereals. *Genes*, 14(7), 1484.
3. Jitendra Kumar, Choudhary, A. K., Sen Gupta, D., & Shiv Kumar. (2019). Towards Exploitation of Adaptive Traits for Climate-Resilient Smart Pulses. *International Journal of Molecular Sciences*, 20(12), 2971.
4. Khan, M. H. U., Wang, S., Wang, J., Ahmar, S., Saeed, S., Khan, S. U., … & Feng, X. (2022). Applications of Artificial Intelligence in Climate-Resilient Smart-Crop Breeding. *International Journal of Molecular Sciences*, 23(19), 11156.
5. Subramanian, S., Ramamoorthy, P., Alagesan, S., Amalraj, J. J., Muthurajan, R., Alagarsamy, S., … & Kathiresan, P. (2025). Unraveling the genetic potential of Indian rice germplasm for reproductive stage drought tolerance. *Frontiers in Plant Science*, 16, 1454299.
6. Mann, A., Sanwal, S. K., Kumar, A., Prakash, N. R., Dahiya, A., Kumar, A., & Yadav, R. K. (2025). Harnessing genome editing for developing climate-resilient crops. *Indian Farming*, 75(11), 09-12.
7. Chaudhary, D., & Joshi, S. (2024). Smart Breeding Revolutionizes Climate-Resilient Agriculture. *Biotica Research Today*, 6(6), 353–354.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Meta analysis in integrated nutrient management for yield on Groundnut Cultivation

K.Maruthupandi[1], P.Papitha [2], R.Priyanka[3], K.Ashokkumar[4], S. Rajaguru[5] , G.ArunPrasath[6], S.T.Ponsiva[7],S. Bharathi[8], A.Yogapriya[9], A.G.Meena [10]

[1,]Department of Agronomy, [2]Department of Soil Science and Agricultural Chemistry, [3,5]Department of Agricultural Extension,[4,7]Department of Plant Breeding and Genetics, [6]Department of Agricultural Economics, [8]Department of Vegetable Science, [9]Department of Agricultural Entomology, [10]Department of Plant Pathology,
Gandhigram Rural Institute-Deemed to be University, Cinnalapatti, TamilNadu

The yield Meta analysis was conducted to study the effect of integrated nutrient management on groundnut, The treatment consisted of ten different integrated nutrient management treatments practices. The integration of inorganic fertilizers along with seed inoculation of biofertilizers viz., *Rhizobium* and phosphates solubilising bacteria (PSB) recorded significantly higher pod and haulm yield of summer groundnut as compared to rest of the treatments. Combined application of 75 % recommended dose of nitrogen (RDN) and 25 % RDN through vermicompost or farm yard manure (FYM) along with seed inoculation of *Rhizobium* and phosphates solubilising bacteria (PSB) recorded higher pod and haulm yield on groundnut (Jesal Joshi and A. G. Patel 2021). The experiment 10 treatments,viz. T_0, control, T_1, 10 t FYM/ha; T_2, 50 kg P_2O_5/ha; T_3, 50 kg P_2O_5 + 10 t FYM/ha; T_4, 50 kg P_2O_5 + 50 kg K_2O/ha; T_5, Rhizobium; T_6, 10 t FYM/ha + Rhizobium; T_7, 50 kg P_2O_5/ha + Rhizobium; T_8, 50 kg K_2O + 10 t FYM/ha and T_9, 50 kg P_2O_5 + 50 kg K_2O/ha + Rhizobium. Application of Rhizobium culture in combination with 50 kg P_2O_5 + 50 kg K_2O/ ha resulted in the highest pod and seed weight/plant. The inoculation of Rhizobium culture along with 50 kg P_2O_5 +50 kg K_2O/ha showed 45% increment in pod yield (from 1.37 to 1.95 t/ha) over the control. The highest haulm yield (3.57 t/ha) was obtained with FYM 10 t/ha,(Data *et al*., 2014). The experiment pooled results indicated that application of 75% RDF + Vermicompost 2 t ha^{-1} to groundnut crop recorded significantly higher yield attributes and yield *viz*., number of pods per plant (18.15), pod weight per plant (13.53), pod (2343 kg ha^{-1}) and haulm (3802 kg ha^{-1}) yield of groundnut(Patel *et al*., 2024).

Introduction

India is the second largest producer of groundnut in the world which produces around 10.30 million tones of groundnut from 4.96 million hectares of land and 2075 kg ha-1 productivity under irrigation (Anonymous, 2023) . Groundnut is unique and important legume cum oilseed crop in India. It is largely grown in Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra (Jesal Joshi and A. G. Patel 2021). Groundnut (*Arachis hypogaea* L.) commonly referred to as the "POOR MAN'S ALMOND," is an annual herbaceous legume that is autotetraploid and self-pollinating. Such a plant exists, and every component of it boosts the farmer's income. Ranking 13th among food crops and 4th in importance among oilseed crops worldwide, it is the world's greatest source of edible oil (Ramanathan, 2001). The kernel also contain carbohydrates (6.0 to 24.9%), minerals and vitamins (Das, 1997). Groundnut area, production and productivity of Gujarat were 1.76 million hectares, 4.53 million tonnes and 2570 kg ha-1, respectively (Anonymous, 2023) . Groundnut is an important annual legume in the world, mainly grown for oilseed, food and animal feed (Pande *et al*., 2003). It is a safe, cheap and renewable N source for crops, which are capable of fixing N_2 and therefore profitable for agriculture and eco-friendly for environment (Vance, 2001). The crop also has potential to increase soil fertility, check soil erosion along with meeting the requirement of vegetable oil and protein. Groundnut is an exhaustive crop, hence integrated use of nutrients from chemical, organic and biofertilizers is the most efficient way to supply plant nutrients for sustained

ISSN: 3049-2289

crop productivity and improved soil fertility (Singh *et al.*, 2002). The continuous use of high levels of chemical fertilizers is adversely affecting the sustainability of agricultural production and causing environmental pollution. In coming decades a major issue in designing sustainable agricultural system will be the management of soil organic matter and the rational use of organic inputs such as animal manures, crop residues, green manures, sewage, sludge and food industry waste. However, since organic manures cannot meet the total nutrients need of modern agriculture, integrated use of nutrients from fertilizers and organic sources seems to be a need of the time. The basic concept underlying the integrated nutrient management system (INMS), nevertheless, is the maintenance and possible improvement of soil fertility for sustained crop productivity on long term basis and also to reduce fertilizer input cost (Patel *et al*., 2024).

Discussion:

Significantly higher number of pods per plant and dry weight of pods per plant were recorded by the application of RDF + *Rhizobium* + PSB. It was followed by 75% RDN + 25% N through vermicompost + *Rhizobium* + PSB and 75% RDN + 25% N through FYM + *Rhizobium* + PSB. The plants were healthy with the application of combination FYM, vermicompost and biofertilizers and it was reflected in their yield attributes viz. number of pods and dry weight of pods per plant. The lower number of pods per plant and dry weight of pod per plant were recorded by 50% RDN + 50% N through FYM. Application of fertilizer along FYM and vermicompost increased the number of pods and dry weight of pods per plant significantly and further increased the pod and haulm yield of summer groundnut. Mohapatra and Dixit (2010) also reported that pod and haulm yield were significantly higher with the application of FYM, vermicompost and biofertilizers. Application of recommended dose of nutrients through different sources (*viz.* chemical fertilizers, FYM, vermicompost etc.,) along with biofertilizers (viz., *Rhizobium* and PSB) significantly increased the pod and haulm yield of summer groundnut. Application of RDF along with biofertilizers (*Rhizobium* + PSB) resulted in significantly higher pod and haulm yield and it was closely followed by 75% RDN + 25% N through vermicompost + *Rhizobium* + PSB and 75% RDN + 25% N through FYM + *Rhizobium* + PSB. In case of pod and haulm yield, the latter two treatments in combination with FYM and vermicompost were found statistically at par. The increase in pod yield was 22.8, 22.0 and 20.9 per cent than that of 50% RDN + 50% N through FYM. This might be attributed to rapid mineralization of chemical nitrogen and slow supply of nitrogen from FYM and vermicompost along with biofertilizers which might have met the nitrogen requirement of crop at critical stages of growth. Further, FYM and vermicompost act as nutrient reservoirs and upon decomposition produce organic acids, thereby absorbed ions are released slowly during entire growth period leading to improvement in crop yield attributes and ultimately pod and haulm yield of groundnut. The percent increase in pod yield by fertilizing the crop with 100% RDF + *Rhizobium* + PSB (T_{10}), 75% RDN + 25% N through vermicompost + *Rhizobium* + PSB (T_9) and 75% RDN + 25% N through FYM + *Rhizobium* + PSB (T_7) was tune to the tune of 22.8, 22.0 and 20.9 per cent, respectively over 50% RDN + 50% N through FYM. Similar trend was observed by (Abraham and Thenua ,2010). Dhadge and Satpute (2014) also reported significantly higher the pod and haulm yield due to integration of inorganic and organic sources of nutrients.

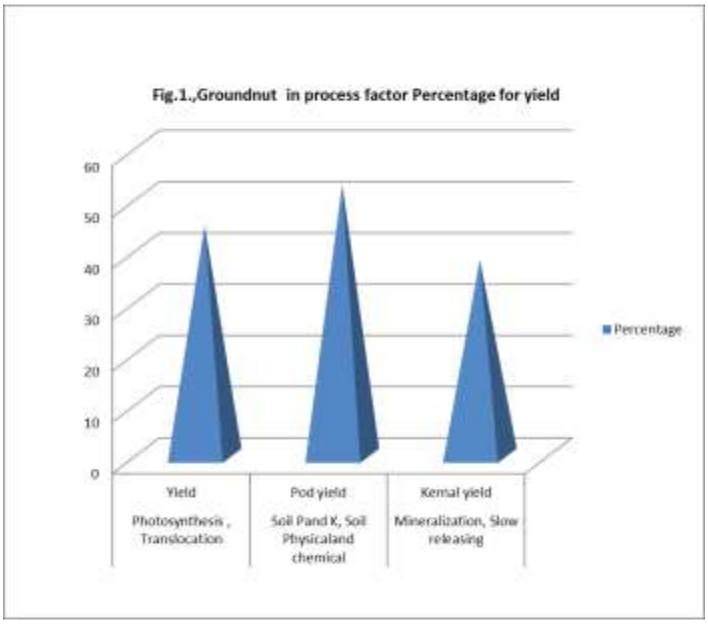
Data on a higher number of pods per plant (18.55, 17.75, and 18.15 in 2022, 2023 and pooled, respectively) were observed when 75% RDF + Vermicompost 2 t ha^{-1} (T_3) was applied in both the year of experiment and the pooled study. This was statistically comparable to the application of 75% RDF + FYM 5 t ha^{-1} (T_2) and 100% RDF (T_1) in both the year of experiment and the pooled study. The percent increase in number of pods per plant at harvest was to the tune of 7.56, 3.42, 38.81 and 23.26 over treatment T_1, T_2, T_4 and T_5, respectively. The higher number of pods per plant could be because of the combined effect of vermicompost and

ISSN: 3049-2289

inorganic fertilizers that provided balanced nutrition throughout growth period resulted in favourable effect on pod formation. These results are in agreement with the findings of Konthoujam *et al*. (2013) in soybean, Jesal and Patel (2021) in groundnut and Pandey *et al*. (2022) in soybean. Application of 75% RDF + Vermicompost 2 t ha^{-1} (T_3) gave significantly higher pod weight per plant (13.70, 13.37 and 13.53 g in 2022, 2023 and pooled study, respectively) which was statically at par with 75% RDF + FYM 5 t ha^{-1} (T_2) and 100% RDF (T_1) in both the year of experiment as well as in pooled study. Application of fertilizer along vermicompost and FYM increased the pods weight per plant significantly and further increased the pod and haulm yield of *kharif* groundnut. The increase in the pod weight could be due to continuous supply of (Fig.1.,) macro and micro nutrient to the crop which help in photosynthesis, assimilation and translocation of photosynthate from source to sink. Jesal and Patel (2021) and Vala *et al.*(2017) also reported higher pod weight with the application of vermicompost and FYM.

Among different treatment, application of 75% RDF + Vermicompost 2 t ha^{-1} (T_3) gave significantly highest pod (2371, 2315 and 2343 kg ha^{-1}) and haulm yield (3840, 3765 and 3802 kg ha^{-1}) in 2022, 2023 and pooled, respectively in both year and pooled study, which was remained statistically at par with 75% RDF + FYM 5 t ha^{-1} (T_2) and 100% RDF (T_1) in both year of experiment as well as pooled study . Higher pod yield could be attributed to favourable changes in physical and chemical characteristics of the soils which might have enabled better pod formation. Moreover, the positive influence of these treatments through immediate supply of nutrients from inorganic sources especially at the early stage of the crop and slow and steady supply of nutrients from vermicompost and FYM throughout the crop growth period improved adequate biomass production and improvement in yield parameters resulting in higher pod and haulm yield. Similar findings are reported by Ola *et al*. (2013) , Bhosale and Pisal (2017) , Kumar *et al*. (2019), Jesal and Patel (2021) and Arsalan *et al*. (2024) . Groundnut yield components were significantly influenced by different nutrient management. Significantly highest pod weight/plant and kernel weight/plant were recorded under treatment, where seeds were inoculated with *Rhizobium* culture and crop received 50 kg P_2O_5 and 50 kg K_2O/ha. The results confirm the findings of Zalate *et al*. (2009). The lowest pod and seed weight/plant were observed under the control plot.

Pod and haulm yields were significantly influenced by different nutrient management. *Rhizobium* inoculation of groundnut seed along with soil application of 50 kg P_2O_5/ha and 50 kg K_2O/ha recorded significantly maximum pod yield (1.96 t/ha). This may be owing to the fact that seed inoculation with biofertilizer and soil phosphorus and potassium significantly increased the yield components and yield of groundnut. Zalate *et al*. (2009) also reported similar result. Minimum pod yield was recorded in the control plot. Highest Stover yield was obtained with application of 10 t FYM/ha. The FYM not only supplied macro and micro nutrients, viz. N, P, K, and S but also improved soil physical condition and availability of nutrients thereby increased yield of crops. Similar result was reported by Mohapatra *et al*. (2010).



ISSN: 3049-2289

Conclusion:

It was concluded that to get maximum productivity, profitability and energy-use efficiency from groundnut in acidic soils of Tripura, the crop should be managed with *Rhizobium* inoculation along with application 50 kg P_2O_5 + 50 kg K_2O/ha Based on the two-year experimental findings, it is concluded that the combined application of organic manures and fertilizers had significant and positive effect on growth, yield and quality of groundnut crop.The application of 75% RDF (9.38: 18.75: 00: 18.75 kg N: P_2O_5: K_2O: S ha-^{1}) along with 2 t ha^{-1} of vermicompost recorded higher number of pod, pod weight, pod yield and haulm yield of groundnut. This nutrient management practice is effective in improving the protein content in kernel of groundnut. It may be concluded that application of 100% RDF + *Rhizobium* + PSB resulted in significantly higher pod and haulm yield, protein content, oil yield and also higher net realization and B: C ratio of summer groundnut.

From the Meta analysis yield is influenced by Integrated nutrient methods and quantity, manures, enriched manures and recommended dose of fertilizers. Here 45% of yield increase through photosynthesis and translocation process with in INM. Fertilizers with INM involved the Podyield 53% increased by availability of soil Phosphorus and potash and Soil physical and chemical process influenced with in INM and compared to these two with INM of Agronomic practices increased kernel yield 38.3% increased by Mineralization and slow releasing nutrient process.

Reference

1. Jesal Joshi and A. G. Patel 2021.Effect on Integrated Nutrient Management on Productivity, Quality and Nutrient Uptake on Summer Groundnut (*Arachis hypogaea* L.). *International Journal of Plant & Soil Science 33(23): 316-322.*
2. Datta, M., G.S. Yadav and sandip chakraborty 2014.Integrated nutrient management in groundnut (*Arachis hypogaea*) in subtropical humid climate of north-east India. *Indian Journal of Agronomy* 59 (2): 322—326.
3. Patel, KK., JM Patel, PP Chaudhari, KJ Chauhan, RM Patel and DM Patel 2024. Effect of integrated nutrient management on growth, yield and quality of groundnut (*Arachis hypogaea* L.) under north Gujarat condition. International Journal of Research in Agronomy, SP-7(10): 706-709.
4. Anonymous 2023. Data retrieved from https://commodities.cmie.com. Accessed on 19th April,2024.
5. Ramanathan T 2001. Genetic improvement of groundnut.Associated Publishing Company, New Delhi: 2001;9.
6. Das, PC. 1997.Oilseeds Crops of India. Kalyani Publishers, Ludhiana India. 1997; 80-83.
7. Pande, S., Bandyopadhyay, R., Blummel, M., Rao, J., Thom, D. and Navi, S.S. 2003. Disease management factors influencing yield and quality of sorghum and groundnut crop residue.*Field Crop Research.* 84(1-2): 89–103.
8. Vance, C.P. 2001. Symbiotic nitrogen fixation and phosphorus acquisition, plant nutrition in a world of declining renewable resources. *Plant Physiology* 127: 390–97.
9. Singh, H., Mishra, D. and Nahar, N.M. 2002. Energy use pattern in production agriculture of a typical village in Arid Zone India (Part I). *Energy Conversion and Management* 43: 2,275–86.
10. Mohapatra AKB, Dixit L 2010. Integrated nutrient management in rainy season groundnut. Indian Journal of Agronomy. 55(2):123-127.
11. Abraham T, Thenua OVS 2010. Influence of organic and inorganic sources of nutrients and their methods of application on growth and yield attributes of groundnut. Indian

Journal of Agricultural Research. 44 (3):216-220.

12. Dhadge SM, Satpute NR 2014. Effect of integrated nutrient management on growth, yield and quality of summer groundnut. International Journal of Agricultural Science. 10:314 -316.
13. Arsalan M, Latif A, Khan M, Syed S, Ullah R, Ahamd I 2024. Integrated effect of organic amendments and chemical fertilizers on yield of groundnut and soil health under rainfed condition. Journal of Applied Research in Plant Sciences. 5(1):99-104.
14. Bhosale NA and Pisal AA 2017. Effect of nutrient management on productivity of summer groundnut (*Arachis hypogaea* L.). Advanced Agricultural Research and Technology Journal. 1(1):88-91.
15. Konthoujam ND, Tensubam BS, Athokpam HS, Naorem BS, Shamurailatpam D 2013. Influence of inorganic, biological and organic manures on nodulation and yield of soybean [*Glycine max* (L.) Merrill] and soil properties. Australian Journal of Crop Science.7(9):1407-1415.
16. Kumar CR, Ganapathy M, Ganesamoorthy D, Karthikeyan A, Saravanaperumal M, Murugan G 2019. Effect of INM on growth, yield and quality parameters of irrigated groundnut (*Arachis hypoagea* L.) var.VRI-2 for sandy loam soils.Plant Archives. 19(2):745-749.
17. Ola BL, Pareek BL, Yadav RS, Shivran AC, Sharma OP 2013.Influence of integrated nutrient management on productivity and quality of groundnut in Western Rajasthan. Annals of Agricultural Research. 34(2):156-159.
18. Pandey DD, Tiwari RB, Keshry PK 2022. Effect of integrated nutrient management on growth and yield of soybean (*Glycine max* L.). The Pharma Innovation Journal. 11(6):2228-2230.
19. Vala FG, Vaghasia PM, Zala KP, Buha DB 2017. Effect of integrated nutrient management on productivity of summer groundnut (*Arachis hypogaea* L.). International Journal of Current Microbiology and Applied Science. 6(10):1951-1957.
20. Zalate, P.Y. and Padmani, D.R. 2009. Effect of organic manure and biofertilizers on growth and yield attributing characters of *kharif* groundnut (*Arachis hyopgaea*). *International Journal of Agriculture Sciences* 5(2): 343–45.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Sowing Hope in Dry Lands: Small Millets as the Climate Warrior Crops

Rajesh C
M. Sc. (Agri) college of agriculture, Bengaluru, UAS, GKVK, Bengaluru.

Small millets (finger millet/ragi, foxtail, little, kodo, barnyard, proso and browntop) have been quietly sustaining millions of smallholder families across South Asia and Africa for centuries. Today they are resurging not as nostalgic relics but as pragmatic, farmer-friendly crops that match the realities of marginal soils, unpredictable rainfall and rising input costs. In an era where farmers battle erratic monsoons, scorching heat and shrinking water tables, a quiet revolution is taking root in the drylands led by the humble small millets. Often called *"climate warrior crops"* these hardy grains are emerging as sustainable allies for both farmers and ecosystems. Unlike water-hungry cereals, small millets sustain where other crops fail. They also proving that **resilience can be sown, not imported.** Their success is redefining dryland farming from vulnerability to vitality and from uncertainty to empowerment

Millets tolerate drought, heat where as demanding about 70–80% less water than rice and tolerating temperatures up to 40°C and also edaphically resilient, can thrive in low fertile soil better than most cereals; they stabilise yields under variable weather, which reduces income risk for farmers. Several agronomic traits allow millets to survive the stress of long-term drought and heat, such as millets' short stature, small leaf area, thickened cell walls and dense root systems. Further, some research indicates millets such as pearl and finger millet can grow in soils with a marginal to high salinity condition. As a plant with a C_4 photosynthesis system, millets have enhanced photosynthetic rates in warm conditions and are able to use water and nitrogen efficiently, 1.5 to 4 times higher than C_3 plants such as rice and wheat. Millets' C_4 status also means improved carbon fixation in crops. Moreover, all these benefits are derived from millet crops within their short growing period of two to three months, while C_3 crops take much longer to grow.

In the many parts of India once dominated by water-intensive crops like soya, Bt cotton and maize, the area was facing an agrarian crisis presently because of apparent weather situations. With dwindling yields and incomes, farmers were searching for alternatives. The answer came in the form of millets.

In the rugged terrain of Kolli Hills (Namakkal district, Tamil Nadu), tribal farmers and women's self-help groups have turned the tide through a revival of traditional small millets like foxtail, finger and little millet. Led by the M.S. Swaminathan Research Foundation and local seed-banks, over 20 local millet varieties were conserved and re-introduced, enabling farmers to cultivate these hardy crops on marginal slopes with minimal external inputs. What began as a modest effort on parched parcels of land, totalling 50-acres, has now grown into a successful agricultural movement, spanning over 2,000 acres across 23 villages in Dharwad and Haveri districts. Nearly 3,000 farmers came together to revive drought-stricken farmlands through cultivation of millets — quietly turning years of adversity into a sustainable success story. In Jhadol block of Udaipur district, a pilot initiative revived indigenous millet varieties (finger millet, proso, foxtail, kodo) among farmers who had switched to monocultures and high-chemical farming. The project saw local livelihoods improved and sustainable farming practices revived.

The resurgence of small millets is more than an agronomic shift — it is a movement of resilience, revival and regeneration. Across India's dry zones, these tiny grains are reshaping the landscape of sustainability. In the drought-hit tracts of Bundelkhand (Uttar Pradesh and Madhya Pradesh), farmers who once abandoned their fields due to

ISSN: 3049-2289

repeated crop failures are now returning to cultivate barnyard and kodo millet, witnessing stable yields even under erratic rainfall. Similarly, in Bastar, Chhattisgarh, millet-based farming systems promoted under the “Millet Mission” have not only restored degraded soils but also enhanced women’s participation in community seed banks and value chains. Their hardy nature and short crop duration make millets an ideal fit for rainfed ecologies, reducing dependency on external irrigation and fertilizers. Research by the ICAR–Indian Institute of Millets Research (IIMR), Hyderabad highlights that small millets produce up to 40–50% higher biomass than maize under drought stress, offering both grain and fodder security. In the foothills of Uttarakhand, traditional farmers cultivating finger and barnyard millet have turned to integrated systems intercropping with pulses and vegetables which not only improve soil fertility but ensure nutritional diversity. These success stories echo a simple truth: millets are not relics of the past but harbingers of future-ready farming. They embody the essence of climate-smart agriculture crops that sustain the soil, nourish the people and empower the farmer. As the world seeks solutions to feed a growing population amid worsening climate crises, India’s small millets stand tall small in size, but mighty in resilience and promise.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Himalayan Aromatic Gold: Black Cardamom Cultivation and Its Economic Potential in Arunachal Pradesh

Biki Islary, Dora Ponio, Lemhai Wangjen, Likha Phon, Nemcha Jugli, Raja Yangfo, and Kasinam Doruk.
Himalayan university, Jollang, Itanagar, Arunachal Pradesh,

Black cardamom *(Amomum subulatum Roxb)* is a high-value perennial spice of the Eastern Himalayas, widely cultivated in Arunachal Pradesh. It is prized for its large brown pods, smoky aroma, and medicinal uses. The crop thrives under cool, humid, shaded forest conditions, making it ideal for hill agroforestry systems. Key production practices include rhizome propagation, shade management, organic fertilization, pest and disease control, manual harvesting, and smoke-curing, with modern interventions like solar drying improving post-harvest quality. Despite challenges such as climate variability, fungal diseases, and post-harvest losses, black cardamom offers significant opportunities for sustainable high-value agriculture, supporting rural livelihoods, promoting ecological conservation, and enhancing economic growth.

Introduction

Black cardamom, often called the "queen of spices," is a shade-loving perennial herb of the Zingiberaceae family. Its large, aromatic pods are used in culinary dishes, traditional medicine, and export markets. The Eastern Himalayan region, particularly Arunachal Pradesh, provides ideal growing conditions, with altitudes of 1000–2000 m, cool temperatures (10–22 °C), high humidity, and well-drained loamy soils. Cultivation of black cardamom supports farmers' income, rural livelihoods, and forest-based agroforestry systems (Sood *et al*., 2006; Upadhyay *et al*., 2025).

Rising domestic and international demand has made black cardamom a high-value cash crop. Its cultivation demonstrates how traditional knowledge combined with modern practices can produce high-quality pods while maintaining ecological balance. Integration into shade-based agroforestry systems ensures sustainability and promotes eco-friendly high-value agriculture in the Himalayan hills (Tripathi & Bhandari, 2025).

Figure 1: Black Cardamom plantation thriving in the cool, humid valleys of Arunachal Pradesh.

Figure 2: Mature Black Cardamom capsules before harvest.

Agro-Climatic Requirements

Table 1: Shows the Climatic requirement.

Requirement	Details
Altitude	1000–2000 m
Temperature	10–22 °C
Rainfall	1500–2500 mm annually
Soil	Loamy, well-drained, organic-rich; pH 5–6.5
Shade	50–60% canopy cover (forest or tree cover)

ISSN: 3049-2289

Black cardamom is a shade-loving sciophyte, making it highly suitable for hill agroforestry systems.

Propagation & Planting

- Method: Rhizome division ensures disease-free planting
- Season: April–June
- Spacing: 2 × 1.5 m
- Planting depth: 5–7 cm
- Soil prep: Enrich with compost or organic manure

Figure 3: Healthy Black Cardamom Rhizomes used for vegetative propagation.

Crop Management

- Shade & Mulching
- Maintain 50–60% shade
- Mulch with forest leaves or compost to conserve moisture and suppress weeds

Figure 4: Planting Black Cardamom suckers at appropriate spacing.

Irrigation

- Primarily rain-fed; supplemental irrigation during dry periods

Fertilization

- Organic manure (FYM, compost)
- Biofertilizers like Trichoderma enhance disease resistance (Sarkar *et al*., 2024)

Pest & Disease Control

- Pests: White grubs, caterpillars
- Diseases: Shoot/capsule rot, fungal blight (*Colletotrichum gloeosporioides*)
- Control measures: Disease-free planting material, proper spacing, drainage management

Harvesting & Post-Harvest Handling

- Manual harvesting: Mature pods (Sept–Nov)
- Traditional curing: Smoke-fire drying for aroma

Figure 5: Harvested mature Capsule.

Figure 6: Cleaned Mature Capsule.

Figure 7: Traditional smoke-curing.

Figure 8: Post-curing of Black Cardamom.

Yield & Economic Potential

1. Yield: 300–500 kg dry pods/hectare
2. Economic value: High market demand makes it profitable for smallholder farmers
3. Sustainability: Compatible with agroforestry and organic systems, supporting rural livelihoods

ISSN: 3049-2289

Challenges & Opportunities

Challenges

- Climate variability and moisture stress
- Fungal diseases and post-harvest losses
- Limited access to improved planting material and market infrastructure

Opportunities

- Integration with shade-based agroforestry systems
- Use of improved cultivars suited to altitude and microclimates
- Farmer training and value-added processing

Conclusion

Black cardamom, the aromatic gold of the Himalayas, combines high economic potential, ecological sustainability, and cultural significance. Adoption of modern crop management practices, improved cultivars, and efficient post-harvest techniques can enhance yield and quality, strengthen rural livelihoods, and conserve forest ecosystems in Arunachal Pradesh. Its cultivation represents a model of eco-friendly, high-value agriculture in the Himalayan region.

References

1. Sood, R.K., Singh, R.D., & Ahuja, P.S. (2006). Cultivation of Large Cardamom in Himachal Pradesh. BVAAP, 14(2), 156–160.
2. Upadhyay, V., Devi, K., & Yazar, T. (2025). Economic potential of large cardamom in Lower Subansiri, Arunachal Pradesh. Applied Agricultural Sciences, 3(1), 1–15.
3. Tripathi, A., & Bhandari, A.K. (2025). Amomum subulatum Roxb.: Transforming Himalayan livelihoods. PhytoTalks.
4. Sarkar, S., Padaria, R.N. (2024). Model large cardamom village in Eastern Himalaya. Indian Journal of Extension Education.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Millets: The Future Smart Grain Revolution in Modern Bakery Industry

[1]Amar Bikram Sahoo, [2]S. Kshanti Somanath, [3]Aswini Kumar Sahoo ,
[4]Ipsita Rautaray, [5]Kamakshi Kamalini Jali
M.Sc. Research scholars (Department of food and nutrition)
College of Community Science,
Odisha University of Agriculture and Technology (OUAT), Bhubaneswar

Millets' outstanding nutritional profile, climatic resistance, and useful health advantages are making them smart grains for the future. Millets provide a creative substitute for traditional baked goods made with wheat flour, meeting the growing need for low-glycemic, gluten-free, and healthful baked goods. Dietary fiber, resistant starch, essential amino acids, antioxidants, and micronutrients like calcium, iron, zinc, and magnesium are all abundant in millets such finger millet, pearl millet, sorghum, foxtail millet, barnyard millet, and small millet. Their incorporation into baked goods promotes intestinal health, decreases glycemic response, boosts nutritional quality, and aids in the prevention of disease. Technological developments like composite flour technology, enzymatic modification, extrusion, fermentation, controlled milling, and hydrothermal processing have greatly enhanced their sensory acceptability and functional performance in bakery applications, despite obstacles like the lack of gluten and susceptibility to rancidity. Due to its low water requirements, ability to adapt to hard climates, and lower carbon impact, millets also support sustainability. Millet-based products offer a viable sustainable alternative for future food systems as customers throughout the world move toward wholesome and useful baked goods.

Introduction

Because refined wheat flour has a desired gluten structure and baking qualities, it is typically used to make bakery goods, which are among the most popular convenience foods in the world. However, given the rising prevalence of diabetes, obesity, and metabolic diseases, refined wheat's high glycemic index, poor fiber content, and restricted micronutrient profile have sparked nutritional concerns. Millets are one of the nutrient-dense grain substitutes that have attracted a lot of attention due to the shift in customer preferences toward clean-label, functional, and healthful meals. Millets with a high dietary fiber content, essential amino acids, antioxidants, and minerals including iron, calcium, and zinc include pearl millet, sorghum, finger millet, and foxtail millet. According to studies by Srivastava & Ahmed (2022) and Taylor & Emmambux (2019), adding millet to baked goods enhances their nutritional value, reduces glycemic response, and boosts antioxidant consumption, making them appropriate for those with diabetes and those who are health-conscious. Furthermore, Kumari and Gupta's research from 2021 showed that millet-based biscuits and muffins were highly acceptable to consumers when they were accompanied by improved formulations and sensory enhancements. Beyond their nutritional value, millets are crucial for sustainable agriculture because they are climate-smart crops that need less fertilizer and water. Global interest in millet-based value-added goods has increased dramatically after the United Nations declared 2023 to be the International Year of Millets. Millets are now effectively included into bread, biscuits, muffins, crackers, and other bakery goods because to developments in processing methods such composite flour mixing, fermentation, extrusion, and hydrocolloid inclusion. Their application supports innovation, sustainability, and health in the contemporary baking sector and is in line with future food system objectives.

Nutritional Value of Millets

High concentrations of fiber, bioactive substances, and vital micronutrients are found in millets. A comparison of important millets and wheat is shown in the table below:

ISSN: 3049-2289

Nutrients (per 100g)	Wheat	Pearl Millet	Finger Millet	Foxtail Millet
Protein (g)	11.8 g	11.5 g	7.3 g	12.3 g
Dietary Fiber (mg)	10 g	8.5 g	15.2 g	8.0 g
Calcium (mg)	41 mg	42 mg	344 mg	31 mg
Iron (mg)	3.6 mg	8.0 mg	3.9 mg	2.8 mg
Fat (%)	2 %	5.0%	1.5%	4.3%
Glycemic Index	High (70–85)	Moderate - low	Very Low	Low (50–55)

Foxtail millet is particularly valued for its **low glycemic index, high protein content, essential fatty acids, and slow-digesting carbohydrates**, making it suitable for diabetic-friendly bakery foods.

Technological Role of Millets in Bakery Formulations

Millets enhance the nutritional quality of bakery items but present challenges such as:

- Texture of product affected by coarse granulation
- Lack of gluten might affect dough structure
- Lipid oxidation and rancidity may cause short shelf life

Modern food technologies now enable better application of millet flours:

1. **Composite Flour Technology**

   Structure and crumb softness are enhanced when millets are blended with wheat flour or hydrocolloids (xanthan gum, psyllium husk).

2. **Fermentation & Germination**

   It enhances flavor, makes minerals more bioavailable, and aids in the reduction of antinutrient substances like phytates.

3. **Extrusion, Popping & Roasting**

   increases shelf life, sensory quality, and digestibility.

4. **Controlled Milling & Vacuum Packaging**

   maintains freshness and lessens rancidity.

Comparison Between Wheat Bakery Products and Millet Bakery Products

1. **Glycemic Response**

   Wheat bakery products generally have a **high glycemic response**, meaning they break down quickly into glucose and cause a rapid rise in blood sugar levels. This can lead to increased hunger and long-term metabolic issues. In contrast, **millet-based bakery products have a low glycemic response**, due to their high fiber and complex carbohydrate structure. This helps in slow glucose release, making millet products suitable for diabetic and health-conscious consumers.

2. **Fiber Content**

   Low amounts of fiber is common in wheat baked goods, particularly when refined wheat flour is used. Constipation, rapid digestion, and overeating can all be caused by low-fiber diets. However, the naturally high dietary fiber content of millet baked goods improves digestion, increases satiety, supports gut health, and aids in weight management.

3. **Gluten Content**

   Natural gluten found in wheat gives baked goods their structure, elasticity, and softness. Although gluten is beneficial for baking, those who have celiac disease or gluten sensitivity may experience negative responses. Since millets are primarily gluten-free, they may be used to create bakery recipes that are allergy-friendly and for populations who are gluten-sensitive.

4. **Mineral Density**

   Important elements including calcium, iron, zinc, and magnesium are somewhat less abundant in baked goods made from wheat.

ISSN: 3049-2289

However, baked goods made from millet are high in micronutrients, including iron (which is crucial for preventing anemia), calcium (which promotes bone health), zinc (which increases immunity), and magnesium (which improves nerve and muscle function).

5. **Satiety Level**

   Items from wheat bakeries offer moderate satiety, which can result in overeating because the feeling of fullness is short-lived. Millet products, on the other hand, offer a high degree of satiety because of their slow digestion rate and high fiber content, which helps consumers feel fuller for longer periods of time and consume fewer calories.

6. **Suitability for Different Health Needs**

   Products from wheat bakeries are often appropriate for the general public with no dietary requirements. However, millet bakery goods are more in line with contemporary health and nutrition goals since they are particularly helpful for those with diabetes, obesity, metabolic syndrome, gluten sensitivity, and lifestyle-related diseases.

Health Benefits of Millet-Based Bakery Products Compared to Conventional Bakery Products

- Help manage diabetes and obesity
- Improve gut microbiome
- Support bone health (finger millet – rich calcium)
- Reduce cholesterol due to high soluble fiber
- Provide sustainable energy release due to complex carbohydrates

Market Potential and Consumer Demand

The global nutrition market favors ancient grains, functional foods, and gluten-free bakery items. Millet bakery products include:

- Millet Muffins, Cakes & Brownies
- Millet Pasta & Pizza Base
- Millet Biscuits & cookies
- Gluten-Free Millet Bread
- Energy Bars & Breakfast Granola

Their acceptance is rising among health-conscious consumers, athletes, children, and elderly populations.

Sustainability and Agricultural Significance

1. **Low Water Requirement** Because millets require 70–90% less water than rice and wheat, they are ideal for areas that are prone to drought and water scarcity.
2. **Minimal Fertilizer and Chemical Input** Millet crops may thrive without the use of heavy pesticides or fertilizers, which lowers production costs and pollution levels in the environment.
3. **High Climate Resilience** Millets are perfect for areas impacted by climate change since they are inherently resistant to heat, drought, and irregular rainfall.
4. **Suitable for Marginal and Degraded Soils** While main cereals cannot thrive in poor, low-fertility, sandy soils, millets can.
5. **Short Growth Cycle** Many millet cultivars reach maturity in 60 to 90 days, giving farmers faster harvests and a lower chance of crop loss.
6. **Supports Biodiversity** By decreasing monocropping patterns and enhancing ecological balance, millet production increases agro-biodiversity.
7. **Energy Efficient Crop** Millets have a lower carbon footprint because they use less irrigation energy, less agricultural activities, and little machinery.
8. **Low Risk Farming Option for Smallholders**
   For small and marginal farmers who depend on rain-fed farming, millets are a reliable crop since they provide consistent returns with minimal resources.

ISSN: 3049-2289

9. **Enhances Soil Health**
In agricultural settings, millets help restore soil fertility by enhancing the organic matter content, structure, and microbial activity of the soil.

10. **Contribution to Food and Nutrition Security**
Millets offer a dependable grain source that supports sustainable food systems and long-term nutritional security in the face of growing global hunger and climate problems

Conclusion

Millets are considered to have a great deal of promise as the grain of the future for use in baking. They are better than baked goods made from refined wheat because of their high nutritious content, low glycemic response, and practical health advantages. The sensory and functional performance of millet-based baked goods has been greatly enhanced by ongoing developments in processing, formulation engineering, and packaging, despite technical constraints. Millets are at the forefront of the evolution of the food system because to the growing emphasis on sustainability, health-conscious diets, and gluten-free substitutes throughout the world. Millets have the potential to transform the baking business and enhance nutrition security, farmer empowerment, and climate resilience with industry investment, consumer knowledge, and supporting legislative frameworks. Innovations in millet-based baking signify a long-term shift toward more sustainable and healthful food systems, not merely a passing fad.

References

1. Rao, B. Dayakar., Prasad, R., & Patil, J. (2021). A detailed review discussing the nutritional significance and health advantages of millet consumption. *Indian Journal of Agriculture.*
2. **Food and Agriculture Organization (FAO). (2023).** Report published for the International Year of Millets, discussing global relevance and utilization trends.
3. **Srivastava, S., & Ahmed, S. (2022).** An analytical review of how millets contribute functional characteristics to baked products. *Journal of Food Science.*
4. **Kumari, L., & Gupta, R. (2020).** Exploration of processing and value addition approaches for millet-based food systems. *Food Technology Reviews.*
5. **Taylor, J. R. N. (2019).** Discussion on gluten-free cereal crops and their role in food formulation. *Cereal Science Journal.*
6. **Kumari, A., & Yadav, R. (2024).** Evaluation of bioactive compounds and nutraceutical benefits of foxtail and finger millet. *International Journal of Nutrition.*
7. **Indian Council of Medical Research – National Institute of Nutrition (ICMR-NIN). (2023).** Updated national dietary recommendations.
8. **Singh, P., & Tiwari, K. (2021).** Study on oxidative deterioration issues encountered during storage of millet flour. *Food Chemistry.*
9. **Kaur, G. (2022).** Assessment of consumer perception and acceptance of bakery products made from millets. *Journal of Dietetics Innovation.*
10. **World Health Organization (WHO). (2024).** Global analysis of trends related to nutrition and functional grains.

AGRICULTURE BULLETIN
ISSN: 3049-2289

Combatting Hidden Hunger through Food Fortification – A National Priority

[1]S. Kshanti Somanath, [2]Amar Bikram Sahoo ,[3]Ipsita Rautaray,
[4]Aswini Kumar Sahoo, [5]Kamakshi Kamalini Jali
M.Sc. Research scholars (Department of food and nutrition)
College of Community Science,
Odisha University of Agriculture and Technology (OUAT), Bhubaneswar

Hidden hunger—basically, a lack of essential vitamins and minerals—still hits hard in many developing areas. People might get enough calories, but they miss out on key nutrients their bodies need to grow and stay healthy. You don't always see it right away, but this kind of malnutrition wears people down. Kids struggle to learn. Adults get sick more often and can't work as well. It's especially tough for children, women of childbearing age, and families with little money. Food fortification steps in as a real solution. The idea's pretty simple: add important nutrients like iron, iodine, zinc, folic acid, and vitamin D to everyday foods—stuff like rice, flour, oil, salt, and milk. Big organizations like WHO and FAO back this up, and countries like India have picked it up through national programs. The best part? People get a nutrition boost without changing how they eat or what their food tastes like. But there's more to the puzzle. Fortification works best with other efforts—mixing up diets, handing out targeted supplements, improving health services and sanitation, breeding more nutritious crops, and keeping a close eye on results. National surveys, like India's NFHS-5, show just how urgent this is. Take Odisha, for example—anemia rates there are sky-high, especially among kids and women. So, what actually helps? Stronger policies, better quality checks, spreading the word, and making sure fortified foods reach everyone. That's how you chip away at hidden hunger and help build healthier, more productive communities.

Introduction

Food fortification stands out as one of the strongest, most practical ways to fight micronutrient deficiencies—what experts often call "hidden hunger." This isn't the kind of hunger you see on the surface. People might eat enough food, but their bodies still miss out on key vitamins and minerals. Over time, this weakens the immune system, stunts growth, cuts down productivity, and leaves people more likely to get sick. By adding essential nutrients to everyday foods, we can boost the health of entire communities with one simple move. This approach isn't just smart—it's affordable, too. Fortifying foods like rice, wheat flour, salt, oil, and milk helps fill nutritional gaps most people don't even realize exist. It's a strategy backed by big organizations like the WHO and FAO.

Understanding Hidden Hunger

Hidden hunger—basically, not getting enough essential vitamins and minerals—hits more than two billion people around the world. It's especially tough on women and young kids. Take India, for example. Over 80% of teenagers and more than half of women who can have children are anemic. Nearly two out of three kids there don't get the nutrients they need, either. India doesn't have an official spot on a "hidden hunger" list, but the 2024 Global Hunger Index places the country at 105 out of 127, which says a lot about how serious malnutrition is, especially with so many children wasted by hunger. Look at Odisha's numbers from NFHS-5. The state's got a big problem: 64% of young children and just over 64% of women are anemic. Among Particularly Vulnerable Tribal Groups, it's even worse—more than one in three men and women have severe anemia. That's a clear sign of deep, widespread micronutrient deficiency in the region. When people talk about hidden hunger, they mean missing out on key nutrients like iron, iodine, vitamin A, zinc, folic acid, and vitamin D. You might eat enough calories and still be lacking these essentials. This hits kids, adolescent girls, pregnant women, and older adults the hardest. Hidden hunger doesn't always look like starvation, but it's just as damaging.

What Causes Hidden Hunger?

Hidden hunger isn't about not getting enough food—it's about missing out on the vitamins and minerals your body needs to work right. You might eat enough calories, but if you're short on things like iron, iodine, zinc, vitamin A, folate, or vitamin D, your health takes a hit. There's not just one reason for this problem. It's a mix of different factors, all tangled up together:

1. **Poor Variety in What People Eat**

A lot of folks get most of their calories from cheap staples—think rice, wheat, or maize. They barely touch fruits, veggies, pulses, animal foods, or nuts. That's a recipe for missing out on the nutrients you need to grow and stay healthy.

2. Poverty and Food Insecurity

When money's tight, people go for foods that fill them up, not foods that actually nourish them. Nutrient-rich options cost more, so families struggling to make ends meet often settle for what's affordable, not what's best for their health.

3. Traditions and Social Norms Around Food

Sometimes, culture or community rules shape what's on the table. Traditions, taboos, or social expectations can steer people away from certain healthy foods—often hitting women, pregnant moms, and children the hardest.

4. Not Enough Nutrition Know-How

Many people just don't know what a balanced diet really looks like. Without clear info about what nutrients matter or how to eat right, they make choices that lead to deficiencies. Sometimes, they don't realize how much these gaps can impact them down the line.

5. Health Problems That Block Nutrient Absorption

Even a decent diet can't help much if your body can't absorb what you eat. Illnesses like diarrhea, gut infections, or digestive disorders mess with the body's ability to soak up nutrients, causing deficiencies even when food is available.

6. Challenges in Farming and Soil

Some areas have soil that's low in minerals like zinc or iodine. If the crops don't soak up enough of these minerals, neither do the people eating them. Entire communities can end up short on essential micronutrients just because of where they live.

7. Gaps in Maternal and Child Nutrition

When mothers don't get enough nutrients, or if breastfeeding stops too soon, babies and young kids lose out too. Skipping nutrient-rich complementary foods only makes things worse, putting children at even greater risk for hidden hunger

. **How do you tackle hidden hunger?**

Well, you need a mix of smart health policies, changes in the food system, and real action at the community level. Here's what actually works:

1. Food Fortification

Think of this as boosting everyday foods—like rice, flour, salt, oil, and milk—with extra vitamins and minerals. People don't have to change what they eat, but they still get better nutrition. It's affordable and it really works. Lots of countries have seen good results with this.

2. Dietary Diversification

Basically, get more variety on your plate. Eating more fruits, leafy greens, beans, eggs, milk, meat, and those good old traditional foods brings balance. Simple things like starting a kitchen garden, choosing local crops, or eating what's in season can make a big difference.

3. Supplementation Programs

Sometimes you've just got to go straight to the source. Giving iron and folic acid tablets to pregnant women, vitamin A drops to kids, or zinc during diarrhea can fix deficiencies fast in people who need help the most.

ISSN: 3049-2289

4. Stronger Public Health and Disease Control

It's tough to get nutrients if you're always sick. Clean water, better sanitation, keeping up with vaccinations, and fighting infections all help your body actually use the nutrients in your food.

5. Education and Behavior Change

People make better choices when they know better. Teaching about nutrition in schools, through community groups, healthcare workers, or even on the radio or TV can help families understand why a balanced diet matters.

6. Biofortified Crops

Some crops are bred to be naturally richer in nutrients—think iron-packed pearl millet or sweet potatoes loaded with vitamin A. Promoting these crops helps people get more nutrition right from the farm.

7. Supportive Government Policies and Monitoring

None of these sticks without good laws, strong national nutrition programs, and proper monitoring to make sure food quality stays up and everyone actually benefits.

Why Fortify Food?

Food fortification matters, especially with so many people facing anemia, stunted growth, weak immune systems, or missing key micronutrients. Low-income groups get hit hardest. The great thing about fortifying staple foods is you boost nutrition without messing with taste or how people cook and eat. It's cheap, practical, and people accept it.

Types of Food Fortification

1. **Mass fortification**: Adding nutrients to staples like rice, wheat flour, oil, salt, or milk that everyone eats.

2. **Targeted fortification**: Aimed at specific groups—like supplements or fortified foods for pregnant women or babies.

3. **Market-driven fortification**: Food companies voluntarily add nutrients to products like breakfast cereals or energy drinks.

All these steps together help chip away at hidden hunger, making sure people get the nutrients they need to stay healthy and thrive.

Fortified Food	Added Nutrients	Key Health Benefits
Salt	Iodine	Prevents goiter, cognitive impairment, and intellectual disabilities
Wheat Flour	Iron and Folic Acid	Reduces anemia and prevents neural tube defects in newborns
Milk	Vitamin D	Prevents rickets, strengthens bones and teeth
Rice	Iron, Zinc, and Vitamins (e.g., B Vitamins)	Helps correct multiple micronutrient deficiencies and supports growth
Edible Oil	Vitamin A and Vitamin D	Supports immunity, vision, and bone health

Process of Food Fortification

Selection of Staple Food ➜ Population Nutrient Assessment ➜ Identification of Deficient Nutrients ➜ Standardized Fortification Process ➜ Quality Control & Compliance Testing ➜ Packaging and Distribution ➜ Community Consumption ➜ Improved Public Health and Reduced Hidden Hunger

Benefits of Food Fortification

- Reduces micronutrient deficiencies on a large scale
- Improves immunity and workforce productivity
- Supports child growth and cognitive development
- Prevents diseases such as anemia, goiter, bone disorders, and vision problems

ISSN: 3049-2289

- Affordable and easily scalable

Challenges and Limitations

- Limited awareness among population
- Risk of overconsumption if not regulated
- Uneven coverage in rural areas
- Need for strong quality control systems

Global and Indian Initiatives

What's Happening Around the World and in India? Big organizations like WHO and FAO keep pushing countries to fortify staple foods, since that's one of the quickest ways to fix micronutrient gaps everywhere. India's stepped up with a bunch of policies aimed at fighting hidden hunger and making fortified foods more common. There's POSHAN Abhiyaan, the Eat Right India campaign, and the National Food Security Act, with FSSAI setting the rules. Programs like ICDS and the Mid-Day Meal Program actually get fortified foods — things like iodized salt, fortified milk, and cooking oil — into the hands of people who need them most. It's a lot of effort, but it's working its way through.

Conclusion

Hidden hunger is a huge problem in many developing countries. People might get enough to eat, but their diets are missing key vitamins and minerals. You see the effects everywhere—kids who get sick more often, adults who feel tired and can't focus, whole communities that just aren't thriving the way they could. The people hit hardest? Children, women, and low-income families. Solving this isn't just about serving up more food. What really matters is what's in that food. Fortifying staples, mixing up diets, teaching people about nutrition, and making healthier choices affordable—all of that makes a real difference. Good policies help, along with regular check-ins to see what's working, and getting local communities involved. When we tackle hidden hunger, people get healthier, kids learn better, and entire societies move forward.

Recommendations

- ❖ Make national laws stronger so that food fortification isn't just optional—it's required for the staples everyone eats. That way, everyone gets the same nutritional quality.
- ❖ Put more fortified foods into government food programs, especially the ones that help people who need it most. The goal is for these healthier options to be easy to find, not just a luxury.
- ❖ Keep a close eye on quality. Labs need to run regular, accurate tests to make sure fortified foods actually meet the standards set for them.
- ❖ Get the word out. Run big education campaigns so people know what fortified foods are, why they matter, and why they can trust them.
- ❖ Get everyone working together—food companies, researchers, schools, and public health groups. When these groups team up, it's a lot easier to make fortification work and reach more people.Finally, collect data all the time. Use research and regular reviews to fine-tune fortification strategies and make sure they actually work in the long run.

ISSN: 3049-2289

References

1. World Health Organization. *Guidelines for the Fortification of Foods with Essential Micronutrients*. Geneva: WHO.
2. Food Safety and Standards Authority of India. *Regulatory Standards for Food Fortification in India*. Government of India, New Delhi.
3. United Nations Children's Fund and Global Alliance for Improved Nutrition. *Fortification Progress and Expansion in Africa and Asia*. 2022.
4. Ministry of Women and Child Development. *Annual Progress Report of POSHAN Abhiyaan*. Government of India, New Delhi.
5. Food and Agriculture Organization and World Food Programme. *Global Reports and Research Articles on Nutrition and Food Security*.

Call for Articles

Next Edition of Agriculture Bulletin
A Monthly Publication on Agriculture Trends
ISSN: 3049-2289

Agriculture Bulletin, a monthly publication on agriculture trends, is now accepting submissions for its December 2025 edition. We invite ***popular articles, case studies, opinion, reviews, and latest innovation updates*** *from researchers, professionals, and enthusiasts in the field.*

Important Dates

📅 ***Manuscript Submission Deadline:*** **25 December 2025**

📅 ***Publication Date:*** **31 December2025**

Submission Details

- Submit your article according to our guidelines by visiting: www.agriculturebulletin.in