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Smart Fertlizer Vs Nano Fertlizers

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ABSTRACT

In response to the global challenges of declining soil fertility, inefficient nutrient use, and environmental pollution caused by conventional fertilizers, two innovative approaches *i.e.,* smart fertilizers and nano fertilizers have emerged as promising solutions in modern agriculture. Smart fertilizers are designed to release nutrients in a controlled or slow manner, synchronized with plant nutrient demand and environmental conditions. They often employ polymer coatings, nutrient inhibitors, or sensor-based systems to optimize nutrient delivery, improving nutrient use efficiency (NUE) by up to 50 per cent compared to traditional methods. In contrast, nano fertilizers leverage nanotechnology, incorporating nutrients in nanoscale form (1–100 nm) or within nano-carriers for enhanced plant uptake, faster absorption, and reduced losses through leaching or volatilization. As of 2025, products like IFFCO's Nano Urea are being commercially adopted in countries like India, with data showing that just 500 mL of nano urea can replace a 45 kg bag of conventional urea, reducing input costs and environmental burden. While both technologies aim to enhance sustainability and crop productivity, smart fertilizers are generally broader in scope and include digital or sensor-based delivery systems. Whereas nano fertilizers specifically target improved nutrient delivery at the molecular level. Despite their promises, the challenges remain such as high production costs, lack of regulatory frameworks, and limited long-term field data- especially concerning nano fertilizers. Nevertheless, with increasing global emphasis on sustainable agriculture and climate-smart practices, the adoption of these next-generation fertilizers is expected to grow significantly in the coming decade (Liu *et al*., 2025).

Introduction

In olden days, fertilization depended entirely on organic materials like manure, compost, and crop rotations, with applications guided by observation and traditional knowledge. The

Industrial Revolution introduced synthetic fertilizers applied by hand or simple machines, which improved yields but lacked precision. These methods often caused uneven fertilization, wasting resources and harming the environment through nutrient runoff and water pollution. As agriculture intensified, inefficiencies became evident studies show that up to 60 per cent of fertilizer remains unused by crops, leading to economic losses and ecological damage. In order to address this problem many technologies were evolved which includes the application of smart fertilizers, nano fertilizers and precision agriculture technologies.

Smart Fertilizers

Smart fertilizers are advanced fertilizers designed to release nutrients in a controlled and efficient way according to the needs of plants and soil conditions. They use technologies like polymer coatings, nanomaterials, or bio-based carriers to control nutrient release and minimize losses. Unlike traditional fertilizers that release nutrients quickly and unevenly, smart fertilizers supply nutrients gradually, improving nutrient-use efficiency (NUE) and reducing environmental pollution such as leaching and runoff. These fertilizers help crops absorb more nutrients, enhance yields, lower input costs, and support sustainable farming. Examples include controlled-release urea, polymer-coated NPK, and nano-fertilizers like nano-urea. Smart fertilizers are an essential part of precision agriculture, promoting both productivity and environmental protection (Shanmugavel *et al.,* 2023).

Types:

1. **Controlled-release fertilizers (CRF):**
   - Nutrients are coated with polymers, sulfur, or resins
   - Release is regulated by temperature, moisture, or microbial activity
   - *Example:* Sulfur-coated urea, polymer-coated NPK
2. **Slow-release fertilizers (SRF):**
   - Nutrients are gradually available through chemical or microbial degradation
   - *Example:* Urea-formaldehyde, isobutylidene diurea (IBDU)
3. **Site-specific nutrient management (SSNM):**
   - Based on soil testing, GPS, or remote sensing data
   - *Example:* Precision agriculture using sensors and drones

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4. **Smart biofertilizers:**
    - Combine beneficial microbes with carrier materials or smart coatings for extended survival and activity

Advantages:

1. **Improved Nutrient-Use Efficiency (NUE):** Nutrients are released gradually according to plant needs, reducing wastage.
2. **Higher Crop Yield and Quality:** Ensures a steady nutrient supply, leading to better growth and productivity.
3. **Reduced Environmental Pollution:** Minimizes nutrient losses through leaching, volatilization, and runoff.
4. **Lower Input Frequency:** Fewer fertilizer applications are needed, saving time and labor.
5. **Supports Sustainable Farming:** Promotes balanced nutrient management and soil health.
6. **Compatible with Precision Agriculture:** Works well with modern technologies like sensors and GPS for targeted application.

Limitations:

1. **High Initial Cost:** Production and application technology are more expensive than conventional fertilizers.
2. **Complex Application:** Requires technical knowledge and proper calibration for effective use.
3. **Limited Availability:** Not widely accessible in some regions, especially for small-scale farmers.
4. **Slow Adoption:** Farmers may be reluctant to switch due to lack of awareness or training.
5. **Environmental Concerns of Coatings:** Some synthetic coatings (like polymers) may not be biodegradable.

NANO FERTILIZERS

Nano fertilizers are advanced fertilizers that use nanotechnology to deliver nutrients to plants more efficiently. They contain nutrients in nano-sized particles (1–100 nanometers), which increases their surface area and improves absorption by roots or leaves. Nano fertilizers can release nutrients slowly and precisely, reducing losses from leaching or volatilization and enhancing nutrient-use efficiency (NUE) (Gangwar *et al.,* 2023).

Types:

1. **Nano-scale nutrients:** Nutrients in pure nano form (e.g., nano-ZnO, nano-Fe_2O_3)
2. **Nano-encapsulated fertilizers:** Nutrients enclosed in nanocarriers (e.g., nano-clay, chitosan, or carbon nanotubes)
3. **Nano-emulsion fertilizers:** Nutrient solutions dispersed as stable nano-droplets

Mechanism of Manufacturing of Nano fertilizers:

- High surface area → faster absorption by roots/leaves
- Controlled release → sustained nutrient supply
- Foliar application → direct and efficient uptake

Examples:

- Nano-ZnO → improves enzyme activity and chlorophyll formation
- Nano-Urea (by IFFCO, India) → 4% nitrogen, reduces conventional urea use by ~50%

Benefits:

1. **Enhanced Nutrient Uptake:** Nano-sized particles are easily absorbed by roots and leaves, improving nutrient availability.
2. **Higher Nutrient-Use Efficiency (NUE):** Reduces nutrient losses through leaching and volatilization, ensuring more nutrients reach the plants.
3. **Improved Crop Growth and Yield:** Promotes better photosynthesis, enzyme activity, and root development, leading to higher yields.
4. **Controlled and Sustained Release:** Provides nutrients slowly over time, matching plant requirements throughout the growth cycle.

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5. **Reduced Environmental Pollution:** Requires smaller doses and minimizes fertilizer runoff, protecting soil and water quality.
6. **Supports Sustainable Agriculture:** Encourages efficient resource use and reduces dependence on chemical fertilizers.

Limitations:

1. **High Production Cost:** Manufacturing nano fertilizers is expensive compared to conventional types.
2. **Limited Field Data:** Long-term effects on soil health, crops, and ecosystems are still under research.
3. **Potential Nanotoxicity:** Excessive or improper use may affect beneficial soil microorganisms or plant physiology.
4. **Storage and Handling Issues:** Nanoparticles may require special storage conditions to maintain stability.
5. **Regulatory and Safety Concerns:** Lack of clear guidelines for safe use and environmental impact management.

Comparison of Smart fertilizers & Nano fertilizers on growth and yield of crops

Aspect	**Smart Fertilizers**	**Nano Fertilizers**
Nutrient Release	Controlled or slow release based on soil moisture, temperature, or microbial activity	Gradual and targeted nutrient release at the nano-scale, improving plant uptake efficiency
Nutrient-Use Efficiency (NUE)	Increases by 30–50% through precise and timed nutrient availability	Increases by 60–80% due to enhanced absorption and reduced losses
Plant Growth Impact	Promotes steady, sustained growth with minimal nutrient stress	Accelerates metabolic activity, root development, and chlorophyll production

Aspect	Smart Fertilizers	Nano Fertilizers
Crop Yield	Improves yield by ensuring balanced nutrition throughout the growth cycle	Boosts yield by enhancing nutrient uptake and photosynthetic efficiency
Environmental Impact	Reduces nutrient leaching and greenhouse gas emissions	Minimizes environmental pollution and fertilizer wastage even further
Cost and Accessibility	Moderately higher cost, suitable for large-scale use with precision tools	Higher production cost but requires smaller doses; still developing commercially

Future Perspectives

- Integration with AI, IoT, and sensors for smart nutrient delivery
- Nano-biofertilizers combining nanotechnology with microbes
- Policies for safe use and standardization

Conclusion

Both smart and nano fertilizers enhance crop growth and yield by improving nutrient availability and efficiency. Smart fertilizers focus on controlled nutrient delivery, while nano fertilizers offer ultra-efficient absorption at the cellular level. Combined use in precision agriculture can maximize productivity while maintaining soil and environmental health.

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CLIMATE SMART AGRICULTURE: THE NEED OF THE HOUR

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ABSTRACT

The world is facing the dual challenge of feeding a growing population and combating the impacts of climate change on agriculture. By 2050, global food demand is expected to rise by 60%, yet extreme weather events, such as droughts, floods, and heatwaves, are already threatening food production and livelihoods, especially in developing countries. Climate-Smart Agriculture (CSA) offers a comprehensive solution by combining improved agricultural practices, innovative technologies, and supportive policies to enhance productivity, increase resilience, and reduce greenhouse gas emissions. CSA focuses on integrated farming systems that include conservation agriculture, efficient water management, agroforestry, climate-resilient crop varieties, integrated nutrient management, and improved livestock practices. These approaches not only help farmers adapt to climate risks but also open new economic opportunities, such as carbon credit markets and climate-linked insurance. Young agronomists play a pivotal role in advancing CSA by driving innovation, conducting localized research, engaging farmers, and influencing policy. Their active involvement is critical to scale up CSA solutions and ensure they meet local and global needs. Ultimately, CSA represents a necessary transformation toward a more sustainable, resilient, and productive agricultural future ensuring food security, environmental protection, and economic growth for generations to come.

Keywords: Climate change, climate-smart agriculture, food security, greenhouse gases, resilience

Introduction

The world is at a critical juncture when it comes to addressing climate change and its effects on agriculture. As the global population grows and environmental challenges intensify, agricultural systems are under greater pressure to produce more food while managing the increasing unpredictability of weather patterns. However, future intensification of climate change and global warming is predicted to have a significant influence on agricultural output (Chand et al., 2024), especially in developing nations like India due to their agrarian economies (Anil et al., 2025). Since agriculture made up around 14% of India's GDP, a 4.5–9% decline in productivity indicated that the yearly cost of climate change might have reached 1.5% of GDP (Subba Rao et al., 2025). The faster rate of change in climate variables combined with the occurrences of extreme weather events (Senapati et al., 2024a; Parapurath et al., 2025a) have significant impact on agriculture (Parapurath and Veluswamy, 2025).

The escalating climate crisis, driven by anthropogenic greenhouse gas emissions, poses severe threats to ecosystems, economies, and human well-being. The combustion of fossil fuels, industrialization, deforestation, agricultural practices, space explosion, grazing, degradation of wetlands, and changes in land use are all linked to rising GHG emissions (Senapati et al., 2024b). While conventional strategies such as renewable energy deployment, reforestation, and policy reforms remain vital, as they are insufficient to match the accelerating pace and complexity of climate change (Parapurath et al., 2025b). In this context, Climate-Smart Agriculture (CSA) emerges as a viable solution that offers farmers a way to adapt to these changes while continuing to produce food sustainably. CSA is an approach that combines practices, technologies, and policies to enhance agricultural productivity, strengthen resilience to climate impacts, and reduce greenhouse gas emissions. As the need for sustainable agriculture becomes more urgent, CSA represents not just a set of practices but a paradigm shift in how we approach the complex relationships between climate, agriculture, and society.

This article explores the concept of CSA, its core principles, examples from around the world, and the critical role young agronomists and researchers play in driving this change.

Facing the Climate Challenge

By 2050, the global population is expected to grow by one-third, adding around 2 billion people, mostly in developing countries. At the same time, more people will live in cities, increasing the demand for food. The Food and Agriculture Organization (FAO) estimates that agricultural production will need to rise by 60% to meet the growing demand (Ouda and Zohry, 2022). However, climate change poses a major challenge to this goal, as it leads to extreme weather events and unpredictable climate patterns that affect agriculture. Agriculture has always depended on nature's rhythms. But today, farmers are facing unprecedented challenges: erratic rainfall, prolonged droughts, heat waves, floods, and new pest outbreaks.

To ensure food security and sustainable development, agriculture must adapt to these climate changes while reducing greenhouse gas emissions. This transformation requires efficient use of natural resources such as land, water, and soil. Small-scale farmers, particularly in developing countries, are highly vulnerable to these changes and often lack the knowledge, resources, and access to technology. A shift toward more resilient and sustainable agricultural practices is necessary to support food production and mitigate climate change impacts.

Before CSA

After CSA

Fig. 1. Differences between before CSA and after CSA

Climate-Smart Agriculture

Climate-smart agriculture (CSA) is an integrated approach to managing landscapes cropland, livestock, forests and fisheries that address the interlinked challenges of food security and climate change. Although it is built on existing agricultural knowledge, technologies, and sustainability principles, CSA is distinct in several ways. First, it has an explicit focus on addressing climate change in the agrifood system. Second, CSA systematically considers the synergies and tradeoffs that exist between productivity, adaptation, and mitigation. And third, CSA encompasses a range of practices and technologies that are tailored to specific agro-ecological conditions and socio-economic contexts including the adoption of climate-resilient crop varieties, conservation agriculture techniques, agroforestry, precision farming, water management strategies, and improved livestock management. CSA is an integrated farming approach with three main goals:

1. **Increased productivity:** Produce more and higher quality food without putting an additional strain on natural resources, to improve nutrition security and boost incomes, especially for 75 percent of the world's poor who live in rural areas and mainly rely on agriculture for their livelihoods.

2. **Enhanced resilience:** Reduce vulnerability to droughts, pests, diseases and other climate-related risks and shocks; and improve the capacity to adapt and grow in the face of longer-term stresses like increased seasonal variability and more erratic weather patterns.

3. **Reduced emissions:** Reduce greenhouse gas emissions of the food system, avoid deforestation due to cropland expansion, and increase the carbon sequestration of plants and soils.

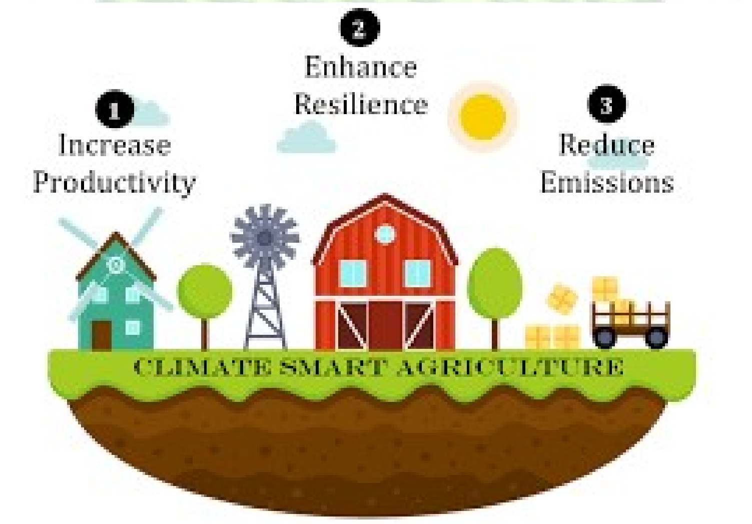

Fig. 2. Three main goals of climate smart agriculture

Why it matters today

Agriculture is both a victim and contributor to climate change. It is responsible for about 20–25% of global greenhouse gas (GHG) emissions, mainly from methane (livestock, rice cultivation), nitrous oxide (fertilizers), and carbon dioxide (land-use change, deforestation). Yet, ironically, smallholder farmers - who produce much of the world's food - are among the most vulnerable to climate change impacts such as droughts, floods, heatwaves, and shifting growing seasons.

This is where Climate-Smart Agriculture (CSA) becomes crucial. CSA is not just about reducing emissions; it's about helping farmers adapt to changing conditions while increasing productivity and sustainability. By adopting CSA practices, farmers can improve soil health, conserve water, and diversify crops making their farms more resilient to climate shocks. Additionally, CSA opens new income opportunities. Farmers can participate in carbon credit markets, where they get paid for adopting practices that sequester carbon (like agroforestry or cover cropping). They can access climate-linked insurance that protects against weather-related losses or sell products into premium sustainable markets that value low-emission or climate-resilient practices. Most importantly, CSA empowers farmers with the knowledge and tools to manage climate risks, protect their livelihoods, and secure a more stable future for the next generation.

Techniques in Climate-Smart Agriculture

Climate-Smart Agriculture (CSA) uses a wide range of practical techniques that help farmers adapt to climate change, boost productivity, and reduce greenhouse gas emissions.

- **Conservation agriculture**: Practices like minimal soil tillage, crop rotation, and cover cropping help maintain soil health, reduce erosion, and improve water retention (Parapurath et al., 2024).
- **Efficient water management:** Drip irrigation, rainwater harvesting, alternate wetting and drying (AWD) in rice, and precision irrigation technologies reduce water use and improve water-use efficiency.
- **Agroforestry:** Integrating trees with crops or livestock systems enhances carbon storage, improves biodiversity, and provides additional income through tree products.
- **Improved crop varieties:** Using drought-tolerant, flood-tolerant, or heat-resistant crop varieties helps farmers maintain yields under changing climate conditions.
- **Integrated nutrient management:** Combining organic manures, compost, and balanced fertilizers reduces nutrient losses and emissions while maintaining soil fertility.
- **Livestock management**: Improved feeding practices, rotational grazing, and better manure management reduce methane emissions and improve animal productivity.

These techniques, when combined and adapted to local conditions, create resilient, productive, and sustainable farming systems, making CSA a powerful tool for addressing climate challenges in agriculture.

Digitalization in Climate Smart Agriculture

Digitalization in climate smart agriculture involves the integration of digital technologies throughout the agricultural value chain to optimize production, improve resource management, and enhance decision-making processes. Integrating Machine Learning (ML), big data analytics, and advanced algorithms optimize crop yields, enables precision agriculture, and supports sustainable practices for better productivity. Smart farming and Agriculture 4.0, incorporating IoT, AI, and sensors revolutionize traditional farming methods, increasing efficiency, and reducing labour costs. Overall Digital agriculture represents a transformative approach to farming that leverages advanced technologies to optimize production, improve resource management, and enhance decision-making (Prakash et al., 2024). Among the digital agricultural tools, satellite technology, and Artificial Intelligence (AI) integrated image processing have revolutionized climate science, allowing for faster and more precise assessments in agriculture sector (Prakash et al., 2025). Moreover, the integration of farm management software, IoT-based sensors, and precision agriculture demonstrate significant potential in enhancing crop production and sustainability. However, challenges persist particularly in technology adoption, data privacy, and security. Overcoming these barriers requires investment in infrastructure, supportive legislation, and farmer education. Notably, e-commerce platforms and blockchain technology offer new avenues for market access and supply chain management (Ajmal et al., 2025).

The Role of Young Agronomists

Young agronomists and students play a crucial role in driving the shift toward Climate-Smart Agriculture (CSA). With their fresh ideas, up-to-date scientific knowledge, and passion for change, they are well-positioned to develop and promote innovative, climate-resilient farming solutions tailored to local needs. They can engage directly with farmers to raise awareness about climate risks and share practical adaptation strategies, helping rural communities make informed decisions. Through research and field trials, young agronomists can identify which practices work best under local soil, water, and climate conditions, ensuring solutions are both effective and scalable. Beyond the farm, they can also serve as advocates, pushing for supportive government policies, securing funding for CSA initiatives, and ensuring that the voices of smallholder farmers are heard in climate discussions. By connecting science, policy, and grassroots action, young agronomists are key drivers of a more resilient and sustainable agricultural future.

Conclusion

Climate-Smart Agriculture (CSA) is not just an option, rather it is a necessity for ensuring global food security in the face of climate change. As agriculture faces increasing challenges from extreme weather, resource depletion, and rising greenhouse gas emissions, transforming farming systems to become more resilient, efficient, and sustainable is urgent. CSA offers practical pathways to help farmers adapt, improve productivity, and reduce environmental impact. Importantly, the active involvement of young agronomists, researchers, and policymakers will be essential to drive innovation, promote awareness, and scale up these solutions. By working together across sectors, we can build a farming future that not only feeds the world but also protects the planet for generations to come.

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Empowering Women through Horticulture-Based Livelihood Enterprises

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ABSTRACT

Agriculture continues to be the mainstay of our country's economy. Nearly 85 per cent of the population lives in rural areas. Majority of the rural families depend on the agriculture and allied activities for their livelihood. The overall growth of the country's economy and success of poverty alleviation efforts largely depend on agricultural performance. In India, farm women constitute an important work force in agriculture and allied sectors and are vital to the well-being of farm households. Women contribute significantly to agricultural development and allied fields, which include crop production, livestock production, horticulture, post-harvest operations, fisheries, etc. A large number of women from rural area are engaged in farm operations as cultivators, assistants to male cultivators or as agricultural labourers.

In recent years, horticulture has emerged as a promising sector not only for enhancing farm income but also for empowering women through various subsidiary enterprises. By actively participating in horticultural ventures, rural women are transforming themselves from mere helpers to successful entrepreneurs.

Horticulture: A Pathway to Prosperity

Horticulture, which includes the cultivation of fruits, vegetables, flowers, medicinal, and aromatic plants, post-harvest techniques offers immense opportunities for income generation. Compared to traditional crop farming, horticulture provides quicker returns, requires less land, and allows women to engage in activities that are compatible with household responsibilities.

Women in Horticulture-Based Enterprises

Women have shown exceptional potential in managing small-scale horticultural enterprises such as:

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- **Nursery management:** Raising fruit and ornamental plant seedlings for commercial sale.
- **Floriculture:** Cultivating flowers like marigold, jasmine, and rose for garland making and decoration.
- **Mushroom cultivation:** A low-investment, high-return enterprise suitable for home-based production.
- **Beekeeping:** Producing honey and other value-added products like beeswax.
- **Fruit and vegetable processing:** Making pickles, jams, squashes, and dehydrated products.
- **Aromatic and medicinal plant cultivation:** Producing essential oils and herbal products.

These enterprises require relatively low investment but provide steady income and employment opportunities throughout the year.

Economic and Social Empowerment

Participation in horticultural enterprises has significantly improved the economic status of rural women. The additional income generated helps them to meet household needs, support children's education, and contribute to family savings. Beyond income, these activities enhance their confidence, decision-making power, and social recognition within the community.

Training and Institutional Support

Several government and non-government organizations are promoting women's participation in horticulture through training, credit support, and market linkages. Schemes like the **National Horticulture Mission (NHM)**, **National Rural Livelihood Mission (NRLM)**, and **Rashtriya Krishi Vikas Yojana (RKVY)** have special components for women. Training in nursery management, post-harvest handling, and value addition has helped women adopt improved technologies and develop entrepreneurship skills.

Conclusion

Empowering women through horticulture-based livelihood enterprises is not just an economic intervention—it is a social transformation. When women are given the right skills, resources, and opportunities, they become powerful change-makers who can uplift their families and communities. Strengthening women's participation in horticulture is, therefore, a key step toward achieving inclusive rural development and sustainable livelihoods.

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Abiotic Stresses and Their Management in Vegetable Crops

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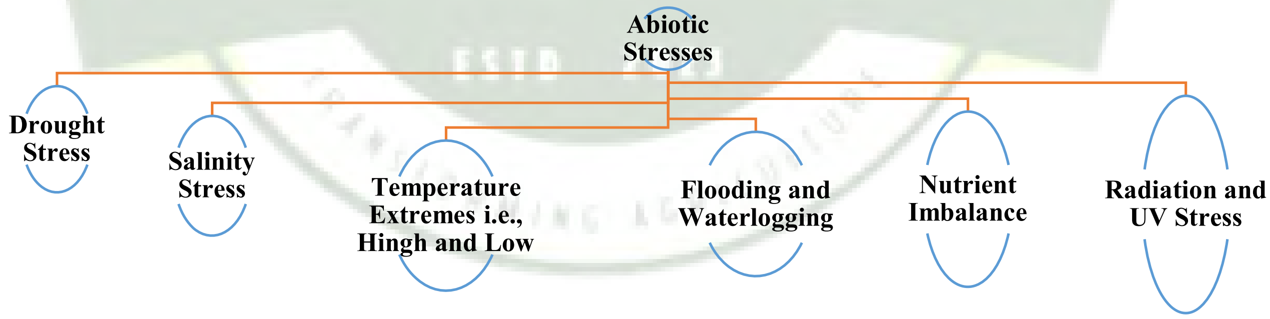
INTRODUCTION

Vegetable crops form an essential component of human nutrition and agricultural economies worldwide. However, their productivity and quality are severely affected by abiotic stresses *i.e.,* non-living environmental factors that adversely affect the plant growth and yield. These stresses include drought, salinity, temperature extremes (heat and cold), flooding, nutrient imbalance and radiation stress. Due to climate change and increased environmental variability, the frequency and intensity of these stresses are rising, posing a significant threat to sustainable vegetable production. To overcome this abiotic stress, we should move toward the management of this stress so the losses of vegetable production can maintain and obtain a good yield and benefits.

Major Abiotic Stresses in Vegetable Crops



Drought Stress- Drought is one of the most critical abiotic stresses affecting vegetables such as tomato, chili, brinjal and cucurbits. It leads to reduced leaf area, impaired photosynthesis and decreased fruit set. Water deficit disrupts cell turgor and physiological processes like nutrient uptake and transpiration.

Salinity Stress- Excess salt concentration in soil or irrigation water affects osmotic balance and ion homeostasis. Crops like onion, carrot, and spinach are particularly sensitive. High Na^+

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and Cl^- ions cause toxicity and reduce uptake of essential nutrients such as potassium and calcium.

Temperature Extremes

- **High temperature:** Causes flower drop, fruit cracking, and sunscald in crops like tomato, pepper, and cucumber.
- **Low temperature:** Leads to chilling injury, delayed germination, and poor seedling establishment in warm-season vegetables like okra and eggplant.
- **Frost:** Damages cell membranes and causes desiccation in leafy vegetables.

Flooding and Waterlogging- Excess water limits oxygen supply to roots, leading to anaerobic conditions. This results in reduced nutrient absorption and root decay, especially in crops like tomato and cabbage.

Nutrient Imbalance- Nutrient stress, whether deficiency or toxicity, impairs metabolic processes. For example, boron deficiency leads to poor fruit development in cauliflower, while nitrogen deficiency reduces leaf growth in leafy vegetables.

Radiation and UV Stress- High radiation levels and UV-B exposure disrupt chlorophyll synthesis, impairing photosynthesis and leading to oxidative damage.

Physiological and Biochemical Responses to Abiotic Stresses

Under stress, plants trigger various **adaptive mechanisms**, such as:

- Accumulation of osmolytes (proline, glycine betaine, sugars) to maintain osmotic balance.
- Antioxidant defense systems (enzymes like superoxide dismutase, catalase, peroxidase) to mitigate oxidative damage.
- Hormonal regulation involving abscisic acid (ABA), salicylic acid (SA), and jasmonic acid (JA) for stress signaling and tolerance.

Management Strategies for Abiotic Stresses

Genetic and Breeding Approaches

- Development of stress-tolerant varieties through conventional breeding and molecular tools.
- Incorporation of genes responsible for osmotic adjustment, ion transport and antioxidant production.

- Use of marker-assisted selection (MAS) and transgenic approaches to enhance tolerance.

Agronomic Management

- **Mulching:** Conserves soil moisture, moderates temperature, and reduces salinity effects.
- **Drip irrigation:** Ensures efficient water use under drought-prone conditions.
- **Raised bed cultivation:** Helps mitigate waterlogging.
- **Soil amendments:** Application of gypsum or organic matter improves soil structure and reduces salinity.

Nutrient and Chemical Management

- Balanced fertilization improves stress resilience.
- Use of biofertilizers enhances root growth and nutrient uptake.
- Application of biostimulants (seaweed extracts, humic acids, amino acids) improves stress tolerance.
- Foliar sprays of micronutrients like zinc, boron, and iron strengthen plants against environmental stress.

Use of Growth Regulators and Protectants

Plant growth regulators like ABA, salicylic acid, and brassinosteroids modulate stress responses. Antioxidants and osmoprotectants such as proline, glycine betaine, and ascorbic acid help maintain cellular homeostasis.

Protected Cultivation

Growing vegetables under polyhouses, shade nets, or tunnels minimizes exposure to extreme weather and improves water and nutrient use efficiency.

Microbial and Biotechnological Interventions

Plant growth-promoting rhizobacteria (PGPR), arbuscular mycorrhizal fungi (AMF) and endophytes play a vital role in stress alleviation by improving root architecture, nutrient uptake and hormonal balance.

Climate-Smart and Integrated Management

The integration of climate-smart agricultural practices, including water harvesting, crop diversification, and use of early-maturing varieties, is essential for long-term adaptation. Combining genetic, physiological, and agronomic strategies ensures a holistic approach to mitigating abiotic stresses in vegetables.

Conclusion

Abiotic stresses are a major constraint to vegetable production worldwide. Effective management requires a multidimensional strategy that integrates advanced breeding, sustainable agronomy, and biotechnological tools. The adoption of stress-resilient varieties, improved cultural practices, and the use of biostimulants can significantly enhance the productivity and stability of vegetable crops under changing climatic conditions.

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Nutritional Importance of Indian States Thalis

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INTRODUCTION

Indian thalis are regionally diverse meals served on a single plate, providing balanced nutrition through a variety of components, including grains, proteins (dal, curd), vegetables, healthy fats, and condiments. A meal format combining several small portions of different dishes, offering variety in taste, texture, ingredients and nutrients.

Nutritional importance lies in providing a spectrum of macronutrients and micronutrients, aiding digestion through fermented foods and spices, promoting portion control, and utilizing seasonal ingredients for maximum nutrient content.

Indian Culinary exhibits diversity from Punjab's protein rich Sarsonda saag and makki di roti to Karnataka's north south combo of Jowar roti and Ragi mudde thalis and these traditional foods are inherently nutritious when consumed in right proportions. Different regional thalis, like the Assamese, Gujarati, or Maharashtrian variations, reflect local ecology and culinary practices, showcasing the holistic and culturally significant nature of this meal format.

Cultural, geographical, climatic, economic, religious influences shape state-wise thalis. A Gujarati thali, which comes from the state of Gujarat in Western India, is one of the most elaborate thalis. It includes several fried snacks, flatbreads, a variety of vegetable preparations cooked in ghee, and sweets. Thali is also not necessarily only vegetarian, in the coastal regions of India, it is variations of fish and seafood thali. Kolhapur, a city in the state of Maharashtra in Western India, is famous for its various spicy mutton thali preparations.

Objective: To understand how regional thalis deliver balanced nutrition, what variations exist across states and how thalis can contribute to public health and dietary guidelines.

Components of a Healthy Thali

A healthy and ideal thali should include the following nutrients for balanced diet.

Carbohydrate rich staple food are also called as "energy giving food" such as rice, roti made up of Jowar, Bhajra, Ragi and other millet based.

Protein sources such as legumes, pulses, plant and animal based protein are necessary for growth, repair and are commonly known as "body building foods

Vitamins and Minerals are obtained from leafy vegetables, roots and fruits these foods provide immunity therefore are called as "protective foods"

Dairy products like curd, buttermilk, paneer are the richest source of calcium and also aid in easy digestion

Fats/oils are required to maintain energy density and enables absorption of fat-soluble vitamins, essential fatty acids

Sweeet/ condiments are served as dessert which provide beneficial phytonutrients but more sugar may be restricted with moderation

Concept of dietary diversity and balanced diet

Dietary diversity is eating a wide range of different foods from all major food groups, while a balanced diet provides all the necessary nutrients—carbohydrates, fats, proteins, vitamins, minerals, and fiber—in the right proportions to maintain optimal health.

State-Wise Thalis and Their Nutritional Profiles

State	Typical Thali Composition	Nutritional Strengths	Possible Weaknesses / Gaps
Punjab	Roti / paratha, daal or rajma, seasonal vegetables, curd or lassi, sometimes meat or fish, sweets	High protein (pulses, dairy), energy rich, good fats, dairy gives calcium; strong in legumes.	Rich in fats, especially ghee; could exceed calorie needs; may lack diversity of vegetables or low in green leafy types depending on region.
Kerala	Rice, fish or meat curry, coconut-based curries, sambar, multiple vegetable side dishes, papad, curd, banana or payasam	Good in essential fats (coconut), micronutrients from vegetables, protein (fish), probiotics (curd), fibre from plant foods.	Might have high saturated fat (coconut oil / coconut milk); sweet items high in sugar; excessive rice; lower intake of pulses in some meals.
Gujarat	Roti, dal, multiple vegetables, kadhi, buttermilk, sweets, pickles etc.	Balanced mix of legumes, vegetables; dairy through kadhi / buttermilk; some sweet but small portion; varieties of vegetables add micronutrients.	Sweet component may add extra sugar; perhaps less animal protein in purely vegetarian meals; possibility of low green leafy vegetables.

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State	Typical Thali Composition	Nutritional Strengths	Possible Weaknesses / Gaps
Tamil Nadu / South India	Rice, sambar, rasam, vegetable kootu / poriyal, curd, sometimes fish; coconut-based curries, chutneys	Good fibre, vitamins from vegetables, probiotics from curd, protein via dal or fish; good in plant fats.	High rice → high carbohydrate load; sometimes low in non-vegetarian protein; coconut oil saturated fats; sweets/snacks in some meals.
Odisha / Eastern States	Rice, fish or vegetarian curry, leafy greens, dal, vegetables, curd, sometimes sweet or jaggery	High in fish protein (if nonveg), leafy greens add iron & vitamin A; jaggery helps micronutrients; use of local vegetables.	Sometimes seasonality limits variety; meals may become heavy in rice; may lack diversity of pulses; under-utilization of milks if per capita consumption is low.

Factors influencing variation in Indian thalis:

Religion: Religious beliefs, such as Hinduism and Sikhism, influence dietary laws and restrictions, impacting which ingredients are used and which are avoided in thalis.

Culture and Tradition:

Cultural customs, traditions and social taboos significantly shape food consumption patterns and the overall composition of the thali.

Social Practices:

Community meal patterns and social norms within different regions also play a role in influencing food choices and the way meals are prepared and served.

Geography and Climate:

India's varied climate and landscape leading to regional variations in locally produced spices and other ingredients makes variations in flavours of thalis suitable to climatic condition of particular region.

Local Produce:

The availability of specific vegetables, grains, and fruits in a region directly influences the components of a thali, with certain staple ingredients becoming more prevalent in different areas

Conclusion

Karnataka Meals commonly include rice / idli / dosa, sambar (lentils + vegetables), vegetable curries / stir-fries (poriyal, palya), chutney / sambhar / rasam, curd / yogurt, perhaps salad or raw vegetables with Jowar roti and Ragi mudde. **Karnataka Thali is more moderate fits more toward "balanced vegetarian thali" models.**

Maharashtrian thali often includes: rice or chapati / bhakri; pulses (amti, dal); vegetable sides; yogurt; sometimes snacks / special items; sweets; chutney / pickles. Non-veg versions also exist in some areas. Maharashtra Thali is on the higher side of energy, roughly similar to Punjabi or Gujarati thalis in some "mixed high-calorie" versions, but with slightly better fiber (24 g) than many other states.

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Organic Farming: Sustainable Solutions for Managing Plant Diseases

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INTRODUCTION

Organic farming is a sustainable and eco-friendly approach to agriculture that promotes harmony between nature, soil, plants, and humans. Unlike chemical-based farming, it avoids synthetic fertilizers and pesticides, instead emphasizing the use of organic manures, composts, and biological control agents. Plant disease management under organic farming focuses on prevention rather than cure. The central idea is to strengthen the plant's natural defense mechanisms and maintain ecological balance in the soil and surrounding environment. When soil is rich in organic matter and beneficial microorganisms, plants develop resilience against most pathogens. Organic farming thus ensures crop health, food safety, and long-term soil fertility while protecting the environment and biodiversity.

Understanding Disease Management in Organic Farming

Plant diseases are caused by complex interactions among host, pathogen, and environment. In organic farming, rather than eliminating pathogens with toxic chemicals, the emphasis is on maintaining balance through cultural, biological, and physical measures.

Healthy soil teeming with beneficial microbes acts as the foundation for disease resistance. These microorganisms not only improve nutrient cycling but also suppress harmful fungi and bacteria by competing for space, nutrients, and energy.The concept is simple yet profound - feed the soil, and the soil will protect the plant.

Key Principles of Disease Management in Organic Farming

1. Soil Health and Organic Matter: Building soil organic matter through compost, green manure, and crop residues improves structure, aeration, and microbial life.

2. Diversity and Crop Rotation: Growing diverse crops reduces disease incidence and breaks pathogen life cycles.

3. Biological Control: Beneficial organisms such as Trichoderma, Bacillus subtilis, and Pseudomonas fluorescens suppress pathogens naturally.

4. Use of Botanicals: Neem, garlic, turmeric, and other plant extracts provide natural protection against diseases.

5. Cultural Practices: Proper spacing, sanitation, resistant varieties, and balanced nutrition are essential for keeping crops healthy.

Organic Inputs for Disease Management

1. Compost and Vermicompost

Organic manure improves soil fertility while enriching it with beneficial microbes. Well-decomposed compost suppresses soil-borne diseases like damping-off and wilt. Vermicomposting contains earthworm secretions that promote root growth and plant vigor. It enhances the plant's ability to resist pathogens naturally.

2. Biofertilizers and Biocontrol Agents

Biofertilizers such as Azospirillum, Rhizobium, and Phosphobacteria help plants absorb nutrients efficiently. Meanwhile, biocontrol agents like *Trichoderma harzianum* and *Pseudomonas fluorescens* protect plants from fungal and bacterial diseases.

These can be used for seed treatment, soil application, or foliar spray. They create a protective microbial shield around roots and leaves, acting as a living defense system.

3. Neem-Based Products

- Neem (*Azadirachta indica*) is the cornerstone of organic pest and disease management.
- Neem seed kernel extract (5%) controls fungal and bacterial infections.
- Neem oil (2–3%) acts as a natural antifungal and repellent.
- Neem cake enriches soil while suppressing root pathogens like *Fusarium* and *Rhizoctonia*.
- Neem compounds are biodegradable, safe, and leave no harmful residues on crops or soil.

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Fig 1. Neem cake

4. Botanical and Herbal Extracts

Locally available herbs can serve as potent disease control materials:

- **Garlic and ginger extract** – antibacterial and antifungal.
- **Chili-tobacco extract** – manages sucking pests and virus vectors.
- **Turmeric decoction** – antifungal and **antiseptic.**
- **Datura or Lantana extracts** – suppress leaf spot diseases.

These formulations, when fermented or mixed with cow urine and dung, form natural broad-spectrum protectants.

5. Cultural and Mechanical Measures

Organic farming relies heavily on preventive cultural practices:

- Crop rotation with non-host plants breaks the disease cycle.
- Proper spacing and pruning improve air circulation.
- Timely sowing avoids periods conducive to disease outbreaks.
- Sanitation—removal of infected debris prevents reinfection.
- Use of resistant varieties provides long-term disease control.
- These low-cost practices form the backbone of organic disease prevention.

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6. Mulching and Green manuring

Organic mulches such as paddy straw, leaves, or crop residues conserve soil moisture and suppress weeds. By reducing soil splashing, they limit the spread of fungal spores. Green manuring with legumes also adds nitrogen and organic carbon, strengthening plant immunity.

Fig.2 Paddy straw mulch

Biological Suppression through Microbes

Beneficial microorganisms are vital components of organic systems:

- ***Trichoderma* spp.** – antagonistic to soil-borne pathogens and promotes root growth.
- ***Bacillus subtilis*** – produces antibiotics that suppress foliar pathogens.
- ***Pseudomonas fluorescens*** – competes with bacterial and fungal diseases in rhizosphere zones.

Using these microbial inoculants regularly enriches soil biodiversity and suppresses disease-causing agents without harming beneficial insects.

Field Experiences from Northeastern India

In the organic fields of Nagaland, farmers have effectively controlled tomato wilt and chilli dieback using neem oil sprays and *Trichoderma*-enriched compost. Similarly, in Sikkim and Meghalaya, vermicompost and crop rotation with legumes have minimized soil-borne diseases.

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Conclusion

Organic farming provides a holistic approach to managing plant diseases without depending on synthetic chemicals. It focuses on prevention through soil health, crop diversity, biological control, and natural formulations.

This eco-friendly system not only safeguards crops from diseases but also enhances soil fertility, ensures food safety, and conserves the environment. For the farmers of Northeast India, where most follow traditional low-input systems, organic farming offers an ideal path toward sustainable and resilient agriculture.

Healthy soils lead to healthy crops—and healthy crops lead to a healthy future for both farmers and consumers.

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Natural Disease Management: Reviving Traditional Wisdom in Modern Farming

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INTRODUCTION

Natural farming is emerging as a holistic alternative to modern chemical-based agriculture. It emphasizes harmony with nature, soil regeneration, and self-sustaining crop ecosystems. Plant disease management under natural farming does not depend on synthetic fungicides or pesticides but instead strengthens plant immunity and ecosystem balance. Healthy soil, rich in microbial activity, forms the foundation of this approach. When the soil is alive, plants develop natural resilience against most pathogens. This ecological method integrates traditional wisdom and scientific understanding to build disease-resistant cropping systems, ensuring both sustainability and food safety.

Understanding Disease Management, the Natural Way

Plant diseases occur when the delicate balance among host, pathogen, and environment is disturbed. In natural farming, the goal is not to kill the pathogen but to restore this balance through ecological means. Instead of focusing on pesticides, the emphasis is on improving soil health, plant nutrition, and biological diversity. Healthy soil acts as a living ecosystem filled with beneficial microorganisms that outcompete harmful pathogens. These beneficial microbes suppress diseases naturally through competition, antibiosis, and improved nutrient cycling.

Key Principles of Natural Disease Management

1. **Soil Health First**: Healthy soil is the best defense against disease.

2. **Diversity for Stability:** Crop rotation and intercropping break disease cycles.

3. **Beneficial Microbes**: Microbial inoculants like *Trichoderma*, *Pseudomonas fluorescens*, and *Bacillus subtilis* protect roots and leaves.

4. **Zero External Inputs**: Local bioresources such as cow dung, urine, and plant extracts are used instead of chemicals.

Major Practices in Natural Disease Management

1. Beejamrit and Jeevamrit

These microbial formulations are central to natural farming.

- Beejamrit, a mix of cow dung, cow urine, lime, and soil, is used for seed treatment. It destroys seed-borne pathogens and promotes early vigor.
- Jeevamrit is a fermented liquid containing cow dung, cow urine, pulse flour, jaggery, and soil. It is applied to soil to enhance beneficial microbes and suppress harmful fungi.

These act as natural probiotics for the soil, improving fertility and immunity.

Fig. 1 Jivamrit and Beejamrit as the central framework to natural methods of disease management

2. Neem-Based Formulations

- Neem (Azadirachta indica) is an eco-friendly biofungicide and insect repellent. Common preparations include:
- Neem Seed Kernel Extract (5%)
- Neem Oil Spray (2–3%)

- Neem Leaf Decoction

Neem helps control fungal diseases like powdery mildew, rust, and leaf spots, while deterring vectors that spread viral diseases.

3. Use of Botanical Extracts

Local herbs are powerful tools for disease control:

- **Garlic-ginger extract** – antibacterial and antifungal
- **Chili-tobacco extract** – effective against sucking pests and viruses
- **Turmeric extract** – natural fungicide and antiseptic
- **Lantana and Datura extracts** – effective for foliar infections

Farmers often combine these in formulations like Agniastra or Brahmastra for broad-spectrum protection.

Fig.2 Key Botanicals as powerful tools of disease management, referred to as daskavya plants

4. Mulching and Soil Cover

Mulching prevents soil-borne infections by minimizing splash dispersal of fungal spores. Organic mulches—straw, leaves, and crop residues—maintain moisture, regulate temperature, and improve microbial activity.

5. Mixed Cropping and Crop Rotation

Natural farming promotes diversity-based cropping systems such as maize–cowpea or chilli–coriander combinations. Crop rotation with legumes enriches the soil and prevents pathogen build-up. This strategy reduces disease incidence naturally without chemical intervention.

6. Application of Beneficial Microorganisms

- *Trichoderma harzianum* suppresses *Fusarium* and *Rhizoctonia* infections.
- Pseudomonas fluorescens reduces bacterial wilt and blight.
- *Bacillus subtilis* prevents damping-off and leaf spot.

These can be mixed with compost or Jeevamrit for soil and foliar application.

Cultural and Mechanical Disease Management

1. Rogueing: Removing diseased plants prevents spread.

2. Proper Spacing: Improves air circulation and reduces humidity.

3. Timely Sowing: Avoiding periods of excessive rainfall or humidity minimizes fungal attacks.

4. Resistant Varieties: Using locally adapted, disease-tolerant varieties offers natural protection.

5. Clean Implements and Water Sources: Reduces contamination risk.

These traditional yet effective methods are key to successful natural farming.

Compost and Vermicompost: Nature's Immunity Boosters

Compost and vermicompost not only supply nutrients but also improve soil structure and microbial diversity. Compost tea—prepared by fermenting compost in water—serves as a foliar spray that strengthens plant immunity and suppresses leaf diseases.

Field Experience from Nagaland

In Longleng district of Nagaland, farmers have successfully managed tomato wilt and chilli dieback using *Trichoderma*-enriched compost and neem oil sprays. Combined with Jeevamrit and mixed cropping, these practices resulted in healthier crops and better yields—without the

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use of synthetic fungicides. Such examples demonstrate that natural disease management is both eco-friendly and economically viable.

Conclusion

Plant disease management in natural farming is rooted in ecological principles rather than chemical intervention. By focusing on soil health, biodiversity, and microbial balance, natural farming builds resilience in crops against pathogens. For the farmers of Northeast India—especially those in hilly and tribal regions—natural farming provides a sustainable and low-cost alternative that aligns perfectly with traditional organic practices. Healthy soil produces healthy plants, healthy plants sustain healthy people, and thus the cycle of nature remains unbroken.

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Oyster Mushroom Cultivation in Longleng, Nagaland: A Sustainable Livelihood Approach

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INTRODUCTION

Oyster mushroom (*Pleurotus* spp.) cultivation is rapidly gaining prominence as a sustainable, low-investment, and high-return agricultural enterprise, especially in regions with abundant organic waste and favourable climatic conditions. In the hill district of **Longleng**, located in the eastern part of **Nagaland**, the practice holds significant promise for improving rural livelihoods, enhancing nutritional security, and promoting circular agriculture by utilizing locally available agro-waste, particularly paddy straw. Longleng's subtropical climate, combined with its traditional jhum-based farming system, generates substantial volumes of crop residues that often go underutilized. With minimal land requirements, quick production cycles, and rising market demand, oyster mushroom farming offers a viable option for small and marginal farmers, women's self-help groups, and unemployed youth seeking alternative income sources. Moreover, the region's natural humidity and moderate temperatures are well-suited for seasonal and even semi-perennial mushroom cultivation with basic infrastructure.

This article provides a comprehensive technical guide to oyster mushroom cultivation tailored for Longleng's agro-ecological context. It includes information on species selection, substrate preparation, environmental management, pest and disease control, economic feasibility, and institutional support—aiming to bridge knowledge gaps and enable scalable adoption among local farmers.

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Agro-Climatic Suitability for Longleng

- **Temperature**: Oyster mushrooms prefer moderate temperatures ~ 20-30 °C for spawn run and fruiting
- **Humidity**: High relative humidity (70-90%) during fruiting is essential. Lower humidity leads to smaller fruit bodies; very high helps with size but also risk of contamination.
- **Seasonality**: In hilly areas (> ~900 m elevation) of Nagaland (likely similar to Longleng), best seasons are often spring to early autumn (March/April through September/October). However, with modifications (shade, humidity management), cultivation can be year-round.
- **Raw Materials**: Readily available agro-wastes such as paddy straw, possibly other straw or forest residues, are valuable substrates. In Longleng, after rice harvest under jhum, paddy straw is abundant and often burnt or left to degrade; using this as substrate adds value and reduces environmental harm.

Varieties / Species

Species / Variety	Color	Temp. Preference	Taste	Key Notes
P. ostreatus	Grey, white, light brown	Cool to moderate	Mild, slightly sweet	Most common variety, easy to grow
P. pulmonarius	White to tan	Warm	Mild, slightly sweet	Faster growth, heat-tolerant
***P. djamor* (Pink)**	Bright pink	Warm and humid	Strong, meaty, fishy raw	Striking color, short shelf life
***P. citrinopileatus* (Golden)**	Bright yellow	Warm	Nutty, cashew-like	Fragile but beautiful and flavorful
***P. eryngii* (King Oyster)**	Cream cap, thick white stem	Cool to moderate	Rich umami, meaty	Gourmet quality, large stem, long shelf life
P. sajor-caju	Grey-brown	Tropical to subtropical	Firm, savory	Popular in Asia, often confused with *P. pulmonarius*

Species / Variety	Color	Temp. Preference	Taste	Key Notes
P. tuber-regium	Grey to white	Tropical	Mild; edible tuber	Produces sclerotia (tuber-like structure)
P. cornucopiae	Pale yellow/golden	Moderate	Mild, pleasant	Funnel-shaped, less common
Blue Oyster (*P. ostreatus* var.)	Blue when young, grey later	Cool	Mild	Cold-tolerant, popular in winter grows
Black Pearl King (Hybrid)	Grey-brown, thick stem	Moderate	Meaty, rich	Hybrid between King Oyster and others
Snow Oyster	Pure white	Moderate to cool	Very mild	Delicate appearance, popular in gourmet dishes

P. ostreatus

P. pulmonarius

P. djamor

Blue Oyster (*P. ostreatus* var.)

***P. eryngii* (King Oyster)**

***P. citrinopileatus* (Golden)**

Production Technology

1. Substrate Selection and Preparation

Common substrates used in Longleng include:

- Paddy straw (most suitable and locally abundant)
- Maize stalks
- Banana leaves
- Sugarcane bagasse
- Sawdust (when mixed with other materials)

Steps:

1. **Collection and Chopping**: Cut the straw into small pieces (2–5 cm in length).
2. **Pasteurization**:
    - Soak the chopped straw in hot water at 65–70°C for 30–45 minutes.
    - Drain and allow to cool under shade until the moisture content reaches around 60–70%.
    - Proper moisture is essential — substrate should feel moist but no water should drip when squeezed by hand.
3. **Drying**: Spread the pasteurized substrate on a clean surface to drain excess water.

2. Spawn Procurement and Preparation

- **Spawn** is the seed material used for mushroom cultivation, containing fungal mycelium grown on sterilized grains (usually wheat or sorghum).
- Farmers should purchase high-quality spawn from certified laboratories or spawn production units.
- **Recommended spawn rate**: 4–5% of the wet substrate weight (approximately 200–250 g per 5 kg of wet straw).

3. Spawning and Bag Preparation

1. Use **transparent or perforated polythene bags** (standard size: 60 cm × 45 cm).

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2. Fill the bags in layers — alternate layers of pasteurized substrate and spawn.
3. Compress the material slightly to remove air gaps.
4. Tie the bag at the top and make 4–6 small holes (1 cm in diameter) around the sides for ventilation.

4. Incubation (Spawn Run Phase)

- Place the bags in a clean, dark room with a temperature of 22–28°C and humidity around 80–90%.
- Ensure the room is free from pests and contamination.
- Allow 12–18 days for full mycelial colonization of the substrate.
- Bags are ready for the next phase once they turn completely white due to mycelium growth.
- Remove and discard any bags showing signs of contamination (green mold, foul smell).

5. Fruiting Induction

1. Once colonization is complete, cut 4–6 horizontal slits (5–8 cm long) in the bags or open the mouth of the bag.
2. Shift the bags to a **fruiting chamber** or well-ventilated area.
3. Maintain the following conditions:
   - **Light**: 12 hours of indirect sunlight or artificial light.
   - **Humidity**: 85–90% (use misting or wet jute sacks for moisture).
   - **Temperature**: 20–28°C.
   - **Air circulation**: Ensure good ventilation to release carbon dioxide buildup.
4. Mist the bags lightly twice a day (morning and evening). Avoid excessive watering.

6. Harvesting

- Mushrooms are ready for harvest 3–5 days after pinhead formation.
- Harvest when the caps are fully expanded but not yet inverted.
- Gently twist or cut the mushrooms at the base to avoid damaging the growing media.

- Typically, 3–4 flushes (harvest cycles) can be obtained over 3–4 weeks.

7. Yield and Economics

- **Expected yield per bag**: 1.2–1.5 kg of fresh mushrooms (from approx. 1.5–2 kg dry substrate).
- **Biological efficiency**: 80–100% (1 kg dry straw yields up to 1 kg fresh mushroom).
- **Crop cycle**: ~30–40 days from spawning to last harvest.
- In pilot units in Longleng, a 50-bag unit yielded a net return of ₹12,000–₹15,000 with a benefit-cost ratio of 3.5:1 or higher.

8. Post-Harvest Handling

- **Shelf life**: 1–2 days at room temperature.
- **Storage**:
  - Refrigerate at 4–8°C to extend shelf life up to 5–7 days.
  - Drying mushrooms (under shade or using solar dryers) extends shelf life to 6 months.
- **Packaging**: Use perforated poly bags or paper bags for market sale.

Common Problems and Management

Problem	Cause	Management
Green mold (Trichoderma)	Poor hygiene, improper pasteurization	Use clean substrate; discard infected bags
Bacterial blotch	Excess humidity, poor air flow	Ensure ventilation; avoid overwatering
Insect pests (flies, beetles)	Unclean environment	Maintain hygiene; use nets and fly traps

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Best Practices for Longleng Region

- Use **locally available paddy straw** to reduce input costs and avoid burning of residues.
- Align production during **cooler dry months** for better results, or use shade net structures during summer.
- Encourage **group-based spawn production** through SHGs or FPOs for regular and low-cost supply.
- Promote **cluster-level mushroom houses** for training, demonstration, and collective marketing.
- Monitor environmental conditions and maintain hygiene for consistent production and reduced losses.

Steps for Implementation in Longleng

1. **Baseline survey**: Identify interested farmers; assess resources: access to straw, water, labour, shade / shelter.
2. **Training & capacity building**: On spawn preparation, cultivation, disease management, harvest, and post-harvest handling. ICAR Nagaland Centre has conducted such trainings in Longleng villages.
3. **Pilot units / demonstration plots**: Establish small units (say 50-100 bags) as demonstration for best practices.
4. **Spawn supply chain**: Either establish unit locally or partner with spawn labs elsewhere for regular supply.
5. **Infrastructure**: Mushroom house / cropping area with shade, shelter from rain, good ventilation. Tools: boiling drums, bags, sprayers, etc.
6. **Monitoring & record-keeping**: Track input costs (substrate, spawn, labour), yields per bag, losses, market price, so that farmers know what works and what doesn't.
7. **Marketing & value chain**: Identify markets early; local markets, hotels, possibly Kolkata or Guwahati, depending on transport. Value addition (drying, packaging) to extend shelf life.

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Policy & Institutional Support

- Government of Nagaland's Horticulture Department and ICAR bodies have shown support (training, spawn units, grants) for mushroom cultivation. Funds under schemes like MIDH (Mission for Integrated Development of Horticulture), NSRLM, and other agricultural/horticultural support programs could be tapped.

Conclusion

Oyster mushroom cultivation in Longleng is technically feasible, financially promising, and aligns well with local resources and socio-economic conditions. With good spawn, proper substrate preparation, environmental management, and market linkages, smallholder farmers can add a profitable enterprise. Scaling up will require concerted efforts in training, spawn availability, infrastructure and awareness.

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Beyond Urea: Smarter Ways to feed your Crops with Nitrogen

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INTRODUCTION

As the global agricultural sector grapples with soaring fertilizer prices and supply chain disruptions, one nutrient stands at the centre of the storm: **Nitrogen**. Traditionally delivered through urea—a fertilizer that provides a whopping 46% nitrogen—this essential element is now harder and costlier to come by. The urea crisis has prompted farmers, researchers, and policymakers to urgently explore **alternative nitrogen sources** that are sustainable, cost-effective, and locally available.

The Urea Conundrum

Urea has long been the go-to nitrogen fertilizer due to its high nitrogen content and affordability. However, recent geopolitical tensions, rising energy costs, and overdependence on imports have exposed the vulnerabilities of relying on a single source. In countries like India, where agriculture is the backbone of the economy, the crisis has triggered a wake-up call to diversify nitrogen inputs.

Organic Alternatives: Nature's Nitrogen bank

Organic sources not only supply nitrogen but also improve soil health and microbial activity. Here are some promising options:

- **Green manure**: Leguminous crops like *dhaincha*, *sunhemp*, and *clover* fix atmospheric nitrogen through symbiotic bacteria in their root nodules. When plowed back into the soil, they enrich it naturally.
- **Animal manure**: Cow dung, poultry litter, and pig manure are rich in nitrogen and other micronutrients. Proper composting enhances their nutrient availability and reduces pathogens.

- **Compost**: Decomposed plant and kitchen waste slowly release nitrogen and improve soil structure.
- **Blood Meal & Bone Meal**: By-products of the meat industry, these are high in nitrogen and phosphorus, respectively, and are especially useful in organic farming (Harvest Harmonics, 2022.)

Biofertilizers: Harnessing microbial power

Biofertilizers are living microorganisms that enhance nutrient availability. Key players include:

- **Rhizobium**: Used with leguminous crops to fix atmospheric nitrogen.
- **Azospirillum & Azotobacter**: Free-living nitrogen-fixing bacteria suitable for cereals and vegetables.
- **Blue-Green Algae (BGA)**: Common in paddy fields, BGA fixes nitrogen and improves soil fertility.

These are cost-effective, eco-friendly, and reduce the need for chemical inputs.

(Agrisearchindia.com., 2025)

Inorganic Alternatives

While organic options are ideal for long-term sustainability, some inorganic alternatives can bridge the gap in the short term:

- **Ammonium Sulphate & Calcium Ammonium Nitrate (CAN)**: These provide nitrogen with added benefits like sulphur and calcium.
- **Ammonium Phosphate Sulphate (APS)**: Promoted as a balanced alternative to DAP and urea, APS offers both nitrogen and phosphorus, reducing the need for multiple fertilizers (Vivek, 2025)
- **Controlled-Release Fertilizers**: These release nitrogen slowly, minimizing losses due to leaching and volatilization.

Innovative technologies on the horizon

Cutting-edge research is redefining nitrogen efficiency and sustainability.

➢ Nano-Urea

• Liquid formulations with nano-sized particles promise 40–50% higher use efficiency.

- Biochar-Enriched Fertilizers

  • Combines charcoal's adsorption capacity with nutrient release, locking nitrogen in the root zone.

- On-Farm Sensor Networks

  • Real-time soil N monitoring guides site-specific fertilizer application, cutting waste.

India's strategic shift

India is actively working to reduce its dependence on imported urea. Initiatives include:

- Promoting **nano urea**, a liquid formulation that delivers nitrogen more efficiently.
- Encouraging **balanced fertilization** through soil health cards and awareness campaigns.
- Supporting **indigenous production** of alternative fertilizers and bio-inputs.
- Encouraging **balanced fertilization** via soil health cards.

Policy, Practice and Farmer empowerment

Building a resilient nutritional strategy requires collaboration across sectors.

- <u>Extension Services & Soil Health cards</u>

  • Tailored recommendations prevent overuse of urea and encourage balanced fertilization.

- <u>Subsidy Reforms</u>

  • Shifting support from single nutrients to integrated packages can drive adoption of alternatives.

- <u>Farmer Cooperatives</u>

  • Group procurement of biofertilizers and organic inputs reduces costs and shares knowledge.

The Road ahead

The urea crisis, while challenging, presents an opportunity to rethink nitrogen management. A diversified approach—combining organic, biological, and innovative inorganic sources—can build resilience, reduce environmental harm, and ensure food security.

Farmers, agronomists, and policymakers must collaborate to scale up these alternatives, invest in research, and create incentives for sustainable practices. After all, the future of farming depends not just on what we grow, but how we nourish the soil that sustains us.

Here is a straightforward, farmer-friendly guide that speaks directly to cultivators, with practical tips, dos, and don'ts.

Farmer's Guide:

Nitrogen is the lifeblood of crops. But with urea becoming costly and scarce, farmers can't depend on it alone. The good news is—there are other ways to feed your soil and crops.

Organic Sources (Natural & Soil-Friendly)

✅ **What to do**

- Grow green manure crops like *sunhemp, dhaincha, or clover* before the main crop. They fix nitrogen naturally.
- Apply well-rotted farmyard manure (FYM) or compost to enrich soil and add nitrogen slowly.
- Use poultry litter or goat manure in small, controlled amounts—they are rich in nitrogen.
- Add oilseed cakes (neem, castor) for both nitrogen and pest control.

❌ **What not to do**

- Don't apply fresh dung directly—it can burn plants and spread pests.
- Don't overuse poultry litter—it may increase soil salinity.

Biofertilizers (Microbial helpers)

✅ **What to do**

- For pulses, treat seeds with Rhizobium culture before sowing.
- For cereals and vegetables, use Azotobacter or Azospirillum biofertilizers.
- In paddy fields, encourage blue-green algae (BGA) growth—it adds nitrogen naturally.

❌ **What not to do**

- Don’t expose biofertilizer packets to direct sunlight—they lose effectiveness.
- Don’t mix biofertilizers with chemical pesticides or fungicides.

Inorganic Alternatives (Quick Fixes)

✅ **What to do**

- Use ammonium sulphate or calcium ammonium nitrate (CAN) if urea is unavailable.
- Try ammonium phosphate sulphate (APS)—it gives both nitrogen and phosphorus.
- Explore nano urea sprays (liquid form)—they save cost and improve efficiency.

❌ **What not to do**

- Don’t apply all nitrogen at once—split doses give better results.
- Don’t ignore soil testing—wrong fertilizer can harm crops and waste money.

Smart Practices for all farmers

✅ **Do this**

- Follow soil health card recommendations for balanced fertilization.
- Rotate crops with legumes (like groundnut, pigeon pea) to naturally add nitrogen.
- Store fertilizers in a cool, dry place to avoid loss of quality.

❌ **Avoid this**

- Don’t depend only on urea—diversify your nitrogen sources.
- Don’t over-fertilize—excess nitrogen leads to weak plants and pest attacks.

Conclusion

The urea crisis is a catalyst to rethink nitrogen management. A mosaic of organic, biological, and innovative mineral sources creates a buffer against supply shocks, lowers environmental impact, and secures food production over the long term.

By combining organic amendments, microbial biofertilizers, innovative inorganic inputs, and precision farming, agriculture can reduce its overdependence on urea.

The future of farming lies in **diversification and efficiency** in feeding crops while nurturing the soil, ensuring resilience against future shocks, and safeguarding food security.

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Rehabilitation of Degraded Soils Using Sustainable Practices

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ABSTRACT

Soil degradation is one of the principal challenges to world food security and environmental sustainability due to erosion, nutrient loss, salinization, and overuse of chemicals. In India and much of the world, vast tracts of good agricultural lands have suffered loss of fertility and structural stability, negatively impacting agricultural production and environmental balance. Recovery of these degraded lands is essential in re-establishing their productivity and promoting long-term sustainability. This paper discusses sustainable methods of soil rehabilitation that involve the application of organic amendments (compost and vermicompost), conservation tillage, rotation of crops, agroforestry, biofertilizers, and integrated nutrient management. These methods improve the structure of the soil, add organic matter, enhance water holding capacity, and rejuvenate microbial diversity. The socio-economic advantages and disadvantages of sustainable soil regeneration are also discussed in the article. Balanced combinations of farmer training, policy support, and community involvement are required for effective adoption and sustainable effects of these practices.

Introduction

Soil degradation is an environmental and agricultural problem of major concern to the global food security and health of ecosystems. When soils are degraded, they lose their productive potential through processes such as erosion, salinity, nutrient depletion, pollution, and loss of organic matter. The FAO estimates that approximately 33% of the world's soils have been degraded to some extent. In India, land degradation covers around 120 million hectares, mainly as a result of inappropriate agriculture, deforestation, overgrazing, and industrial pollution.

Rehabilitating such soils is not only critical to enhancing agricultural productivity but also to promoting long-term environmental sustainability. Sustainable soil rehabilitation aims at restoring soil structure, fertility, and biodiversity using environmentally friendly and resource-

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conserving approaches. This paper discusses the causes of soil degradation, the concepts of sustainable soil rehabilitation, and several practices that restore soil health.

Causes of Soil Degradation

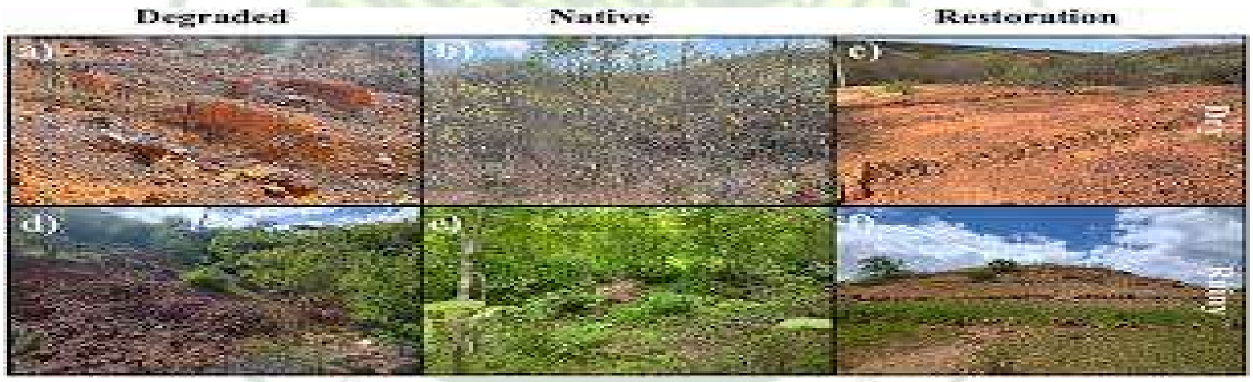
1. Soil Erosion: Topsoil, full of nutrients and organic content, is stripped away by water and wind erosion.

2. Chemical Degradation: Over application of fertilizers, pesticides, and industrial effluents causes acidification, salinization, and pollution of the soil.

3. Physical Degradation: Waterlogging and compaction lower the porosity of the soil and impair root development.

4. Biological Degradation: Disappearance of healthy soil organisms as a result of chemical application and absence of organic matter.

5. Nutrient Depletion: Ongoing cropping without replenishment of nutrients results in the depletion of necessary plant nutrients.



Source: https://www.nature.com/

Principles of Sustainable Soil Rehabilitation

Sustainable rehabilitation focuses on least environmental disturbance and sustained soil health. The key principles are:

- Restoring Organic Matter: Constructing soil carbon through composting, cover crops, and reduced tillage.
- Enhancing Biodiversity: Encouraging diversified microbial and faunal populations within the soil.

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- Improving Water Retention: Employing mulching and agroforestry to increase the soil's ability to retain water.
- Balancing Nutrients: Use of organic and bio-based inputs to recharge fertility.
- Preventing Excessive Use of Chemicals: Reducing synthetic inputs that negatively impact soil structure and biology.

Sustainable Practices for Soil Rehabilitation

1. Organic Amendments

Organic Amendments like Farmyard Manure (FYM), compost, green manures, and vermicompost are crucial for enhancing soil health. They raise the organic matter content, microbial activity, and structure of the soil. Such amendments enhance the availability of nutrients and water retention property of soils, and soils become more durable. Steady application of organic matter also restores the original fertility, buffering capacity, and long-term productivity of the soil, and sustains sustainable and environmentally friendly farming.

2. Cover Cropping and Crop Rotation

Are low-impact, soil-holding practices. Cover crops, including legumes, keep the soil from eroding, inhibit weed growth, and add nitrogen to the soil. Crop rotation breaks pest and disease cycles, increases nutrient cycling, and slows soil exhaustion. The two combined keep the soil structure, fertility, and diversity intact, ensuring long-term agricultural sustainability without exploiting soil resources excessively.

3. Agroforestry and Shelterbelts

Agroforestry and Shelterbelts entail the intercropping of trees with crops or pastures to improve soil stability and farm resistance. Rooting of trees stabilizes the soil against erosion, while leaf fall adds organic matter to enrich soil fertility. Shelterbelts serve as natural windbreaks and shield topsoil against wind erosion and conserve moisture, rendering them good methods of reclaiming degraded land and sustainable agriculture.

4. Reduced and Conservation Tillage

Conservation Tillage and Reduced Tillage refer to small soil disturbance to maintain soil health and structure. Less tillage means conservation of moisture, erosion reduction, and healthy soil microbes. It prevents soil compaction, organic carbon is maintained, and long-term soil fertility is sustained, so it is a good method of sustainable soil management as well as land reclamation of degraded lands.

6. Biofertilizers and Microbial Inoculants

Are the favorable microorganisms such as Rhizobium, Azotobacter, Phosphobacteria, and Mycorrhiza that promote nutrient availability and plant nutrient uptake? They minimize the use of chemical fertilizers, enhance soil fertility, and facilitate sustainable and environmentally friendly nutrient management in agriculture.

7. Integrated Nutrient Management (INM)

INM is an ecologically friendly method that integrates organic (manure, compost), inorganic (chemical fertilizers), and biological (biofertilizers) sources to supply balanced nutrient supply to crops. It enhances soil fertility, increases fertilizer application efficiency, and reduces loss of nutrients to the environment, encouraging long-term agricultural productivity and environmental sustainability.

8. Soil Reclamation Techniques

- Reclamation of sodic soils by gypsum application.
- Maintenance of drainage to waterlogged soils.
- Adjustment of pH by lime or sulfur based on the soil's alkalinity or acidity.

Socio-Economic and Environmental Benefits

- Increased Productivity: Better soil health translates to increased and better stable yields.
- Climate Resilience: Soils in good health sequester more carbon and enhance flood and drought resilience.
- Economic Empowerment: Locally accessible and cheap inputs minimize farmer reliance on costly chemicals.
- Biodiversity Conservation: Sustainable soils sustain a diverse array of organisms ranging from microbes to insects and plants.

Challenges and Way Forward

In spite of established advantages, large-scale adoption of sustainable soil rehabilitation is confronted with challenges such as:

- Limited awareness and technical know-how among farmers.
- High initial costs and labor inputs.
- Limited access to organic inputs and biofertilizers.
- Gaps in policies and weak incentives for conservation activities.

Way forward:

- Training and Extension: Education programs for farmers on sustainable practices.
- Policy Support: Subsidies and incentives for organic inputs, compost plants, and agroforestry.
- Research and Innovation: Development of region-specific soil rehabilitation packages.
- Public Participation: Community-led watershed and soil conservation efforts.

Conclusion

Rehabilitating degraded soils is not only an agricultural necessity but also an environmental and ethical responsibility. Sustainable practices such as organic amendments, conservation tillage, crop diversification, and biofertilizers use offer practical, eco-friendly, and economically viable solutions. Long-term soil health ensures food security, rural development, and ecological stability. Therefore, a holistic approach that includes farmers, policymakers, researchers, and communities is essential to revive our soils and secure our future.

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Role of Meal Sequence in Nutritional Health

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ABSTRACT

Recent advancements in nutritional science have introduced a nuanced perspective on not just *what* we eat, but *how* and *in what order* we consume our food. The concept of meal sequencing strategically eating fibre, protein, fats, and carbohydrates in a specific order has been increasingly explored for its potential to positively influence metabolic health. Drawing on current literature, this review investigates how food order impacts postprandial blood glucose levels, insulin response, satiety, digestion, and long-term metabolic outcomes. Clinical trials and observational studies consistently show that consuming fiber and protein before carbohydrates leads to more stable blood glucose levels, delayed gastric emptying, and increased satiety, which may be beneficial in the prevention and management of type 2 diabetes, obesity, and cardiovascular diseases. While the mechanisms remain under exploration, emerging evidence suggests that adopting strategic food sequencing may serve as a practical, low-cost intervention with significant public health implications. This paper synthesizes evidence from peer-reviewed research and expert opinions to assess whether food order matters and how it can be effectively integrated into modern dietary recommendations.

Keywords: Food sequencing, glycemic control, postprandial glucose, dietary strategy,

Introduction:

For decades, nutritional science has emphasized the importance of dietary composition focusing on macronutrient ratios, calorie intake, and nutrient density. However, an emerging body of research proposes a paradigm shift: the sequence in which we eat our food might be just as important as the food itself. This concept, known as meal sequencing, refers to the strategic order of consuming different food groups during a meal typically beginning with fiber-rich vegetables, followed by proteins and fats, and finishing with carbohydrates. Food sequencing is the practice of eating different food types in a specific order during a meal to

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help control blood sugar levels. The idea is to begin with low-glycemic index (GI) foods like non-starchy vegetables, nuts, legumes, whole grains, or proteins which slow down the absorption of carbohydrates consumed later. This results in a steadier rise in blood glucose rather than a rapid spike [1].

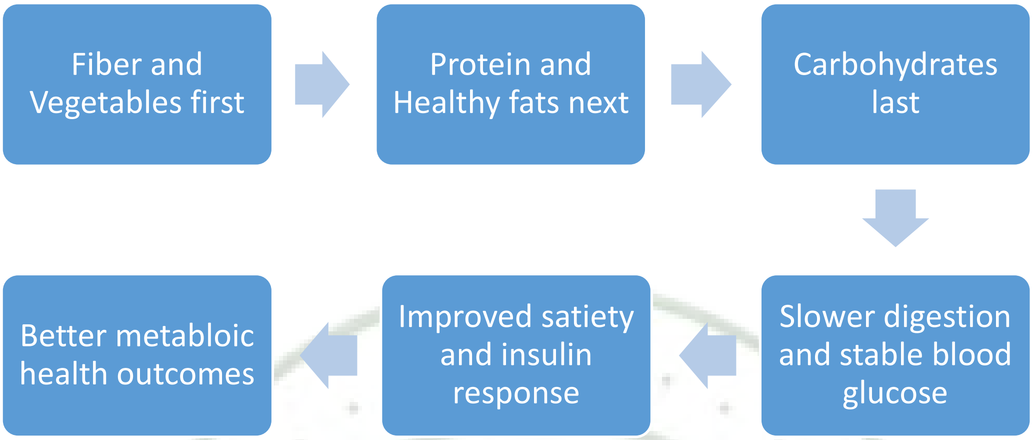

Fig. 1 [2]

The goal of meal sequencing is to modulate postprandial (after-meal) metabolic responses by influencing the rate of gastric emptying, nutrient absorption, and hormonal responses. When carbohydrates are consumed at the end of the meal rather than at the beginning, studies show a significant reduction in blood glucose spikes due to slower digestion and a more gradual release of glucose into the bloodstream. This method has shown promise not only for individuals with type 2 diabetes and insulin resistance but also for healthy individuals seeking to improve metabolic health, satiety, and energy balance.

Criteria for food sequencing:

The sequence in which we consume different food groups during a meal can have profound effects on metabolic health. Food sequencing are particularly consuming fiber, protein, and healthy fats before carbohydrates plays a critical role in maintaining blood glucose stability, supporting hormone regulation, enhancing nutrient absorption, and promoting satiety.

1. Improved Glucose Management: Starting meals with fibre-rich vegetables, then protein and fats, and finishing with carbs slows gastric emptying. This leads to a gradual release of glucose into the bloodstream, preventing sharp spikes and promoting a steady insulin response.

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2. Balanced Hormonal Response: Eating fibre, protein, and fat first boosts GLP-1 hormone secretion, which enhances insulin release, reduces glucagon, and further slows digestion. This supports better blood sugar control and prolongs satiety [3].

3. Better Nutrient Absorption & Gut Health: Fiber acts as a prebiotic, fuelling beneficial gut bacteria and forming a gel-like barrier that enhances nutrient absorption. This supports a healthy microbiome, digestion, and metabolic function.

4. Enhanced Satiety & Weight Control: Slower-digesting fibre, protein, and fat increase fullness hormones, helping reduce hunger and caloric intake. This prevents glucose crashes and supports energy balance and healthy weight maintenance [4].

Benefits of Food Sequencing

Food sequencing during a meal offers numerous health advantages, with both immediate and long-term benefits for metabolism, digestion, and overall well-being:

Benefits	**Description**
1. Enhanced Nutrient Absorption	Starting meals with fiber-rich vegetables or lean proteins improves nutrient absorption, ensuring maximum benefit from each meal.
2. Improved Energy Levels	Slower glucose release prevents energy crashes, maintaining steady focus and energy throughout the day.
3. Balanced Blood Sugar	Sequencing meals with fiber, protein, and healthy fats before carbs stabilizes blood sugar, reducing the risk of diabetes and insulin resistance.
4. Reduced Cravings	Stable blood sugar and efficient nutrient absorption curb cravings and control appetite, helping prevent overeating.
5. Reduced Bloating and Digestive Discomfort	Starting with fiber-rich foods promotes smoother digestion, reducing bloating and digestive discomfort.
6. Weight Management	Meal sequencing helps control portion sizes and reduce calorie intake by stabilizing hunger and blood sugar.

7. Hormonal Balance	Food sequencing supports the release of hormones like GLP-1 and PYY, promoting fullness and regulating metabolism.
8. Reduced Risk of Heart Disease	Regulating blood sugar and insulin reduces inflammation and improves lipid profiles, lowering heart disease risk.
9. Support for Gut Health	Fiber and healthy fats promote a healthy gut microbiome, improving digestion and immune function.
10. Long-term Metabolic Health	Consistent food sequencing reduces the risk of metabolic disorders, supporting fat-burning and muscle mass.
11. Improved Digestion and Gut Motility	Starting with fiber and proteins optimizes digestion, reducing discomfort and improving nutrient absorption.

Table No. 1 [4]

Scientific evidence to supporting meal sequencing

Numerous studies have demonstrated the benefits of meal sequencing:

A 2015 study published in Diabetes Care found that eating vegetables and protein before carbohydrates resulted in significantly lower post-meal glucose spikes (30-40% lower) compared to eating carbohydrates first. This highlights the impact of food order on blood sugar control.Research in the Journal of Clinical Endocrinology & Metabolism showed that meal sequencing improves the levels of satiety hormones like GLP-1 (glucagon-like peptide-1) and reduces ghrelin, the hormone that stimulates hunger. This means you feel fuller and more satisfied after your meal.A 2019 study in BMJ Open Diabetes Research & Care confirmed that eating vegetables before carbohydrates significantly improved postprandial glucose and insulin levels in people with type 2 diabetes [5].Further research supports the role of meal timing and sequence in weight management. A study published in Obesity (2022) indicated that consuming the majority of daily calories earlier in the day, combined with strategic meal sequencing, can aid in weight loss efforts [6].

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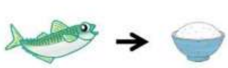
Secretion and Role of Glucagon- like Peptide-1 (GLP-1)

GLP-1 is a key incretin hormone released by intestinal L-cells in response to nutrient intake. It enhances glucose-dependent insulin secretion, suppresses glucagon release, and slows gastric emptying and help to control post-meal blood sugar levels. Due to these effects, GLP-1 is a major target in type 2 diabetes treatment. GLP-1 receptor agonists not only improve glycemic control but also aid weight loss by reducing appetite and food intake, offering significant benefits for individuals with obesity [8].

Impact of Preloading Protein and Fats Prior to Carbohydrate Ingestion on Postprandial Glycemia

Consumption of protein and fat before carbohydrates can significantly reduce post-meal blood sugar spikes by stimulating GLP-1, enhancing insulin secretion, and slowing gastric emptying. Studies show that preloading with 55 g of whey protein or 40 g of glutamine improves hormonal responses and lowers postprandial glucose in both diabetic and non-diabetic individuals. Fat preloads like 30 mL of olive oil also reduce glucose spikes by delaying gastric emptying, though they don't boost insulin like protein does.

Since high-dose preloads may not be practical, recent studies have explored more realistic options like eating boiled mackerel or grilled beef before rice which also showed improved glucose control, making food sequencing a feasible strategy for everyday diets [9].

		 PUFA	 SFA, MUFA
Incretin	GLP-1	↑↑	↑↑
	GIP	↑	↑↑
Gastric emptying		delayed	delayed
Postprandial glucose excursion		Improved	Improved

Fish and Meat Preloading Prior to Carbohydrate Intake: Preloading with fish or meat before carbs helps reduce post-meal glucose spikes by boosting GLP-1 and slowing gastric emptying. However, meat rich in saturated and monounsaturated fats also increases GIP secretion more than fish, which is higher in polyunsaturated fats. While GIP supports glucose control, it also

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promotes fat storage, suggesting that frequent meat preloads may contribute to weight gain over time [10].

Preloading Dietary Fiber Prior to Carbohydrate Intake

Consuming dietary fiber before carbohydrates has been shown to reduce post-meal glucose spikes and support metabolic health by slowing nutrient absorption and modulating the gut microbiota. Fiber increases gastric content viscosity, which may delay gastric emptying though some studies report no significant change in GLP-1 levels or emptying rate when vegetables are consumed first[12,13].Starting meals with vegetables consistently lowers glucose levels, especially when followed by protein and then carbohydrates. This suggests fiber may act through mechanisms different from protein or fat, and combining them could have additive effects.

Long-Term Effects of Preload-Based Dietary Strategies

Emerging evidence suggests meal sequencing can improve glycemic control and support weight management. In an 8-week study, individuals with type 2 diabetes who ate protein and fat before carbs saw significant reductions in HbA1c. Similarly, it was found that consuming vegetables before carbs improved HbA1c and reduced BMI.[14]

A recent national health initiative in Japan also showed that prediabetic individuals receiving meal sequencing guidance lost more weight than those following standard nutritional advice, highlighting its potential as an effective strategy for metabolic health [15].

Conclusion

Food sequencing, particularly the practice of consuming protein, fat, and fibre before carbohydrates, has demonstrated significant benefits in mitigating postprandial glucose spikes across various studies. These interventions engage distinct physiological mechanisms, including enhanced secretion of hormones like GLP-1, which helps regulate blood sugar and appetite. As a result, food sequencing has shown consistent positive effects on blood glucose control and weight management, offering a promising strategy for preventing and managing conditions like type 2 diabetes and obesity.These positive outcomes, the precise mechanisms underlying food sequencing remain largely unexplored. For example, it is still unclear why the timing of nutrient intake such as consuming protein or fat before carbohydrates affects GLP-1 secretion, while the reverse sequence does not produce the same effect. Additionally, the role of other hormones, such as cholecystokinin and glucagon, as well as the vagus nerve's influence

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on gastric emptying, requires further investigation to fully understand the complex interactions at play.

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Good Agricultural practices for foxtail millet to enhance farm income in tribal areas of Odisha

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ABSTRACT

Foxtail millet is a short-duration, climate-resilient crop well-suited to the hilly regions of Odisha. It is valued for its wide adaptability and multiple uses, serving as a staple food for the tribal community during the early part of the harvesting season. The crop responds well to good cultural practices, particularly water and organic nutrient management. Resource-use efficiency and productivity of rainfed upland ecosystems can be enhanced either through vertical intensification of foxtail millet with red gram as an intercrop or through horizontal expansion by including horse gram or green gram as sequential crops.

Key words: Hill agriculture, mixed cropping, organic nutrition

Introduction

Millets are small grained cereal crops gaining popularity for its nutritional food value and climate resilience. Among the millets, globally foxtail millet (*Setaria italica* L.) popularly called as Italian millet or German millet ranks second next to sorghum in-terms of production. It also known for its value as fodder crop, cover crop, green manure crop and weed suppressing crop. Grains of foxtail millet are rich in nutrients and each 100 g have crude fibre (8.0 g), protein (12.3 g), fat (4.3 g), minerals (3.3 g) and carbohydrates (60.0g). Foxtail millet is considered as useful for stabilization of degraded lands, reclamation of mine lands and steep slopes. It is a short duration (70-85 days) crop and known to produce substantial grain yield with limited water and nutrients. A seasonal rainfall of 400-500 mm is sufficient to realize the optimum yield. It can also grow well in the moderate rainfall areas with good drainage facility. The crop is suitable for growing in hill slopes, bottom and hill tops up to an altitude of 2000 m.

In India, foxtail millet is grouped under small millets and cultivated in Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu, Rajasthan, Madhya Pradesh, Uttar Pradesh, Odisha and several north eastern states. The crop is cultivated in an area of 0.87 lakh ha with production of 0.66 lakh tons of grains and average productivity of 762 kg/ha. Foxtail millet is locally known as *Kangu* or *Kangam* in Odisha and traditionally grown in North Eastern Ghat (Rayagada, Gajapati, Ganjam and Kandhamal), Eastern Ghat High lands (Koraput and Nabarangapur) and South Eastern Ghat (Malkangiri and parts of Koraput) agro-ecological regions. It is normally grown in hill top, slope and base, and also in marginal uplands during *kharif* season as a pure crop or mixed crop. Owing to the interventions from Odisha Millet Mission (OMM), the crop is also spreading to other agro-ecological regions like North Western Plateau and Western Undulation Zone of Odisha. *Kangu* rice is consumed by the tribal peoples as stable food like rice. Domestic consumption and market demand of foxtail millet is increasing for its food and medicinal value. The productivity of foxtail millet is far below the national average productivity. Appropriate varieties with recommended crop management practices can enhance the resource use efficiency, productivity and farm income of tribal farmers.

Causes of low adaptation and productivity of Foxtail millet in Odisha

- Foxtail millet is mostly grown in marginal soils under rainfed fragile ecosystem.
- In most of the growing region's crop is cultivated under hill tops, slopes and bottoms under mixed cropping
- Limited availability of farmer's friendly high yielding and locally improved varieties
- Limited availability of quality seeds.
- Poor crop establishment and crop yield under direct sowing.
- Lack of weed management practices at critical period of crop-weed competition.
- Lack of proper nutrient management practices.
- Lack of need based Integrated Pest Management practices.
- Limited knowledge on water management practices.
- Difficulties in processing of foxtail grains and low level of family consumption.
- Lack of awareness about the food, feed, nutritional and value added products.

- Non-availability of minimum support price and poor market linkage.

Good agricultural practices of organically grown foxtail millet

Foxtail millet is normally grown under marginal soil with limited use of external inputs. The crop performs better under organic management practices. There is great potential to enhance the productivity of foxtail millet in rainfed upland ecosystem of Odisha. Some of the good agricultural practices are described on this text.

(i) Growing season*:* Foxtail millet is normally cultivated during *kharif* season. First fortnight of June to first fortnight of July is the optimum sowing time. Frontline demonstrations conducted at farmers field under OMM revealed that it can also be grown during summer season with irrigation. Second fortnight of January to first fortnight of February is suitable sowing time for the summer crop. The crop can be well fitted in to rice-fallow in irrigated lands.

Varieties: Recommended varieties of foxtail millet as per the growing region, cropping system and consumer preference are presented in Table 1.

Table 1: Recommended varieties of foxtail millet for Odisha

Variety	Duration (days)	Average Yield (t/ha)	Special characters
High Yielding Varieties			
SiA 2644 (Sree Laxmi)	80-85	2.3 – 2.5	Suitable for late kharif, drought tolerant
SiA 326 (Prasad)	70-75	1.8-2.2	Wider adaptability
SiA 3085	80-85	2.0-3.0	Resistance to blast and downy mildew
SiA 3088 (Suryanandi)	70-75	2.0-2.5	Non-lodging, suitable for double cropping
PS 4	80-85	1.8-2.0	Wider adaptability
Locally Improved Varieties			
Dhala Kangu	80	Good yield	Biotic stress free, Good taste, long panicle
Lal Kangu	80	Good yield	Biotic stress free, Good taste, no grain shattering

Seed treatment: Seed treatment with bio-stimulants helps in better crop establishment and disease tolerance. Soak 1kg of foxtail millet seed in 200 ml of *Beejamruta* for 15 minutes and dry it under shade. Alternatively, prepare a solution by mixing 500 ml of cow urine in 2.5 litres of water, and dip the seeds for 30 minutes with a muslin cloth. Otherwise as a simple practice, treat the seeds with *Trichoderma harzianum* dust + *Pseudomonas fluorescence* @ 10 g each per kg seed.

Crop establishment: Direct seeding is common method of establishment. Demonstrations conducted at farmers' fields reflected that line sowing is better than the broadcasting of seeds. Field experiment conducted at ICAR-IIWM, Bhubaneswar research farm revealed that line transplanting of foxtail millet resulted in significantly higher grain yield as compared to direct seeding. During dry season, transplanting of seedlings is the better option.

Nursery for transplanted crop: Age and health of seedlings is one of the key yield enhancing factors in transplanted little millet. Community nursery for seedling production may be promoted to obtain healthy seedlings in time. The land having assured irrigation and drainage facilities may be selected for nursery. About 300-400 m^2 area is sufficient to produce seedlings for one-hectare area. Prepare raised seed bed of 1.2 m length × 4.5 m width × 0.1 m height. Add 2-3 baskets of FYM/cow dung per 10 m^2 nursery area. Seeds after mixing with sand in 1:2 ratio should be sown at shallow depth in rows 5-8 cm apart. After sowing, nursery beds are covered with a thin layer of well decomposed FYM/dry soil. Maintain soil moisture of nursery bed by sprinkling water at regular interval.

Seed rate: A seed rate of 8-10 kg/ha is ideal for line sowing whereas for broadcasting 12-15 kg/ha is required. For transplanting 5-6 kg/ha of seeds is sufficient to obtain seedlings for one ha area.

Crop geometry: For line sowing, 25 × 10 cm is ideal to achieve optimum plant population and crop yield. Thinning of excess seedlings and gap filling by using the thinned seedlings at 10-15 DAS during the first intercultural operation is advocated. For transplanting, transplant 10-15 days old seedlings @ 1-2 seedlings per hill at 5cm depth at a spacing of 25 cm × 10 cm.

Nutrient management: Integrated approach to meet the nutritional requirement of foxtail millet to obtain potential yield is advocated. Include horse gram or other short duration pulse crops in cropping sequence to enrich the soil health. Inter cropping of foxtail millet with redgram or cowpea during *kharif* season helps in better utilization of water and nutrients. Apply 5t/ha well decomposed FYM or 0.4 t/ha *Ghanajeebamruta* at the time of land preparation.

Spray 400 litres/ha of *Jeebamruta* to the soil just after first intercultural operation. Rest 100 litres/ha of *Jeebamruta* diluted with 500 litres of water may be sprayed in two splits at panicle initiation and flowering stage. Spraying of *Handikhata* @ 50 litres/ha after mixing with 500 litres of water in two splits (45-50 and 60-65 days of crop establishment) is advised. Foliar application of *Panchagavya* @ 3% at 20 DAS or DAT significantly increases crop yield.

Weed management: Experimental findings revealed that critical period of weed competition is 25-40 DAS. Weed competition results losses up to 63 and 27% of grains and straw, respectively. Manual weeding at 20 and 30 DAS is recommended for weed control. As an alternate use cycle weeder for intercultural operation twice at 20 DAS and 30 DAS in direct seeded crop is recommended. In transplanted field, run the cycle weeder twice at 15 DAT and 30 DAT.

Water management: Based on soil type and growing season, about 250-300 mm of water is required for foxtail millet varieties of 70-85 days duration. The crop is normally grown in rainfed condition during *kharif*. During the long dry spell, application of life saving irrigation at tillering and grain filling stage are beneficial to minimize the yield loss. The crop needs 2-3 irrigations during *rabi* and 3-4 irrigation during summer. Pre-sowing irrigation followed by irrigation at 20-25 DAS and 40-45 DAS are sufficient for *rabi* season. For summer crop pre-sowing irrigation followed by irrigations at 15, 35 and 55 DAS is ideal to obtain optimum yield. Irrigation scheduling by using soil moisture sensor is beneficial in enhancing water productivity and profitability. Maintain optimum soil moisture at critical growth stages like tillering, flowering and grain filling for higher water productivity, nutrient use efficiency and grain yield. Scheduling of irrigation at 50% depletion of available soil moisture resulted in higher grain yield and yield attributes.

Insect pest and disease management: Shoot fly is common insect pest attack foxtail millet from seedling stage and cause significant yield reduction. Spraying of Neem Seed Kernel Extract @ 5% controls the severity of insect attack. Among the diseases, blast, rust and mildew are common. Need based spraying of *Pseudomonas fluorescence* @ 0.3% twice at 10 days interval takes care of diseases.

***Harvesting and processing*:** Harvesting is done once the ear-heads are physiologically mature (Plate 1). The clean seeds should be sun dried to attain a safe moisture level of 12%. Seeds can be stored for longer period using gunny bags, nylon woven sacs or IRRI super bags.

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Plate 1:

Cropping system: Foxtail millet-based cropping systems have their own importance in tribal dominant regions (Plate 2). The crop is cultivated as a sole crop, inter crop, mixed crop and under different cropping sequence. Early harvest of foxtail millet by the end of September to early October permits to grow another short duration pulses like horse gram, green gram or cowpea. Cropping system approach helps in higher land and water use efficiency, higher farm income and reduces the dependence on external inputs (Table 2 and 3).

Plate 2: Foxtail millet based cropping system in hill slopes

Table 2. Promising foxtail millet-based cropping systems in Odisha

Sl No	Cropping Systems	Districts
Inter or mixed crops		
1	Foxtail millet + Redgram	Rayagada, Gajapati
2	Foxtail millet + Castor	Rayagada, Gajapati, Ganjam

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3	Foxtail millet + Blackgram	Rayagada
4	Foxtail millet + Cowpea	Rayagada
5	Foxtail millet+ Cowpea + Sesame + Sorghum + Redgram	Rayagada, Gajapati,Ganjam
Cropping sequences		
6	Foxtail millet-Horsegram	Rayagada, Ganjam, Gajapati, Nuapada
7	Foxtail millet-Greengram	Rayagada, Ganjam, Gajapati
8	Foxtail millet-Cowpea	Rayagada, Ganjam, Gajapati

Table 3: Foxtail millet-based cropping systems for higher land and water productivity (2023-24); Case study conducted at Gunupur, Rayagada, Odisha

Cropping System	Yield (*kharif*) Kg/ha	Yield (*rabi*) Kg/ha	FMEY Kg/ha	Land productivity (kg/ha/day)	LUI (%)	PWP Kg/m^3	EWP Rs/m^3
Foxtail millet-fallow	750	-	750	9.4	21.9	0.13	5.1
Foxtail millet-grengram	780	500	1665	10.3	43.8.	0.28	11.1
Foxtail millet-horsegram	780	400	1280	8.1	46.6	0.23	9.2

FMEY (Foxtail millet equivalent yield), LUI (Land utilization index), PWP (physical water productivity) and EWP (gross economic water productivity)

Economics: Under optimum level of management foxtail millet gives grain yield of 1.0 to 1.5 t/ha of grain and 2.0 to 3.0t/ha of stover. Survey conducted at farmer's field of several districts of Odisha estimated that farmers sold their surplus grains at local market and earns about Rs15, 000 to Rs 20000/ha as net profit. Inclusion of pulses like horse gram or greengram in the cropping sequence significantly enhances the farm income.

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Conclusions

Foxtail millet is short duration, low nutrient and water requiring, economically competitive, and environmentally friendly crop with wider adaptability. Grains of foxtail millet have high nutritional value and market demand. Availability of location specific farmer's friendly high yielding varieties, quality seed materials and suitable management practices and processing technologies will ensure the wide adoption. Favorable government policies like implementation of Odisha Millet Mission, minimum support price, and inclusion of foxtail millets in public distribution system may help in increasing area, production and consumption of little millet. The Foxtail millet-based cropping system will help to address the problem of malnutrition by taking care of soil and the environment.

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AP Fisheries in Turbulent Waters: "GST Cuts, Disease Outbreaks, and Global Tariff Challenges

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ABSTRACT

Andhra Pradesh is widely recognized as the frontline of India's fisheries sector, leading the country in both fish and shrimp producing more than 40% of the country's total fish and aquaculture output and significantly contributing to state and national economies. The fisheries industry produces over ₹80,000 crore, showing speedy growth from past years. Both the Fish and shrimp farming in the state contributes 7.6% of the state's Gross Value Addition and 22% of the agricultural Gross value addition. The aquaculture industry contribution to Andhra Pradesh's GDP was about ₹65,000 crore, or 3.8% of the state's GDP, in 2023.

Keywords: GVA, Tariffs, GDP, Exports, Products, Subsidy, GST.

Introduction:

India, the second-largest fish producer with more than 195 lakh tonnes of output in 2024–25. India is also one of the world's major shrimp exporters, with seafood exports reaching over ₹60,000 crore in 2023–24. The industry is a pillar of India's Blue Economy, registering appreciable contributions towards farmer revenues, rural livelihood, and foreign exchange earnings.

Andhra Pradesh is at the forefront of seafood exports in India with marine fishery product exports of about ₹19,420 crore every year.The state contributes 22% of the country's fish production and roughly 70% of shrimp production, one of the biggest export items.

High-density aquaculture and advanced technological advances, such as bio-floc technology and cage culture, have raised yields, particularly in shrimp culture.

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Andhra Pradesh aquaculture farmers are confronted with serious issues, namely disease outbreaks, massive export losses from foreign tariffs, high costs of inputs, environmental effects, and weaknesses in the sector's infrastructure

Disease Outbreaks and Economic Losses

Andhra Pradesh loses almost ₹4000 crore every year owing to diseases like EHP (*Enterocytozoan hepatopenaei)* and WSSV (White Spot Syndrome Virus) diseases.

These occur year in and year out, resulting in huge declines in productivity and making eradication all the more challenging due to their durability in pond ecosystems.

Mixed infections add even more financial losses, and disease control continues to be an ongoing, unresolved concern.

Currently the per capita fish consumption in India is 12-13kg annually where as the recommended is 20-30kg the government should also promote to increase per capita income within the state as well as other states.

Export and Trade Issues

The Trump government levied excessive reciprocal tariffs—up to approximately 59.7%—on Indian seafood items, with shrimp exports particularly affected. Such tariffs are a significant jump from earlier combined rates of some 8.56%, significantly degrading India's competitiveness in the US relative to others such as Ecuador that is subjected to much lower tariffs.

Key effects:

Heavy financial losses: Andhra Pradesh alone calculates losses to the tune of Rs 25,000 crore on account of the tariffs. As a whole, Indian seafood exports may lose close to Rs 24,000 crore in terms of trade value.

Loss of market share: US purchasers are stopping or slowing down purchases, and Indian exporters are finding it difficult to divert to other markets like the EU, Japan, China, Russia, and Southeast Asia.

Narrowing margins for exporters and farmers: Shrimp farmers in states such as Odisha and Andhra Pradesh are experiencing significantly diminished returns and risk of bankruptcy as export demand and prices decline.

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The industry, providing employment and state GDP on a huge scale, is demanding immediate government assistance in the form of tax breaks, improved cold storage facilities, and transport infrastructure.

High Input Costs and Market Fluctuations

Feed and seed prices have increased, while shrimp prices have dropped due to falling demand and export difficulties, squeezing farmer margins.

Some aquaculture communities declared crop holidays, citing the financial unsustainability of continuing operations, though not all farmers were able to do so due to long-term financial commitments.

Key Changes in GST Affecting Fisheries

The Indian Government has recently declared substantial GST cuts along the fisheries and agricultural value chain which will be effective from September 22, 2025, that are anticipated to reduce operating expenditure and enhance competition in the sector.

KEY GST REDUCTION

Item	Earlier GST	Current GST
Fish oils, extracts & preserved fish/shrimp	12%	5%
Diesel engines, pumps, aerators, sprinklers	12-18%	5%
Chemicals for pond preparation & water quality	18%	5%
Fishing gear, nets & rods	12%	5%
Seafood processing job work	12%	5%
Composting machines	18%	5%

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GST REFORMS TO BOOST FISHERIES GROWTH

Items	From	To
Fats & oils of fish	12%	5%
Extracts & juices of fish	12%	5%
Prepared/Preserved fish	12%	5%
Crustaceans & molluscs	12%	5%
Seafood processing	12%	5%
Diesel engines	12%	5%
Pumps & aerators	18%	5%
Irrigation & composting equipment	12%	5%
Tractor Tyres & Parts	18%	5%
Tractors	12%	5%
Sprinklers	12%	5%
Ammonia, Nitric & Sulphuric acid	18%	5%
Micronutrients & pond conditioners	12%	5%

Impacts on Fisheries Economics

Reduction of input and operating costs are likely to enhance the profitability of fish farmers and aquaculture enterprises, sustaining livelihoods for more than 3 crore individuals in the sector.

Reduction in GST improves the affordability of value-added seafood among domestic consumers and enhances India's competitiveness in international seafood markets.

India's fisheries sector, which yields almost 195 lakh tonnes every year and sends more than ₹60,000 crore worth of seafood overseas, is likely to witness growth in the foreign exchange earnings and rural incomes.

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The reforms are in favor of India's Blue Economy, where sustainability is encouraged by more affordable composting machines and green pond management.

Low-cost seafood for people

AP government's response towards aqua farmers:

Subsidy on electricity: Aqua farmers with farms up to 10 acres in notified areas are provided power at the concessional rate of Rs 1.50 per unit. This has helped more than 68,000 aqua service connections by way of subsidies worth more than Rs 4,095 crore since 2018.

Decline in prices of shrimp feed by Rs 9 per kg and proposals for subsidized electrical transformer supplies.

A suggested overall package by the Chief Minister comprises 240-day loan interest moratorium, interest subsidy, GST exemption on frozen shrimp, and establishment of a Rs 100 crore corpus fund for cold storage and market development.

Large-scale aquaculture development under the central PMMSY scheme, with an investment of approximately Rs 2,398 crore for schemes such as biofloc pond culture and recirculatory aquaculture system.

Steps for traceability certification of aqua products and more rigorous pollution checks.

Requests the central government for further financial assistance in terms of GST exemptions and opening of domestic markets.

Finance assistance schemes for fishermen and aqua families hit by export losses.

AP chief minister chandrababu took the occasion to promote seafood in the AP assembly, He said that very efficient protein rich fish or shrimp at least once a day.

He further discussed the idea of providing aqua food in schools and colleges once a week.

Conclusion

Andhra Pradesh plays a critical role in India's fisheries and aquaculture industry of state, as well as at the national level. The state remains to lead national shrimp production and seafood exports, making a material contribution to farmer revenue, rural growth, and foreign exchange. Meanwhile, the industry is facing structural frailties like the frequent outbreaks of disease, overseas trade impediments, increasing input prices, and extreme environmental issues.

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Recent lower GST, subsidies, and state reforms bring welcome relief in the form of reduced operating costs and enhanced competitiveness but do nothing to address more fundamental disease-level issues. The government is trying to increase per capita consumption, which helps trade within the country. New trading partners are prompting the state to increase its export production. Proper support from both the central and state governments helps farmers benefit.To sustain the fisheries sector better, disease management strategies should be used by using bio security measures and maintaining water quality and using recent technologies to detect the diseases at an earlier stage. With the right balance of innovation, government support and better farming practices, Andhra Pradesh can not only protect the livelihood of farmers but also strengthen India's position in the global market.

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The Oomycetes Menance: Taro *Phytopthora* Blight

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ABSTRACT

Taro (*Colocasia esculenta*), a vital tropical tuber crop, faces severe yield threats from leaf blight caused by the oomycete pathogen *Phytophthora colocasiae*. This disease, first reported in India in 1913, manifests as water-soaked lesions on leaves, petioles, and corms, leading to rapid tissue necrosis and crop collapse. The pathogen's life cycle involves motile zoospores, appressoria, and haustoria, enabling aggressive intercellular spread. Detection methods have evolved from morphological identification to PCR and nucleic acid hybridization, enhancing early diagnosis. Management strategies include resistant cultivars, bio-control agents like *Trichoderma viride* and *Pseudomonas fluorescens*. The article underscores the urgency of integrated disease management to curb the oomycete menace and safeguard taro cultivation in vulnerable regions.

Keyword: *Phytophthora colocasiae,* Taro leaf blight, Oomycete pathogen

Introduction

Taro (*Colocasia esculenta*), a vital tuber crop in tropical and subtropical agriculture, cultivated for its starchy corms and edible foliage, taro thrives in warm, humid environments with well-drained soils. However, its productivity is increasingly threatened by *Phytophthora* leaf blight, a devastating disease caused by *Phytophthora colocasiae*, an oomycete pathogen. Oomycetes, though morphologically like fungi, belong to the kingdom Stramenopila and are phylogenetically distinct, characterized by cellulose-rich cell walls and biflagellate zoospores. *Phytophthora* species exhibit coenocytic hyphae, lemon-shaped sporangia, and thick-walled oospores that facilitate both rapid infection and long-term survival. The disease manifests as water-soaked lesions on leaves, progresses swiftly to necrosis, crown rot, and corm decay under conducive conditions. Its polycyclic nature and dependence on high humidity and moderate

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temperatures make it a formidable challenge during monsoon seasons. Understanding the pathogen's life cycle, environmental triggers, and epidemiology is crucial for effective management. Diagnostic molecular tools like PCR, qPCR, and LAMP, enables early detection and resistance screening. Integrated disease management – combining cultural practices, fungicides, biocontrol agents, and resistant cultivars – offers a sustainable path forward.

Taro Crop Profile

Taro (*Colocasia esculenta*), a tropical root crop from the family Araceae, is widely cultivated for its starchy corms and nutritious leaves. Botanically, taro is a perennially grown herbaceous that propagates vegetatively through suckers or cormels. Varieties are broadly classified into eddoe types, suited for upland cultivation, and dasheen types, preferred in wetland systems. Taro thrives in warm, humid climates with loamy soils and a pH range of 5.5 to 7.0, and is adaptable to elevations up to 1500 meters. Nutritionally, taro is rich in carbohydrates, fiber, potassium, and vitamin C. Cultivation begins with healthy cormels planted at monsoon onset, spaced adequately to ensure canopy development. Mulching, timely irrigation, and balanced fertilization with farmyard manure and NPK are essential for optimal growth. Taro faces pest threats from aphids, mealybugs, and caterpillars, managed through neem-based biopesticides and integrated pest management. However, the most serious disease is Phytophthora leaf blight, caused by *Phytophthora colocasiae*, which can lead to severe yield losses under humid conditions. Management includes early planting, resistant varieties, and fungicidal sprays. Harvesting occurs 6-8 months after planting. Proper curing and storage reduce post-harvest losses. Research institutions such as ICAR-CTCRI continue to develop improved varieties and agro-techniques to boost productivity and farmer income.

Taxonomic Identity of Oomycetes

Oomycetes, often referred to as "water molds", are a distinct group of filamentous, fungus-like organisms that belong to the kingdom Stramenopila, phylum Oomycota. Despite their morphological resemblance to true fungi, oomycetes are phylogenetically closer to algae and possess several unique features that set them apart. Their cell walls are composed primarily of cellulose and β-glucans, unlike the chitin-rich walls of fungi. Oomycetes exhibit a diploid vegetative phase and reproduce both sexually and asexually. Asexual reproduction involves the formation of sporangia, which can either germinate directly or release biflagellate zoospores capable of swimming in water films. Sexual reproduction occurs through the fusion of oogonia and antheridia, resulting in thick-walled oospores that serve as durable survival

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structures. Taxonomically, oomycetes are classified under the class Oomycetes and order Peronosporales. Their unique biology, aquatic adaptations, and complex life cycles make them a critical focus in plant pathology and molecular diagnostics.

Phytophthora – Morphology and Reproductive Structure

Phytophthora colocasiae in taro, exhibit a unique morphology and reproductive strategy. The vegetative body consists of coenocytic, hyaline mycelium that grows both intercellularly and intracellularly within host tissues. Asexually, the pathogen produces sporangia that are typically ovoid to lemon-shaped, borne terminally or laterally on sympodially branched sporangiophores. These sporangia can germinate directly or release biflagellate zoospores under cool, moist conditions—an adaptation that facilitates rapid spread in waterlogged environments. Zoospores are motile, enabling them to locate and encyst on host surfaces before penetrating through natural openings or wounds. Sexual reproduction involves the formation of oogonia and amphigynous antheridia, which fuse to produce thick-walled oospores. These oospores serve as durable survival structures, allowing the pathogen to persist in soil or plant debris during unfavourable conditions. The dual reproductive modes—rapid asexual multiplication and resilient sexual structures—contribute to *Phytophthora*'s aggressive pathogenicity and its ability to cause recurrent epidemics in taro-growing regions.

Symptomology, Disease Progression and Disease Cycle

Phytophthora leaf blight in taro, caused by *Phytophthora colocasiae*, begins with the appearance of small, water-soaked lesions, which rapidly expands into irregular brown patches with yellow halos. Under humid conditions, these lesions coalesce, leading to widespread leaf necrosis, wilting, and eventual collapse of the foliage. In severe cases, the pathogen invades the petioles and crown, causing soft rot and compromising the entire plant structure. Disease advance is swift, especially during periods of high humidity and moderate temperatures (18–25°C), often resulting in complete crop failure within weeks if unmanaged.

The disease cycle is polycyclic, with multiple infection events occurring in a single season. The pathogen survives between cropping cycles as oospores or chlamydospores in infected plant debris and soil. Upon the onset of favourable environmental conditions, sporangia germinate to release motile, biflagellate zoospores that swim through water films to reach host surfaces. After encysting and penetrating through stomata or wounds, the pathogen colonizes host tissues, producing new sporangia that facilitate secondary spread via rain splash, irrigation, or mechanical contact.

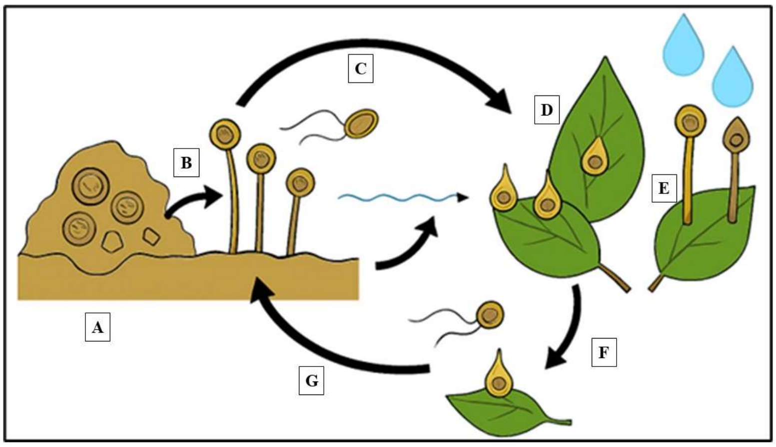

Figure: Life cycle of *Phytophthora colocasiae* A. Survival of conidia in soil debris, B. Germination of sporangia under favourable condition, C. Release of biflagellate zoospores swimming through water films, D. Encystment and penetration into host via stomata or wounds, E. Colonization of host tissue, F. Production of new sporangia and secondary spread through rain splash, irrigation, or mechanical means. G. Re-dispersal

Epidemiology and environmental influence on disease development

The epidemiology of *Phytophthora colocasiae*, is closely tied to environmental conditions that favours its rapid spread and infection cycles. The pathogen thrives in warm, humid climates with frequent rainfall and prolonged leaf wetness—conditions commonly observed during the monsoon season in taro-growing regions like eastern India. Optimal temperatures for disease development range between 18°C and 25°C, while relative humidity above 90% accelerates sporangia formation and zoospore release. Poor field drainage, waterlogging, and dense canopy cover further exacerbate disease severity by creating microclimates conducive to pathogen proliferation. Additionally, fluctuating weather patterns and climate variability have expanded the temporal and spatial window for disease outbreaks, making taro cultivation increasingly vulnerable. Understanding these epidemiological drivers is essential for developing predictive models and implementing timely, location-specific disease management strategies.

Diagnostic Technique and Molecular Characterisation

Diagnosing *Phytophthora colocasiae*, involves a combination of classical and molecular approaches to ensure accurate and timely detection. Field diagnosis typically begins with visual inspection of symptomatic leaves showing water-soaked lesions and necrosis, followed by isolation of the pathogen using selective media such as Carrot Agar and Potato Dextrose Agar.

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Microscopic examination reveals characteristic lemon-shaped sporangia and biflagellate zoospores, confirming the presence of *Phytophthora*. For precise identification and early detection, molecular techniques have become indispensable. Polymerase chain reaction (PCR) using genus-specific ITS primers allow amplification of pathogen DNA from infected tissues, while quantitative PCR (qPCR) enables pathogen load estimation and monitoring of disease progression. Advanced tools such as loop-mediated isothermal amplification (LAMP) offer rapid, field-deployable diagnostics. Together, these diagnostic and molecular tools provide a robust framework for surveillance, epidemiological studies, and integrated disease control in taro cultivation.

Integrated Disease Management

Integrated disease management (IDM) of *Phytophthora colocasiae*, requires a holistic approach to sustainably reduce disease incidence and severity. Cultural practices include early planting to escape peak infection periods, maintaining proper field drainage to prevent waterlogging, and removing infected plant debris to reduce inoculum load. Raised beds and wide spacing improves airflow and reduce leaf wetness, while mulching helps suppress secondary spread. Biocontrol agents such as *Trichoderma viride* and *Pseudomonas fluorescens* have shown promise in suppressing *Phytophthora* through antagonism and induced systemic resistance. Chemical control involves judicious use of fungicides like Metalaxyl, Mancozeb, applied preventively or at early symptom onset limits pathogen proliferation. Genetic resistance using tolerant varieties such as Muktakeshi and Jankhri offers long-term protection, especially when combined with molecular screening for resistance markers. By integrating these diverse tactics, IDM not only curbs disease outbreaks but also promotes ecological balance and economic viability for taro farmers.

Practices	**Recommendation**
Cultural	Plant taro on raised beds of 20-30 cm high to minimise standing water and a wider spacing of 1-1.5 m between plants and rows to improve air circulation, reduce humidity around foliage and limit rain splash.
Resistant cultivar	Use high-yielding hybrids developed by ICAR-CTRCI like Sree Kiran, Sree Rashmi and Sree Pallavi and improved cultivars like Muktakeshi and Jankhri,

Physical	Soak taro corms in hot water 48-50 °C for 20-30 mins before planting to kill surface pathogens followed by cooling them immediately in clean water to prevent damage.
Biological	Use of antagonistic microorganisms like *Trichoderma viride* and *Pseudomonas fluorescens* as soil drenches (50-100 ml/plant) and foliar sprays (0.5-1.0 kg/ha in 200-300 litre of water) induce resistance in taro plants.
Chemical	Metalaxyl or Metalaxyl-M (Ridomil Gold, Apron XL) when applied as foliar spray @ 2.5 – 5 g/L every 10-14 days during monsoon and treating of corms in 0.3% solution for 30 mins before planting reduce disease severity by 60-80%.

Conclusion

Phytophthora leaf blight poses a significant challenge to taro cultivation, especially in humid, rain-fed regions where environmental conditions favour rapid disease spread. The pathogen *Phytophthora colocasiae* exhibits a complex life cycle, that enable swift infection and long-term survival. Its polycyclic nature, combined with conducive conditions, leads to devastating epidemics and substantial yield losses. However, integrated disease management (IDM) offers a sustainable and effective solution. Continued research, farmer training, and access to clean planting material will be key to safeguarding taro as a climate-resilient, nutritionally valuable crop.

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Chinese Potato as a Source of Functional Foods

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ABSTRACT

The Chinese potato (*Plectranthus rotundifolius*), a lesser-known tuber native to Africa and widely cultivated in Asia, is emerging as a promising source of functional foods due to its rich nutritional profile and bioactive compounds. This article explores the potential of Chinese potato as a versatile ingredient in health-promoting diets, highlighting its unique properties and applications in modern food systems. Packed with dietary fiber, essential minerals like potassium and magnesium, and antioxidants such as polyphenols, Chinese potato offers benefits for gut health, blood sugar regulation, and cardiovascular wellness. Its low glycemic index makes it an ideal candidate for managing diabetes, while its prebiotic content supports a healthy microbiome. The tuber's adaptability in culinary applications—from gluten-free flours to nutrient-dense snacks—positions it as a sustainable alternative to conventional staples. Furthermore, its resilience to diverse growing conditions enhances its appeal for food security in changing climates. Recent research underscores its potential in combating malnutrition and lifestyle-related diseases, making it a valuable addition to functional food development. By integrating traditional knowledge with innovative processing techniques, Chinese potato can address global health challenges while meeting the growing demand for natural, nutrient-rich foods. This article delves into the science behind its bioactive components, practical applications in food industries, and its role in sustainable agriculture, advocating for greater recognition of this underutilized crop in promoting holistic health and wellness.

INTRODUCTION:

In an era where health-conscious eating and sustainable food systems are gaining momentum, the Chinese potato (*Plectranthus rotundifolius*), a humble yet nutrient-packed tuber, is stepping into the spotlight. Native to Africa and a staple in parts of Asia, this underutilized crop is poised to redefine functional foods—products that offer health benefits beyond basic nutrition. Unlike common tubers like potatoes or yams, Chinese potato boasts a unique composition, including high dietary fiber, essential minerals, and bioactive compounds like polyphenols, which contribute to improved digestion, heart health, and blood sugar control (Mukherjee et al., 2015). Its low glycemic index makes it a game-changer for managing chronic conditions like diabetes, while its prebiotic properties support a thriving gut microbiome, a cornerstone of overall wellness (Vimala & Nambisan, 2005).

Figure 1: Harvested chinese potato rich in nutritional and functional properties.

Beyond its nutritional prowess, Chinese potato is a culinary chameleon, easily transformed into gluten-free flours, snacks, or hearty dishes, making it a versatile ingredient for health-focused diets. Its resilience in diverse climates positions it as a key player in sustainable agriculture, offering a solution to food security challenges, especially in regions prone to malnutrition (Kana et al., 2012). As global demand for natural, nutrient-dense foods grows, this tuber's potential to bridge traditional knowledge with modern food innovation is undeniable. This article explores how Chinese potato can revolutionize diets, support sustainable farming, and contribute to global health, shining a light on a crop that deserves far more attention than it currently receives.

NUTRITIONAL BENEFITS

- **Rich in Essential Nutrients**: Chinese potato is packed with dietary fiber, potassium, magnesium, and iron, supporting muscle function, blood pressure regulation, and oxygen transport (Vimala & Nambisan, 2005).
- **Antioxidant Powerhouse**: Its polyphenol content helps combat oxidative stress, reducing the risk of chronic diseases like heart disease and cancer (Mukherjee et al., 2015).
- **Low Glycemic Index**: Ideal for managing diabetes, the tuber's low glycemic index ensures gradual blood sugar release, promoting stable energy levels.
- **Prebiotic Properties**: The high fiber content acts as a prebiotic, fostering a healthy gut microbiome, which is crucial for digestion and overall wellness.

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Figure 1: Nutritional Benefit of Chinese Potato

Table 1: Nutritional Composition of Chinese Potato

Nutrient	Unit	Quantity (Range)	% Recommended Daily Allowance (RDA) from 100g*
Energy	kcal	83-94	4%
Carbohydrates	g	19.0-23.3	16%
Protein	g	0.84-1.7	2-3%
Fat	g	0.05-0.48	1%
Dietary Fiber	g	0.30-0.50	-
Starch	g	17.3-19.0	-
Vitamin C (Ascorbic Acid)	mg	10-12	11-13%
Calcium	mg	76.1-86.7	14%
Magnesium	mg	56-62	14-19%
Iron	mg	1.43-1.69	7-8%
Potassium	mg	109-110	10-13%
Phosphorus	mg	91.5-102.8	-
Manganese	mg	0.52-0.60	24-31%
Zinc	mg	0.98-1.1	-
Copper	mg	0.08-0.09	-

CULINARY VERSATILITY

- **Adaptable to Diverse Dishes**: Its mild, nutty flavor and starchy texture make it suitable for boiling, roasting, mashing, or incorporating into soups and stews across African and Asian cuisines.
- **Gluten-Free Innovation**: Chinese potato can be processed into gluten-free flours, catering to the growing demand for allergen-free baking products.
- **Modern Food Applications**: Food industries are transforming it into nutrient-dense snacks like chips, noodles, and fermented products, appealing to health-conscious consumers.
- **Cultural Relevance**: Its use in traditional recipes ensures accessibility, while its adaptability supports innovative products for global markets.

SUSTAINABILITY AND FOOD SECURITY

- **Resilient Crop**: Chinese potato thrives in marginal soils and diverse climates, requiring minimal fertilizers and pesticides, making it a sustainable choice for farmers (Kana et al., 2012).
- **High Yield Potential**: Its ability to produce substantial yields in challenging conditions supports food security, particularly in rural and developing regions.
- **Combating Malnutrition**: The tuber's nutrient density makes it a valuable tool for addressing malnutrition, especially in areas reliant on less diverse staple crops.
- **Diversifying Food Systems**: Promoting Chinese potato reduces dependence on conventional crops like rice and wheat, enhancing agricultural resilience against climate change.

FUNCTIONAL FOOD APPLICATIONS

- **Health-Promoting Products**: Its bioactive compounds, like polyphenols and fiber, are ideal for developing low-glycemic snacks, prebiotic beverages, and fortified baked goods.

Targeting Lifestyle Diseases: Research highlights its potential in preventing diabetes, heart disease, and digestive disorders, aligning with functional food trends (Mukherjee et al., 2015).

- **Innovative Processing**: Techniques like extrusion and fermentation are unlocking new ways to incorporate Chinese potato into health-focused food products.
- **Market Potential**: As demand for natural, nutrient-rich foods grows, Chinese potato offers a scalable solution for food industries aiming to meet consumer needs.

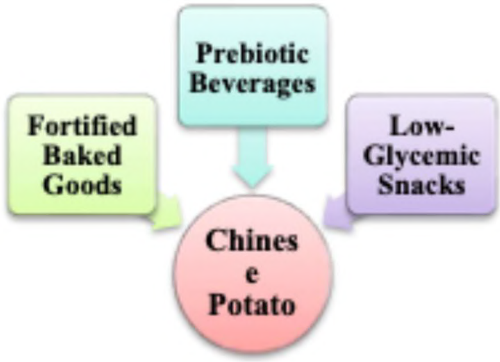

Figure 2: food Potential Applications of Chinese Potato

CHALLENGES AND OPPORTUNITIES

- **Limited Awareness**: Despite its benefits, Chinese potato remains underutilized due to low consumer familiarity and limited marketing efforts.
- **Processing Barriers**: Scaling up production requires investment in processing technologies to create value-added products like flours and snacks.
- **Research Gaps**: More studies are needed to fully explore its bioactive potential and optimize cultivation practices for diverse regions.
- **Future Directions**: Collaboration between researchers, farmers, and food industries can boost awareness, improve supply chains, and integrate Chinese potato into mainstream diets.

CONCLUSION

The Chinese potato is a nutritional and agricultural marvel, poised to make a significant impact as a functional food. Its rich nutrient profile, culinary flexibility, and sustainability make it a vital tool for addressing global health and food security challenges. By investing in research, processing, and consumer education, this underutilized tuber can become a cornerstone of healthier, more resilient food systems, benefiting both people and the planet.

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Therapeutic Efficacy of Mushrooms

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INTRODUCTION

Bioactive substances such lectins, β-glucans, polysaccharides, terpenoids, and phenolic acids are abundant in medicinal mushrooms and provide a number of health advantages that can greatly improve one's quality of life. Many types of mushrooms are known to have therapeutic qualities. For instance, *G. lucidum*, *L. edodes* (shiitake), and *G. frondosa* (maitake) are frequently utilized for therapeutic reasons in various parts of Asia, and are frequently referred to as the "king of medicinal mushrooms" (Zhou *et al*., 2023). *In vitro* studies, *in vivo* experiments, and human clinical trials have demonstrated that fresh edible mushrooms and mushroom extracts offer a wide variety of medicinal benefits, which are further discussed below.

Anti-Inflammation Property

By removing dangerous cells, inflammation serves as a defensive mechanism that increases blood flow to the region of tissue infection and aids in the healing process. But inflammation also causes cells to be destroyed, which is essential for healing. Because of certain characteristics, mushrooms can directly reduce inflammation. Because unsaturated fatty acids are precursors of eicosanoids that balance inflammatory and anti-inflammatory processes, their lipids, which are high in these fatty acids, have anti-inflammatory properties. Polysaccharides are abundant in mushroom taxa including *Agaricus* sp., *Pleurotus* sp., and *Termitomyces* sp. They also produce biomolecules that are essential for defending joints against inflammatory processes. The nucleoside chemical cordycepin, which is found in the mushroom variety *Cordyceps* spp., was studied. It is an anti-inflammatory cytokine compound that increases the production of interleukin 10(Sharifi-Rad *et al*., 2020).

Healing Property

Four phases of healing are distinguished: hemostasis, which involves blood coagulation; inflammation; proliferation, which involves tissue growth; and maturation, which includes tissue remodeling. The process of healing is intricate and includes a number of biological processes, including growth factors, cytokine release, and stimulation of epithelial cells. Various wound-treating processes, including growth factor release, cytokine production, and epithelial cell stimulation, were demonstrated by the extract and metabolites from varieties such as *G. lucidum* and *A. blazei* (polysaccharides). Common *A. bisporus* mushrooms were used to extract chitinous polymers using simple techniques, which were then converted into continuous fibers using a specially made laboratory-scale fiber-spinning machine.

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The resulting spun fibers are made up of a variety of chitin fibers encased in a glucan matrix, and their fiber sizes are carefully controlled by the requirements related to needle gauges. All of the mushroom chitin fibers showed signs of self-healing after 30 seconds of contact with a modest volume of water (less than 10 µL). In research on *G. luciderma* in rats, the polysaccharide fraction produced peptic ulcers for the animals to heal, while indomethacin caused lesions on the stomach mucosa (Chopra *et al*. 2021).

Enhancing Gut Microflora

Prebiotics such as polyphenols, oligosaccharides, and fibers found in mushrooms are important because they boost the metabolic activity of the gut microbiota. Pathogens cannot digest the polysaccharides and peptides found in the fungus *G. lucidum*, which stops them from multiplying and changes the gut flora. By inhibiting the growth of harmful bacteria in the gastrointestinal system and promoting the growth of advantageous probiotic bacteria, these indigestible polysaccharides from mushrooms have a prebiotic function. Among the most commonly reported edible mushrooms that are known to alter gut flora include *G. lucidum, H. erinaceus, L. edodes*, and *G. frondose* (Chugh *et al*. 2022).

Anticancer Properties

The World Health Organization (WHO) estimates that cancer kills over 10 million people each year. Studies have shown that polysaccharides from mushrooms can slow the growth of tumors by boosting the immune system, especially by influencing natural killer (NK) cells and macrophages through T-cell activation and cytokine release. By enhancing the immune response and influencing natural killer cells and macrophages through T-cell activation and cytokine release, polysaccharides found in mushrooms can slow the growth of tumors. Interestingly, around 200 edible mushroom species showed the ability to inhibit the growth of different types of cancer cells. Certain chemicals with anticancer activity have been discovered in several mushroom species. For example, ganoderiol F and ganodermanontriol in *G. lucidum* and galactoxyloglucan in *H. erinaceous* have demonstrated potential in the fight against cancer, while *A. bisporus* includes quinone 490 and 1-oleoyl-2-linoleoyl-3-palmitoyl glycerol.

According to studies, hispolon, an active polyphenol molecule, has strong antitumor effects via a variety of pathways, such as the downregulation of antiapoptotic proteins including c-FLIP, Bcl-2, and Bcl-xL and the activation of death receptors. Hispolon is a potential option for cancer treatment as it also increases the efficacy of chemotherapy drugs. Additionally, several polysaccharides found in *G. lucidum* help to lessen the symptoms of colorectal cancer by lowering the expression of genes linked to rectal cancer. By actively regulating the host immune system and gut microbiota, these polysaccharides also exhibit cancer-preventive and therapeutic effects. A recent *in vivo* investigation shown that a recently discovered acid-soluble polysaccharide isolated from *G. frondosa* protected the thymic and splenic tissues of tumor-bearing mice while also preventing the growth of H22 solid tumors (Li *et al*. 2024).

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Antioxidant Properties

Damage to DNA, proteins, and cell membranes caused by oxidative stress can result in a number of serious illnesses, including renal disease, diabetes, cancers, and neurological disorders. By activating enzymes that eliminate free radicals and lessen oxidative stress, polysaccharopeptides, which are present in mushrooms, might enhance general fitness. Leucine, isoleucine, valine, methionine, proline, alanine, and other hydrophobic amino acids (HAAs) are among the many antioxidant compounds found in mushrooms, along with ergothioneine, ergosterol, carotenoids, phenolics, tocopherols (vitamin E), ascorbic acid (vitamin C), and polysaccharides (acidic polysaccharides).

According to a research, *P. ostreatus*'s enhanced antioxidant qualities may be due to its carbohydrate component, notably β-glucan. Additionally, *P. ostreatus* mushrooms offer a multitude of antioxidants in the food industry, especially when used as food additives. The ability of *A. bisporus* polysaccharide extracts to scavenge free radicals was assessed using an antioxidant test. The extract's free radical scavenging activity at 250 µg/mL was 86.1%, significantly higher ($p < 0.01$) than that of BHT (83%). Consuming mushrooms may thereby improve a person's antioxidative ability and lessen oxidative stress in the body (Zhou *et al*., 2023).

Antidiabetic Properties

Antidiabetic chemicals found in different types of mushrooms usually have the following effects: (1) preventing the death of β cells and encouraging their regeneration; (2) controlling the metabolism of glucose; (3) suppressing oxidation and inflammation; and (4) improving the gut flora. A study on *G. lucidum*'s polysaccharide compounds showed that they effectively reverse the progression of diabetes and lower insulin resistance without endangering pancreatic islet cells. By regulating the expression of glycogen synthase kinase (GSK-3β), glycogen synthase (GS), and glucose transporter 4 (GLUT4), mushroom extracts from *A. bisporus, G. frondosa, H. erinaceus, G. lucidum*, and *Pleurotus* species lower blood glucose levels in the liver and muscle. *G. frondosa* has also been recognized for its function in controlling blood sugar levels (Nagulwar *et al*. 2020).

Antimicrobial Property

The presence of β-D glucan gives the mushroom species *P. ostreatus* its antibacterial qualities, making it a therapeutic mushroom. It contains a number of antimicrobial substances that are advantageous in this and other varieties, including flavonoids, phenolic compounds, and phenolic acids. The antibacterial efficacy of ethanol extracts from two types of mushrooms, *L. edodes* and *A. bisporus*, against *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Enterococcus faecalis*, and *Acinetobacter baumannii* was evaluated. Bacterial cell death was seen after exposure to extracts from *L. edodes* and *A. bisporus*. This was caused by an increase in protein and DNA levels in the surrounding environment, which was a sign that the bacteria cells were deforming in reaction to the extracts.

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Studies on *P. ostreatus* demonstrated antibacterial activity against *Penicillium rapiricol*, *Myrothecium arachidicola*, and *Fusarium oxysporum*. Furthermore, *Lenzites betulina* has exhibited antibacterial activity against *S. aureus*, *E. coli*, *B. subtilis*, *Fusarium graminearum*, *Gibberella zeae*, and *Cercosporella albo maculans*, whereas *A. bisporus* has shown antibacterial qualities against *Neurospora sitophila* (Kaur *et al*. 2022).

Conclusions

Food insecurity, poverty, and hunger are serious problems in both developing and poor nations. One step in addressing these dietary difficulties is the use and production of highly functional foods, such as mushrooms, which are rich in nutrients and bioactive chemicals and provide protection against a variety of diseases. These foods also have therapeutic and preventative advantages against a wide range of disorders. Because of their bioactive components, mushrooms may be consumed in a variety of ways, including food, medication, and nutraceuticals. By supplying vital macro- and micronutrients as well as bioactive chemicals that are absent from ordinary meals, mushrooms increase our daily nutritional intake.

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FLEATHER – TRANSFORMING REPURPOSED FLOWERS INTO VEGAN LEATHER

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ABSTRACT

Fleather is an innovative, sustainable alternative to traditional leather made from repurposed flowers, particularly temple waste flowers, which are often discarded in large quantities. This eco-friendly material addresses both environmental and ethical concerns associated with conventional leather production, which involves animal cruelty and pollution from toxic chemicals used in the tanning process. By utilizing flower waste that would otherwise contribute to pollution, Fleather offers a circular solution that reduces landfill burden and promotes resource efficiency. The process of creating Fleather involves collecting discarded flowers, primarily marigolds and roses, from temples and processing them into a biodegradable material with leather-like properties. Through microbial fermentation and natural binding agents, the flowers are transformed into a flexible, durable, and aesthetically pleasing fabric that can be used in fashion, accessories, and upholstery. Fleather boasts characteristics such as breathability, water resistance, and the ability to be dyed, making it a versatile alternative to animal leather. Fleather represents a pioneering approach to material innovation by transforming waste into a valuable resource, combining sustainability with functionality, and offering an ethical alternative to traditional leather.

Keywords: Fleather, Flowers, Leather, Sustainability, Vegan.

Introduction:

Leather refers to any fabric that is crafted from the hides or skins of various animals. Leather is a versatile and timeless a strong, flexible and durable material that has been used for centuries to create beautiful products, from shoes to handbags to furniture. The manufacturing of leather involves the use of a wide range of chemicals that can have a negative impact on the environment. Leather industry is among the top ten foreign exchange earners in the country. The Percentage involves Indian cattle and buffalo (20%) goat & sheep population (11%). Majority of exports, with April-June 2023-24 exports valued at US$ 511.44 million. Effect of animal leather on environment are high water consumption, usage of toxic chemicals, release of poisonous gases and health risk for workers. On average, a pair of leather loafers uses 7,612

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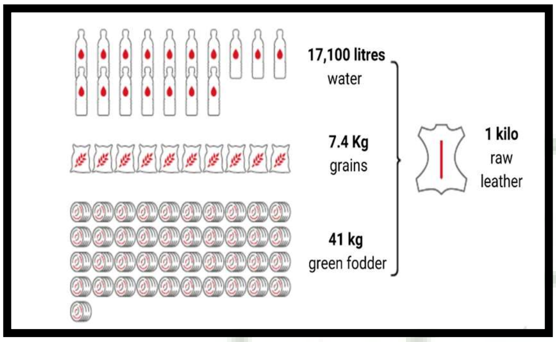

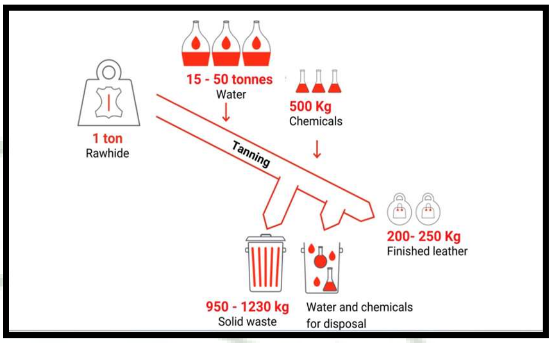

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Synthetic Leather is mainly a material made from plastic or polythene and petroleum derivatives. It is a combination of fabrics and resin polymer, solvent after complicated production process.

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Manufactured from mycelium, the branching structure of threads that makes up fungus colonies, and out of which mushrooms grow. Various fungal species, including those from the *Agaricus, Fomes, Ganoderma*, *Phellinus* and *Pleutorus genera*, are currently being investigated for their potential in this area.

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The accumulation of floral waste in the Ganges River poses a significant environmental challenge, leading to water contamination and air pollution. The sacred nature of temple flowers necessitates an alternative approach to their disposal, prompting the exploration of innovative solutions. A leather made out of a flower is called as fleather. It is a chance discovery on a humid day in 2018, Nachiket Kuntla, head of research and development at

Phool, and other scientists at the company noticed a whitish layer on a pile of waste flowers on the factory floor. When they peered closer, they saw a thin fibrous network. "Someone in the team felt that the touch is leathery", Then they started experimenting on producing leather from flowers which is a fleather.

Development Process and Material Properties

Phool workers collect waste flowers discarded after being offered to the deities at one of Kanpur's biggest temples situated on the bank of the Ganges and seemed some kind of fungal microorganism was trying to grow on the flowers, drawing nutrition from the cellulose in them. They sourced microorganisms from the jungle near the IIT Kanpur campus and fed the flower waste to different microbial strains, tweaking the temperature and humidity to see how it would grow under controlled conditions in a laboratory. Their initial experiments resulted in a thick styrofoam-type material that could be used in packaging. But the researchers soon realized that the texture of the microbial growth felt oddly familiar.

They continued the experiment by couple of other microbes. The researchers began feeding them in liquid form, by boiling the flower petals in water to extract the cellulose and lignin from them and adding some extra carbohydrates. The microorganism feeds on that, and it grows. It produces molecules that are similar to the molecules in leather. This was the beginning of Fleather, which Phool began producing in 2021. To make the material, the team begins with small volumes of the microbes in flasks in an incubator which are gradually grown larger by feeding them on the nutrient-rich flower liquid. *Bacillus subtilis, Aspergillus parasiticus, Aspergillus flavus* and *Aspergillus oryzae* are either utilized alone or in combinations. Using microbes to grow biological fabrics.

This biological alternative to leather is made from cellulose nanofibrils spun by bacteria and yeast. Once the free-flowing liquid turns into a thick slurry, indicating that the microbe has attained maturity. The mixture is poured in trays to nudge the fibrous growth to take the form of a continuous sheet. The tray is then rested for a few days during which an interconnected layer that resembles the rind on a brie cheese takes shape. It is then tanned using a tree-bark powder solution, dried, dyed and embossed with a snake or crocodile pattern. The end result is a soft, supple sheet that feels incredibly similar to animal hide leather. So far Phool has been able to make several Fleather prototypes – wallets, sling bags, sandals and trainers – which, at first glance at least, look quite satisfactory.

Material Properties

- Charlotte Borst and Saatchi Doshi of Fashion for Good, an Amsterdam-based global initiative working on sustainable fashion, They said "Fleather is not only 100% biodegradable, it is also more breathable than other alternatives
- Enhancement Strategies like ongoing efforts to increase the fiber density and tensile strength of Fleather to expand its applicability to various products.

Scalability and Performance Enhancement

- An average of 73 kg (161 pounds) of flower waste to create one square metre of Fleather. Phool, which was part of Fashion For Good's innovation programme in 2020, claims that Fleather decomposes entirely in about 90 days when buried in soil.
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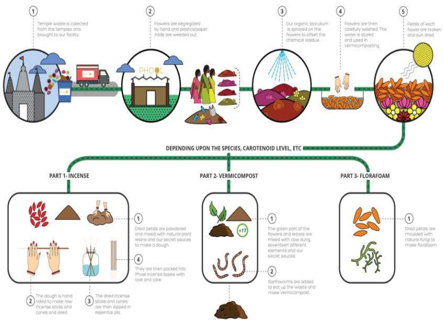
Nachiket Kuntia, head of research and development at Phool, holds up a finished sheet of Fleather, which resembles delicate lamb skin leather (Credit: Sushmita Pathak)



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Showcasing the attention and interest garnered by Fleather from global entities, signaling its potential to disrupt the traditional leather industry. Emphasizing the transformative potential of Fleather in driving environmental and social impact, paving the way for sustainable and ethical fashion practices.

Conclusion:

Fleather represents a groundbreaking advancement in sustainable materials, transforming waste flowers into a viable alternative to traditional leather. By repurposing discarded temple flowers, Fleather not only addresses the environmental impact of leather production but also provides a solution to floral waste pollution. Its production process is eco-friendly and cruelty-free, aligning with the growing global demand for ethical and sustainable products. Fleather offers durability, versatility, and aesthetic appeal, making it suitable for use in various industries, particularly fashion. As a symbol of innovation and sustainability, Fleather holds immense potential to revolutionize the leather industry and contribute to a more sustainable future.

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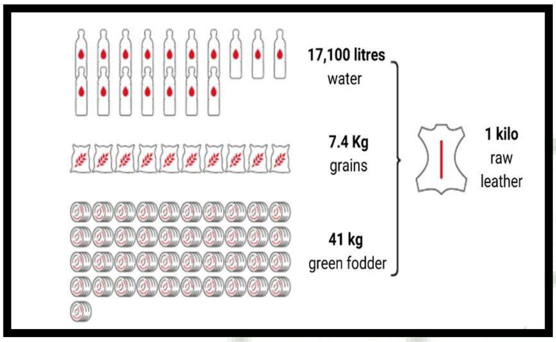

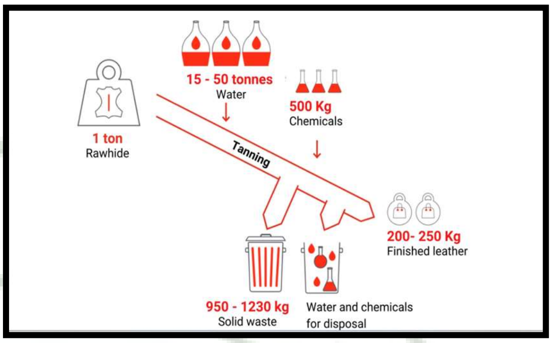

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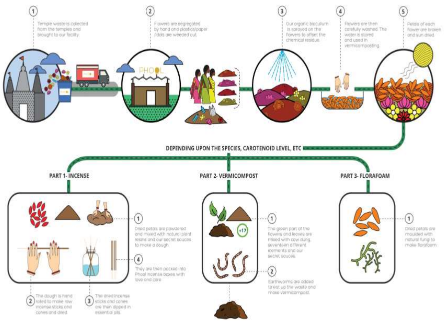

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BLUEPRINT OF THE DEEP – CRAFTING FISH CITIES WITH ARTIFICIAL REEFS

S.Sharon jebash , R.Sasmitha and V.Ezhilarasi
TNJFU - Dr.M.G.R. Fisheries College and Research Institute, Ponneri

INTRODUCTION

Decline of natural fish populations due to habitat loss, overfishing, and climate change has attracted global concern. Artificial reefs (ARs), among the most effective tools available in fisheries management and marine ecosystem restoration, have been created to counter these pressures. A human-built structure that is intentionally located on the ocean floor in order to look like a natural reef and to offer various marine species a variety of shelter, breeding, and feeding opportunities is referred to as an artificial reef (Baine, 2001).

ARTIFICIAL REEFS:

- Any human-made structure placed on the ocean floor to offer hard substrate where little or no hard substrate existed before is referred to as an artificial reef (AR). Purposes differ: provide fish habitat, offer coral some place to grow, shore protection, fisheries enhancement, and/or enhance dive/tourism locations. ARs consist of scuttled vessels, rocks, or "opportunity" reefs made from cleaned buildings, and specially shaped concrete modules (reef balls, layered units).
- Aside from enhancing fish stocks, artificial reefs are now extensively utilized in Asia, Europe, the America, and Australia for restoring habitats, protecting coastlines, and ecotourism.

MATERIALS USED FOR ARTIFICIAL REEF DEPLOYMENT:

The durability, colonization rate, and ecological security of the artificial reefs are all determined by the construction materials used.

- **Concrete Modules:** most popular choice because it is non-toxic and long-lasting. Reef balls and hollow blocks, for instance, provide cover for fish and a surface for algae and coral growth (Seaman & Jensen, 2000).
- **Scuttled Ships & Rigs-to-Reefs**: Huge, retired vessels or oil rigs that have been decontaminated and sunk to form huge, complex habitats. They attract both pelagic and demersal species.
- **Rocks and Boulders:** Used traditionally in countries such as Japan, the approach is simple but effective.

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- **Modern Innovations:** Increased surface complexity and coral settlement opportunity are offered by sustainable designs like polymer-based eco-modules, biorock formations (mineral accretion through low-voltage electricity), and 3D-printed reefs (Ferrario et al., 2021)
- **Natural structures** (top) included sea rods, and dead, actively diseased, and healthy boulder corals. Artificial structures (bottom) included a control and three structures that were built to mimic historically abundant natural structures including soft coral, boulder coral, and branching coral (elkhorn coral, Acropora palmata).
- The 4 structures were designed to imitate different types of natural habitats. The first type consisted of just 1 single length of PVC pipe standing up from a concrete block; this was a structure that lacked physical complexity. The other artificial structures represented a soft coral (created with PVC arms and frayed rope), a boulder coral (created with Vexar mesh around a tomato cage), and a branching elkhorn coral (created with arms wrapped in Vexar extending out from the center) (Figure 2). These different types of artificial structure were referred to as "control", "soft", "boulder", and "elkhorn" respectively. Reef (Fish Associations with Natural and Artificial Structures in the Florida KeysBy Kara Noonan 1,ORCID,Thomas Fair 2

PROCEDURE FOR ARTIFICIAL REEF DEPLOYMENT:

1.Preliminary Assessment

Site selection:

- Choose a location with degraded or barren seafloor, away from natural coral reefs (to avoid damaging existing ecosystems).
- Ensure suitable depth, water quality, current flow, and substrate.

Environmental impact assessment (EIA):

- Conduct surveys for benthic fauna, fish populations, and water quality.
- Assess risks to navigation, fishing grounds, and coastal communities.

Permits and approvals:

- Secure legal authorization from local and national marine authorities.
- Consult with fishermen, local communities, and conservation agencies.

2.Design and Material Selection

Reef design:

- Shapes should provide complexity (holes, crevices, vertical relief) to attract fish and invertebrates.
- Ensure structural stability against waves and currents.

Materials (must be non-toxic and durable):

- Concrete modules, eco-friendly reef balls, steel structures, limestone, or specially designed artificial reef units.
- Avoid harmful materials (painted metals, tires, plastics)

3.Preparation

Cleaning of structures:

- Remove contaminants (oil, paint, toxic coatings).

Marking & mapping:

- Use GPS to chart deployment zones.

Transport & staging:

- Move reef units to staging areas near deployment sites.

4.Deployment

Method:

- Use cranes, barges, or lift bags for precise placement.
- Avoid dumping—place carefully to prevent damage to seafloor habitats.

Spacing & layout:

- Arrange reefs in clusters with gaps (10–50 m apart) to encourage fish aggregation and avoid overcrowding.
- Maintain navigational safety (away from shipping lanes).

5.Post-Deployment Monitoring

Baseline data collection:

- Record initial conditions immediately after placement.

Regular monitoring (quarterly/annually):

- Fish abundance and diversity.
- Coral and algae colonization.
- Structural integrity of reef units.
- Water quality parameters (DO, pH, nutrients).

Adaptive management:

- Modify design or location if negative impacts (e.g., invasive species colonization, erosion) are detected

ROLE IN FISH STOCK ENHANCEMENT:

- **Provision of Shelter and Refuge:**

Overhangs, crevices, and holes in artificial reefs provide structural complexity. Fish, especially juveniles, hide in these places to escape predators. As predators gain ambush locations and prey species gain refuges, the predator-prey relation is enhanced. For example, juvenile snappers and groupers survive better in reef ball modules with multi-sized cavities (Seaman & Jensen, 2000).

- **Spawning and Breeding Grounds:**

Hard substrate is required for courtship, egg-laying, and nest-building by a number of fish species linked to reefs, including groupers and wrasses. Artificial reefs enhance reproductive success because they act as spawning substrata. They also provide aggregation sites, which are periodic meeting points for adult fish to spawn. For example, reef fishes in Florida have converted sunken ships into aggregation sites (Bohnsack & Sutherland, 1985).

- **Nursery Habitat for Juveniles:**

These safe nurseries are shallow man-made reefs with small crevices. Prior to making the migration to deeper reefs, juveniles mature in these environments. ARs enhance recruitments of adults by reducing juvenile death. For example, studies in Japan showed that settlement rates for juveniles were increased near reef modules compared to exposed sandy bottoms (Baine, 2001).

- **Feeding and Foraging Opportunities:**

Artificial reefs are colonized by algae, barnacles, mollusks, sponges, and polychaetes rapidly. Herbivorous, detritivorous, and carnivorous fish consume the benthic Invertebrates. Also, the unsteady flow of the reef entraps planktonic organisms, which makes it more probable that planktivorous fish will feed. Thus, fish populations increase faster and the food web is enhanced (Carr & Hixon, 1997).

- **Increase in Fish Biomass and Diversity:**

Compared to adjacent open seabed's, ARs induce a measurable increase in fish density, biomass, and species richness. Multitrophic levels, from small forage fish to predatory animals, are sustained by structural complexity. Fish assemblages on artificial reefs (ARs) eventually begin to resemble natural reefs' fish assemblages (Wilhelmsson et al., 2006).

ECOLOGICAL BENEFITS:

- Habitat Creation – Transform bare seabeds into fruitful environments by offering hard surfaces and structures for the corals, algae, and invertebrates to colonize.
- Biodiversity Enhancement – Enhance fish numbers and species richness by drawing a number of species (plankton to predators).
- Support for Coral Growth – Help restore the reefs through the provision of surfaces for coral settlement and transplantation.
- Food Web Development – Promote the growth of algae and bottom organisms, which feed the small fish and boost productivity as a whole.
- Nursery Grounds – Improve young fish and invertebrate survival and recruitment by offering them shelter and protection.
- Ecosystem Restoration – Restore areas damaged by trawling, mining, or bleaching, and restore ecological balance. Protection of natural reefs – minimize pressure on vulnerable coral reefs by shifting fishing and tourism practices.
- Coastal Resilience – Act as wave breakers, stop erosion, and enhance water quality by filter-feeding organisms

FISHERIES AND LIVELIHOOD BENEFITS:

Artificial reefs directly benefit the sustainability of fisheries and coastal livelihoods:

- Enhanced Fish Catch: ARs raise fishers' revenues by bringing in commercially important species such as groupers, snappers, and lobsters.
- Reduced Fishing Pressure Elsewhere: Natural reefs can be relieved of fishing pressure by concentrating around ARs (if put under effective management).
- Eco-tourism: ARs are used as dive and snorkeling sites, creating income and employment through tourism.
- Community Involvement: To enhance acceptance and stewardship, most AR projects involve the local fishermen in deployment and monitoring (Pitcher & Seaman, 2000).

CHALLENGES AND RISK:

ARs are not hazard-free, even though they have the potential. Problems might be caused by poor planning or management:

- Attraction vs. Production Debate: Whether ARs actually produce new fish biomass or merely attract fish from surrounding areas to make them more accessible for capture is a critical question (Lindberg, 1997).
- Overfishing Risks: In the absence of controls, concentrated fish surrounding ARs can be overfished within a very short time (Pickering & Whitmarsh, 1997).
- Environmental Hazards: ARs can contaminate instead of rehabilitate if improper materials are employed, e.g., tires or poisonous metals.
- Habitat Displacement: ARs can alter species distribution, and in some cases, this can be detrimental to natural reefs.
- Poor Site Selection: Reefs located where currents are high or sediment is unstable can collapse or damage their environment.

CASE STUDIES on Artificial reefs (India):

1.Kerala – India's first artificial reef.

- Background: In the early 1980s, CMFRI introduced experimental ARs in Kerala, which was the first state to do so.
- Materials: Prefabricated modules, granite boulders, and concrete blocks.
- Outcomes: An impressive increase in fish catch, especially lobsters, groupers, snappers, and perches. Local fishermen indicated that near ARs catch efficiency was two to three times greater than in open waters. Reduced effort expended on fishing (less fuel and time required). Ensured reliable fishing areas, equipping small-scale fishermen. ARs deployed along the Kerala coast have been found to contribute to long-term socioeconomic advantages, as stated by CMFRI (2018).

2.Tamil Nadu – Extensive AR Initiatives

- Background: CMFRI and Tamil Nadu Fisheries Department used ARs intensively in Gulf of Mannar and Palk Bay under the Blue Revolution Scheme (2017–2019).
- Purpose: Enhance the well-being of fishermen, make coastal fisheries more resilient, and reduce the pressure on natural coral reefs.
- Outcomes: An increase in the catch of demersal fish, i.e., squids, snappers, cuttlefish, and rabbitfish. ARs curbed destructive fishing in natural reefs by serving as alternative fishing grounds. Promoted fishery management at the community level. In Tamil Nadu,

Kripa et al. (2018)—CMFRI field studies reported higher catch and fisher incomes from AR areas.

3.Odisha – Trawled Grounds Restoration

- Background: To restore mechanized bottom trawling-damaged benthic habitats, ARs were implemented in Odisha.
- Materials: Concrete structures that are modular.
- Outcomes: Benthic invertebrate (polychaetes, mollusks, and crabs) recolonization. Drew commercially valuable fish species, including anchovies, croakers, and catfish. Provided more fish for traditional and small-scale fishermen. Enhanced biodiversity in previously arid seabed areas. After introducing AR in Odisha, Mohanty et al. (2017) documented ecological recovery and reported that it enhances fisheries production.

4.Lakshadweep Island – Utilizing ARs to Rebuild Coral

- Background: Lakshadweep natural reefs were heavily affected by coral bleaching episodes, for which coral restoration programs based on ARs were implemented.
- Method: Coral transplanted onto prefabricated reef modules.
- Outcomes: Transplanted corals are settling and surviving successfully. Reef fish populations, such as groupers, butterflyfish, and parrotfish, are also recovering. Habitat complexity increased aided fisheries and biodiversity. AR-based coral transplantation was demonstrated by Edward et al. (2016) as an effective technique for reef rehabilitation in Lakshadweep.

FUTURE PROSPECTS OF ARTIFICIAL REEFS:

- Marine spatial planning and strategically: Siting reefs can improve coastal protection, biodiversity, and fisheries.
- Adaptation to Climate Change: Designing reefs that are storm-resistant, erosion-resistant, and shelters for marine organisms affected by acidification and coral bleaching.
- Eco-Engineering and Novel Materials: For greater resilience and support of biodiversity, apply eco-sustainable materials like biorock, 3D-printed modules, and polymer-based systems.
- Fisheries Management Integration: Reefs are situated within Marine Protected Areas to enhance fisheries and ensure sustainable fishing by triggering a cascade of effects.
- Smart Reef Tech: Adaptive reef management and real-time monitoring using Internet of Things sensors, cameras, and data platforms.

- Community-Based Reef Initiatives: Fishermen and coastal communities are engaged in reef deployment, management, and monitoring to enhance ownership and sustainability.
- Multi-Use Reefs: Designing reefs for research, ecotourism, coastal defense, biodiversity conservation, and fisheries development.
- Policy Support: Clear regulations, incentives, and guidelines to grow reef programs in a sustainable way.

CONCLUSION:

Artificial reefs contain huge potential to enhance fish stocks, protect biodiversity, and enhance the quality of life in local communities. Yet, intensive fisheries management, stakeholder engagement, site planning, material choice, and meticulous design are all necessary for achievement. ARs can speed up overfishing or harm the environment if not implemented effectively. Artificial reefs must thus be considered as a part of an integrated fisheries management and marine conservation plan and not as an interim measure.

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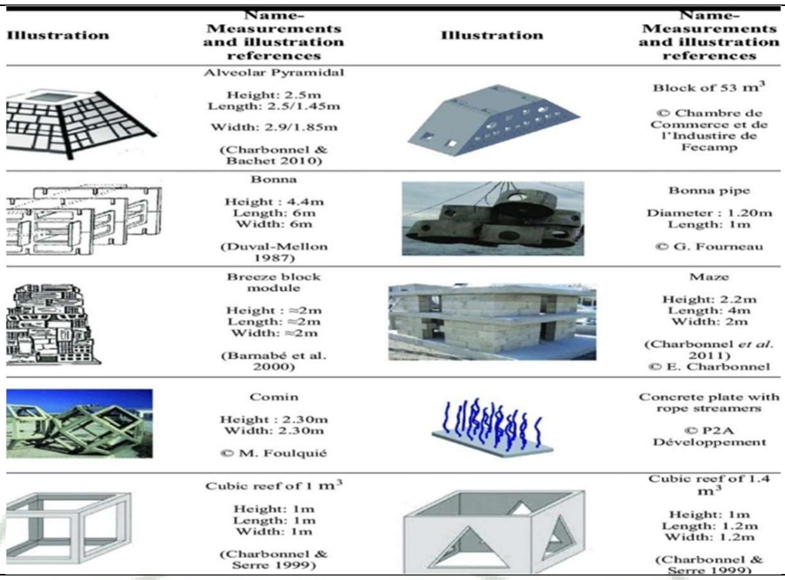

Illustration	Name-Measurements and illustration references	Illustration	Name-Measurements and illustration references
	Alveolar Pyramidal Height: 2.5m Length: 2.5/1.45m Width: 2.9/1.85m (Charbonnel & Bachet 2010)		Block of 53 m^3 © Chambre de Commerce et de l'Industire de Fecamp
	Bonna Height : 4.4m Length: 6m Width: 6m (Duval-Mellon 1987)		Bonna pipe Diameter : 1.20m Length: 1m © G. Fourneau
	Breeze block module Height : ≈2m Length: ≈2m Width: ≈2m (Barnabé et al. 2000)		Maze Height: 2.2m Length: 4m Width: 2m (Charbonnel *et al.* 2011) © E. Charbonnel
	Comin Height : 2.30m Width: 2.30m © M. Foulquié		Concrete plate with rope streamers © P2A Développement
	Cubic reef of 1 m^3 Height: 1m Length: 1m Width: 1m (Charbonnel & Serre 1999)		Cubic reef of 1.4 m^3 Height: 1m Length: 1.2m Width: 1.2m (Charbonnel & Serre 1999)

Figure A) Characteristics of different modules used in deployments of artificial reefs.(Assessment of French artificial reefs: due to limitations of research, trends may be misleading, July 2015.)

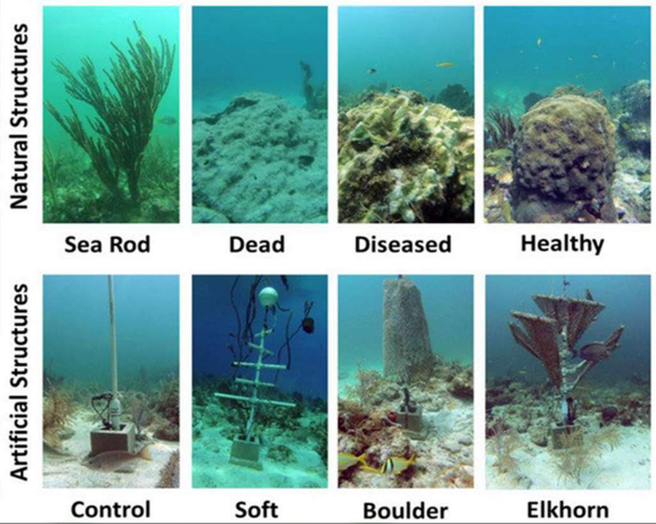

Figure B) Reef fishes' use of structures was monitored on natural and artificial structures

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Figure C) Artifcial reef placement along Chennai coast

Figure D) Coral transplantation activities undertaken by the NCCR in the Gulf of Mannar. Photo: NCCR Mandapam.

Figure E) A coral on an ‘artificial’ reef. Photo: NCCR Mandapam

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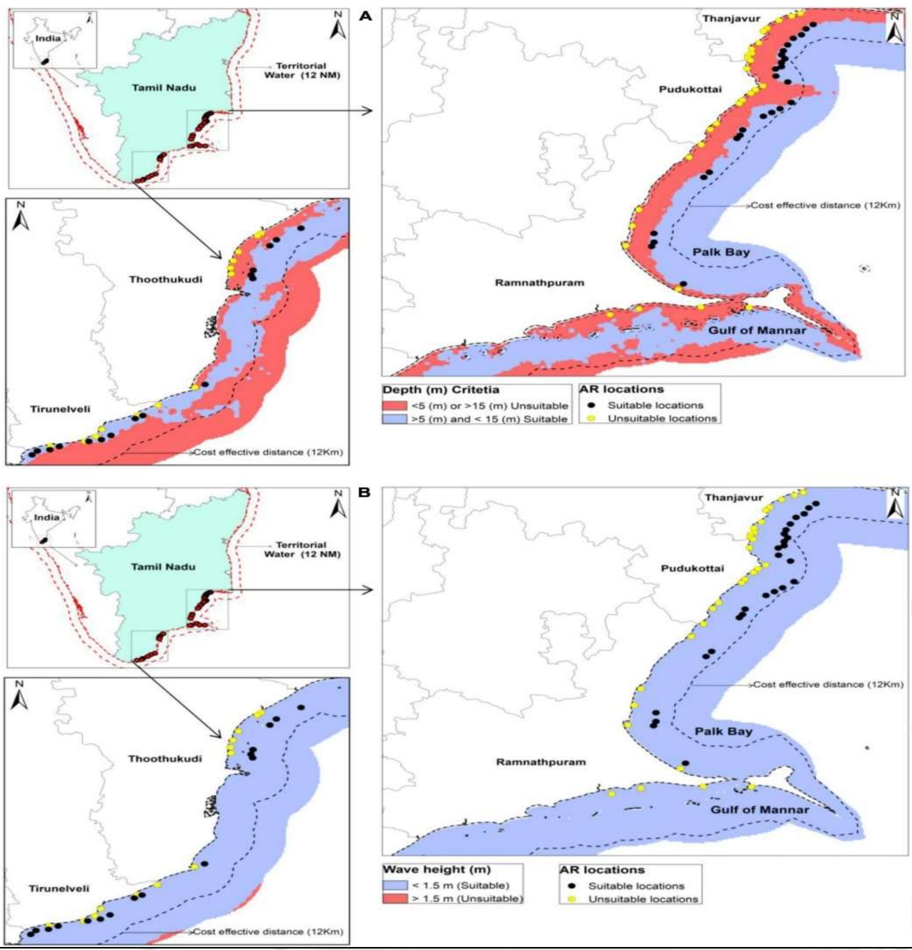

Figure F) Evaluation of Site Suitability for Artificial Reefs Deployment in Southeast Coast of India Using Geographic Information System (GIS).

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Genomic Insights into Zein Protein Composition Across Different Types of Maize

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ABSTRACT

Zein proteins, the major storage proteins in maize (*Zea mays L.*), play a crucial role in determining the nutritional and industrial quality of maize grain. Their distribution and proportion vary widely among maize types—flint, dent, sweet, pop, and waxy—owing to genetic, genomic, and evolutionary differences. Advances in maize genomics have enabled the dissection of zein gene families, regulatory mechanisms, and allelic variation influencing zein expression and ratio. This article discusses the types of maize, their zein protein composition, and how genomic regulation determines the ratio of α-, β-, γ-, and δ-zeins, shaping grain quality traits.

1. Introduction

Maize is one of the most genetically diverse crop species, with a complex genome of approximately 2.3 Gb characterized by a high content of transposable elements and duplicated gene families. Among its major biochemical constituents, zein proteins represent nearly 50–60% of the total endosperm protein. However, the proportion of zein subunits varies significantly among maize types due to selection pressure, domestication, and targeted breeding.

Understanding the genomics of zein protein synthesis and accumulation provides a foundation for improving the nutritional value and processing quality of maize, particularly through biofortification and genetic engineering.

2. Classification of Maize Types and Their Protein Profiles

Maize is generally classified based on endosperm characteristics and kernel texture, each associated with distinct zein profiles and gene expression patterns.

Maize Type	Kernel Feature	Dominant Zein Fraction	Approximate Zein Ratio (α:β:γ:δ)	Protein Content (%)
Flint Maize	Hard, vitreous endosperm	α-zein predominant	70:10:15:5	9–11

Dent Maize	Intermediate, soft core	α- and γ-zein balanced	65:10:20:5	8–10
Sweet Maize	High sugar, low starch	Lower α-zein, higher β-zein	55:15:20:10	6–8
Pop Maize	Hard pericarp, high expansion ratio	High γ-zein, confers hardness	60:8:25:7	8–9
Waxy Maize	High amylopectin starch	Reduced α-zein, increased δ-zein	50:12:25:13	7–9
High-Lysine (Opaque-2)	Soft, opaque kernel	Suppressed α-zein, compensatory non-zein	30:20:35:15	10–12

3. Zein Protein Families and Gene Organization

Zein proteins are alcohol-soluble prolamins encoded by a large multigene family organized into four subclasses based on solubility, molecular weight, and gene sequence similarity:

1. **α-Zeins (19- and 22-kDa):**
   - Constitute ~70–80% of total zeins.
   - Encoded by **Z1A, Z1B, Z1C, Z1D** gene families on chromosomes 4, 7, and 10.
   - Critical for endosperm texture but low in lysine and tryptophan.
2. **β-Zeins (15-kDa):**
   - Rich in methionine.
   - Encoded by a single gene family on chromosome 7.
3. **γ-Zeins (16- and 27-kDa):**
   - Important for protein body initiation and kernel hardness.
   - Encoded by **Z2A, Z2B** families on chromosomes 7 and 2.
4. **δ-Zeins (10-kDa):**
   - High in methionine and cysteine, enhancing nutritional value.
   - Encoded by **Z3** genes on chromosome 6.

Genomic studies reveal that duplication and divergence within these families contribute to the quantitative variation in zein synthesis across maize types.

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4. Genomic Regulation of Zein Protein Expression

The expression of zein genes is tightly controlled at the transcriptional and post-transcriptional levels by **cis-regulatory elements** and **transcription factors** specific to the endosperm.

- **Opaque2 (O2)**: A bZIP transcription factor that activates α-zein genes; its mutation reduces α-zein accumulation, leading to high-lysine maize.
- **PBF (Prolamin-box binding factor):** Regulates the coordinated expression of γ- and δ-zein genes.
- **ZmMADS47 and OHPs (O2-heterodimerizing proteins):** Contribute to fine-tuned regulation of zein synthesis.

Epigenomic studies show that histone acetylation and methylation patterns also determine zein gene accessibility during kernel development. RNA-seq and chromatin immunoprecipitation (ChIP-seq) analyses have mapped several regulatory hotspots responsible for quantitative variation in zein content among maize genotypes.

5. Influence of Zein Ratio on Kernel and Nutritional Traits

The balance among zein fractions determines not only the texture of the kernel but also its nutritional profile:

- **High α-zein content** → Hard kernels, poor lysine and tryptophan.
- **Higher γ-zein proportion** → Increased vitreousness and popping quality.
- **Reduced α-zein and elevated non-zein fractions** → Improved amino acid balance (e.g., in *opaque2* mutants).
- **Enhanced δ-zein expression** → Greater sulfur amino acid content, beneficial for feed quality.

Modern *omics* approaches integrate **transcriptomics, proteomics, and metabolomics** to correlate zein ratios with agronomic performance, allowing breeders to select genotypes with optimized nutritional and processing qualities.

6. Genomic Approaches to Modify Zein Ratios

Recent genomic and biotechnological tools have facilitated precise manipulation of zein synthesis:

- **CRISPR/Cas9-mediated gene editing** of *O2* and *Z1C* genes allows reduction of α-zein levels while maintaining kernel hardness.
- **RNA interference (RNAi)** targeting specific zein transcripts rebalances protein fractions to improve lysine content.

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- **Genome-wide association studies (GWAS)** have identified SNP markers linked with zein gene expression variability, aiding molecular breeding.
- **Transgenic expression of δ-zein genes** under strong endosperm-specific promoters increases methionine content without compromising yield.

7. Conclusion

The ratio and distribution of zein proteins among different maize types reflect a complex interplay of genomic organization, regulatory networks, and evolutionary adaptation. Advances in maize genomics have not only clarified the molecular basis of zein diversity but also paved the way for nutritionally enhanced maize through targeted genomic interventions. The integration of high-resolution genomic tools with breeding programs holds promise for developing next-generation maize varieties that combine superior nutritional value, kernel texture, and processing quality.

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Effectiveness of Mobile-Based Agro-Advisories in Improving Farm Decision-Making

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ABSTRACT

The rapid expansion of mobile communication technologies has transformed agricultural extension systems across the globe. Mobile-based agro-advisories provide real-time, location-specific, and crop-oriented information directly to farmers, improving decision-making, productivity, and sustainability. This article evaluates the effectiveness of mobile-based advisory services in enhancing farmers' knowledge, timely management actions, and adaptive capacity. It further discusses the factors influencing their adoption and the role of digital platforms in strengthening agricultural resilience.

1. Introduction

Agricultural decision-making is highly knowledge-intensive and time-sensitive, particularly under the influence of climate variability, pest outbreaks, and market fluctuations. Traditional extension services, although valuable, often face constraints such as limited manpower, geographical barriers, and delayed communication.

The emergence of mobile-based agro-advisory systems bridges these gaps by providing farmers with instant, tailored, and actionable information through SMS, voice calls, mobile apps, and WhatsApp-based channels. These platforms, backed by ICT (Information and Communication Technology), have emerged as a critical tool for modern agricultural extension.

2. Concept of Mobile-Based Agro-Advisory Services

Mobile-based advisories refer to the dissemination of real-time, location-specific agricultural information to farmers through mobile networks. The advisories can include:

- Weather forecasts and early warnings
- Pest and disease management tips
- Agronomic practices and crop scheduling
- Nutrient and irrigation recommendations

- Market price information and input availability

Examples include Kisan Call Centers (KCC), mKisan Portal, IFFCO Kisan Sanchar Limited (IKSL), Digital Green, and app-based tools like Kisan Suvidha, AgroStar, and RML Farmer.

3. Methodology for Assessing Effectiveness

Effectiveness of mobile-based agro-advisories is commonly assessed using:

- Adoption and usage metrics: Percentage of farmers regularly using the service.
- Knowledge gain: Pre- and post-advisory assessments.
- Behavioral change: Alterations in decision-making patterns and timeliness of interventions.
- Economic impact: Increase in yield, reduction in input costs, or higher market realization.
- Satisfaction and trust index: Farmer feedback and perceived reliability of information.

Empirical studies often employ participatory rural appraisal (PRA), focus group discussions, and econometric models (e.g., logit regression) to analyze determinants of adoption and impact

4. Impact on Farm Decision-Making

Mobile-based advisories significantly improve farm-level decisions through the following mechanisms:

4.1 Timeliness and Precision

Farmers receive timely alerts on rainfall forecasts, pest incidence, or disease outbreaks, enabling preventive action rather than reactive measures. For instance, mobile weather advisories can guide irrigation scheduling and pesticide applications, reducing resource wastage.

4.2 Knowledge Enhancement

Access to digital advisories enhances farmers' knowledge of scientific practices. Research indicates that farmers receiving mobile advisories show 20–40% higher awareness of improved cultivation techniques compared to non-users.

4.3 Risk Reduction

Mobile alerts related to extreme weather events (heat waves, droughts, or floods) allow farmers to undertake risk mitigation strategies, such as altering sowing dates or protecting standing crops.

4.4 Economic and Input Efficiency

Studies in India and Africa have shown that mobile advisories can lead to 10–25% yield improvement and 5–15% cost reduction, primarily due to optimized fertilizer and pesticide use.

4.5 Empowerment and Inclusivity

Mobile platforms democratize access to information, empowering smallholders, women, and marginalized farmers by reducing dependence on intermediaries. Voice-based advisories and vernacular messages further improve inclusivity.

5. Genomic and Technological Integration

Modern mobile-based advisories increasingly integrate geospatial, genomic, and predictive analytics to deliver precision recommendations:

- Satellite and remote sensing data support site-specific nutrient and irrigation advisories.
- AI-driven pest surveillance systems use mobile image recognition to diagnose pest species.
- Genomic data of crop varieties are embedded into advisory databases, allowing the system to recommend varieties best suited to local stress conditions. Such integration enhances both the scientific basis and the field relevance of the advisories.

6. Factors Affecting Effectiveness

The performance of mobile-based advisories is influenced by:

- Network connectivity and smartphone penetration in rural areas.
- Language and literacy barriers, especially for text-based advisories.
- Trust and credibility of the information source.
- Relevance and localization of the advisory content.
- Feedback mechanisms allowing two-way communication between farmers and experts.

To achieve sustainable impact, advisories must be context-sensitive, participatory, and adaptive to local needs.

7. Challenges and Limitations

Despite their success, mobile-based agro-advisories face several challenges:

- Digital divide: Limited access among resource-poor or elderly farmers.
- Information overload: Excessive or generalized messages can reduce engagement.
- Limited integration with local extension services.
- Lack of real-time feedback or accountability.
- Sustainability of funding models for private advisory platforms.

Addressing these issues requires public-private partnerships, open-data frameworks, and inclusion of AI-based personalization algorithms.

8. Policy Implications and Future Outlook

Governments and agricultural research institutions should focus on:

- Strengthening multi-language, voice-based advisory systems for inclusivity.
- Integrating mobile advisories with national agricultural databases and early warning systems.
- Promoting open-access digital platforms for data sharing and farmer interaction.
- Linking advisories with market intelligence and e-commerce systems to ensure farm-to-market connectivity.
The next generation of advisories will likely combine IoT sensors, genomic data, and AI models to deliver hyper-local and dynamic recommendations in real time.

9. Conclusion

Mobile-based agro-advisories have proven to be powerful tools for enhancing farm-level decision-making, improving productivity, and promoting sustainable agricultural practices. Their effectiveness lies in timely, reliable, and contextualized information delivery. To maximize their potential, future efforts should emphasize data integration, personalization, capacity building, and gender inclusion. Strengthening the synergy between digital innovation and grassroots extension will be key to empowering farmers in the digital agriculture era.

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Enzymatic Activities During Seed Germination: A Physiological Perspective

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ABSTRACT

Seed germination represents one of the most dynamic physiological transitions in the plant life cycle, transforming a metabolically quiescent seed into an actively growing seedling. This process is regulated by a complex interplay of metabolic pathways, among which enzymatic activities play a pivotal role. During germination, hydrolytic enzymes mobilize stored macromolecules such as starch, proteins, and lipids into simpler forms to support embryonic growth. Enzyme induction and regulation are tightly coordinated by hormonal signals, environmental cues, and internal metabolic status. This article provides a detailed physiological overview of key enzymatic activities during seed germination, their regulation, and significance in determining seed vigor and viability.

1. Introduction

Seed germination is a crucial physiological process that ensures the continuation of plant species and agricultural productivity. It begins with water uptake (imbibition) by the dry seed and culminates in radicle protrusion through the seed coat. Germination involves reactivation of metabolic processes that were suppressed during seed dormancy or desiccation. The mobilization of seed reserves is primarily driven by a cascade of enzymatic reactions that degrade storage macromolecules accumulated during seed maturation. Understanding these enzymatic activities provides insights into seed physiology, germination efficiency, and crop establishment under diverse environmental conditions.

2. Phases of Germination and Enzyme Activation

Seed germination generally occurs in three phases:

- **Phase I – Imbibition:** Rapid water uptake rehydrates seed tissues, leading to swelling and membrane reorganization. Enzymes present in dry seeds are reactivated.
- **Phase II – Lag Phase:** Metabolic reactivation occurs without further water uptake. De novo synthesis of enzymes begins under hormonal regulation.

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- **Phase III – Radicle Emergence:** Reserve mobilization peaks, and enzymatic hydrolysis provides energy and nutrients for cell division and elongation in the embryo axis.

Each phase exhibits specific enzymatic patterns vital for successful seedling establishment.

3. Major Enzymes Involved in Seed Germination

3.1 Amylases

- Function: Hydrolysis of starch reserves into maltose and glucose.
- Types:
  - α-Amylase (endo-enzyme): Randomly cleaves internal α-1,4-glycosidic linkages in starch.
  - β-Amylase (exo-enzyme): Releases maltose units from the non-reducing ends.
- Site of Activity: Primarily in the aleurone layer and endosperm of cereals.
- Regulation: Induced by gibberellic acid (GA_3) and inhibited by abscisic acid (ABA). The GA_3 signal from the embryo triggers α-amylase synthesis, which is secreted into the endosperm to mobilize starch reserves for embryonic growth.

3.2 Proteases

- Function: Degrade seed storage proteins into amino acids for protein synthesis and energy production.
- Types:
  - Endopeptidases (e.g., cysteine and serine proteases) break internal peptide bonds.
  - Exopeptidases (e.g., carboxypeptidases, aminopeptidases) cleave terminal amino acids.
- Physiological Role: Provide nitrogen and carbon skeletons for developing embryonic tissues.
- Regulation: Protease synthesis is also stimulated by GA_3 in cereal aleurone cells.

3.3 Lipases and Related Enzymes

- Function: Hydrolysis of triacylglycerols into free fatty acids and glycerol.
- Occurrence: Predominant in oilseeds like soybean, sunflower, and castor.

- Subsequent Metabolism: Fatty acids undergo β-oxidation in glyoxysomes, producing acetyl-CoA, which enters the glyoxylate cycle to generate sucrose for the growing embryo.
- Enzymes Involved: Lipase, isocitrate lyase, and malate synthase

3.4 Phosphatases

- Function: Release inorganic phosphate (Pi) from phosphorylated intermediates.
- Types: Acid phosphatase and alkaline phosphatase.
- Role: Supply phosphate for nucleic acid synthesis and energy metabolism (ATP generation).

3.5 Dehydrogenases and Oxidases

- Function: Catalyze redox reactions during respiration.
- Examples: Alcohol dehydrogenase, malate dehydrogenase, cytochrome oxidase.
- Significance: Markers of seed viability and metabolic reactivation during germination. Tetrazolium chloride (TTC) assays often use dehydrogenase activity as an indicator of seed vigor.

4. Hormonal and Environmental Regulation of Enzyme Activity

Germination-related enzymes are under tight regulation by plant hormones and external cues:

- Gibberellic Acid (GA_3): Promotes hydrolytic enzyme synthesis, especially α-amylase, by inducing transcriptional activation in aleurone cells.
- Abscisic Acid (ABA): Inhibits enzyme synthesis, maintaining dormancy.
- Ethylene: Enhances endosperm weakening and enzyme activation.
- Environmental Factors: Temperature, oxygen, and light influence enzymatic kinetics, with optimal ranges varying among species.

5. Metabolic Integration During Germination

Enzymatic activities are integrated within the seed's metabolic network:

- Carbohydrate, protein, and lipid degradation converge to provide substrates for glycolysis, the tricarboxylic acid (TCA) cycle, and oxidative phosphorylation.
- The coordination ensures continuous ATP supply and biosynthesis of structural components necessary for cell division and elongation.

6. Physiological and Agricultural Implications

- Seed Vigor Testing: Enzyme assays (e.g., amylase and dehydrogenase activity) serve as reliable indicators of seed quality and germination potential.
- Stress Tolerance: Seeds with higher baseline enzyme activity exhibit better performance under abiotic stress (drought, salinity, temperature extremes).
- Seed Priming: Techniques such as hydro-priming or osmopriming pre-activate enzymatic machinery, leading to faster and more uniform germination.

7. Conclusion

Enzymatic activities form the biochemical foundation of seed germination, driving the transition from dormancy to active metabolism. The spatial and temporal regulation of hydrolytic and oxidative enzymes determines the efficiency of reserve mobilization, seed vigor, and early seedling establishment. Understanding these enzymatic dynamics not only elucidates seed physiology but also enables the development of strategies for improving crop establishment, stress resilience, and agricultural productivity.

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Blockchain Technology in Agricultural Supply Chain: Enhancing Transparency, Traceability, and Trust

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ABSTRACT

The agricultural supply chain involves multiple stakeholders—from producers and processors to distributors, retailers, and consumers—making it prone to inefficiencies, data asymmetry, and fraud. Blockchain technology, a decentralized digital ledger system, has emerged as a transformative solution to enhance traceability, transparency, and trust in agri-food value chains. This article explores the architecture, working principles, and applications of blockchain in agriculture, highlighting its potential to ensure food safety, fair trade, and efficient logistics while discussing key challenges and policy implications.

1. Introduction

Agriculture is one of the most complex supply networks, with perishable products passing through numerous intermediaries. Traditional supply chains often face challenges such as lack of transparency, product adulteration, delayed payments, and inconsistent data sharing.

Blockchain technology, originally conceptualized for cryptocurrency transactions, has found significant relevance in agricultural logistics and supply chain management due to its capacity for secure, immutable, and distributed record keeping. The integration of blockchain in agriculture enables every transaction—from farm to fork—to be securely recorded, verified, and shared among participants in real-time.

2. Understanding Blockchain Technology

Blockchain is a distributed ledger system that stores transactional data across a network of computers (nodes) in a chronologically linked series of "blocks." Each block contains:

- Transaction data (e.g., product movement, quality test results),
- Timestamp, and
- Cryptographic hash of the previous block.

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This structure ensures that once a record is entered, it cannot be altered, creating an immutable chain of verified information.
Key features relevant to agriculture include:

- Decentralization: No single authority controls the data.
- Transparency: All authorized participants can view verified records.
- Immutability: Data tampering is virtually impossible.
- Smart contracts: Automated digital agreements trigger actions when predefined conditions are met.

3. Structure of Agricultural Supply Chain and Blockchain Integration

The agricultural supply chain typically involves five major stages:

1. Production (Farm Level) – crop cultivation, livestock rearing
2. Processing and Storage – cleaning, grading, packaging
3. Transportation and Logistics – cold chain and warehousing
4. Distribution and Retail – wholesalers, markets, retailers
5. Consumption and Feedback – consumers and regulatory audits

Blockchain integrates into each stage through data capture devices (IoT sensors, QR codes, RFID tags), cloud storage, and smart contract-enabled platforms to record transactions.

Example:
A mango shipment can be tracked from farm harvest to export through blockchain, recording temperature, humidity, and transportation conditions at every node, ensuring traceability and quality assurance.

4. Applications of Blockchain in Agricultural Supply Chains

4.1 Traceability and Food Safety

Blockchain provides end-to-end visibility of the product's journey. Consumers can scan a QR code to verify:

- Origin of produce (farm location)
- Type of inputs used (fertilizers, pesticides)
- Harvest and packaging dates
- Transport and storage conditions

Example: IBM Food Trust and Walmart have implemented blockchain to trace leafy greens within seconds, improving food safety and recall efficiency.

4.2 Fair Pricing and Farmer Empowerment

Smart contracts ensure automatic and transparent payment transfers when delivery and quality conditions are met, reducing exploitation by intermediaries. Example: Blockchain-enabled coffee traceability platforms like Bext360 guarantee fair trade payments directly to farmers.

4.3 Reduction of Post-Harvest Losses

Integration with IoT sensors allows monitoring of temperature and humidity, with blockchain securely logging this data to trigger alerts for corrective action, minimizing spoilage during transit.

4.4 Certification and Compliance

Blockchain can store verified data related to organic certification, pesticide use, or carbon footprint, making audit processes more reliable and reducing paperwork.

4.5 Supply Chain Financing

Financial institutions can access blockchain-verified records of farm produce, facilitating low-interest credit and risk-free insurance claims for farmers based on real-time data.

5. Case Studies and Global Examples

Project	**Region**	**Application**	**Outcome**
AgriDigital (Australia)	Grain supply chain	Smart contracts and digital grain receipts	Faster payment settlement and reduced fraud
IBM Food Trust (USA)	Perishable food traceability	End-to-end transparency for retailers	Recall time reduced from 7 days to 2 seconds
TE-Food (Vietnam)	Livestock tracking	Farm-to-table pork traceability	Enhanced consumer confidence
AgUnity (Africa, Asia)	Smallholder empowerment	Transaction recording for cooperatives	Increased farmer income and transparency
EcoTrac (India)	Organic produce supply chain	Blockchain + IoT traceability	Verified authenticity and export quality control

6. Technological Framework

A blockchain-based agricultural supply chain typically includes:

- Data Input Layer: IoT devices, drones, mobile apps
- Blockchain Layer: Distributed ledger and smart contracts

- Application Layer: Dashboards for farmers, processors, and retailers
- User Interface: Mobile/web-based platforms for monitoring and verification

Smart contracts automate transactions such as:

- Release of payment upon verified delivery.
- Triggering insurance payout after validated crop loss data.
- Generating digital receipts and compliance reports.

7. Advantages

- Transparency and Trust: Eliminates data asymmetry.
- Accountability: Every participant can verify transactions.
- Efficiency: Reduces paperwork and intermediaries.
- Product Authenticity: Prevents counterfeit or adulterated products.
- Sustainability: Enables carbon accounting and green certification.

8. Challenges and Limitations

Despite its promise, several barriers limit large-scale implementation:

- High initial cost and technological complexity
- Low digital literacy among farmers
- Connectivity issues in rural regions
- Interoperability between different blockchain systems
- Legal and data privacy concerns

To overcome these challenges, capacity building, public-private partnerships, and supportive digital infrastructure are essential.

9. Future Prospects and Policy Implications

The integration of AI, IoT, and blockchain can lead to next-generation digital supply chains with predictive analytics, automated compliance, and real-time decision-making. Policymakers must:

- Encourage open blockchain frameworks for agriculture.
- Support pilot projects and digital literacy programs for smallholders.
- Establish standards for data governance, privacy, and interoperability.

- Promote agribusiness innovation ecosystems integrating blockchain with e-NAM and other national agri-markets.

10. Conclusion

Blockchain technology offers a revolutionary approach to transforming agricultural supply chains into transparent, traceable, and trustworthy systems. By recording every step from production to consumption on an immutable ledger, blockchain enhances food safety, farmer income, and consumer confidence. However, for widespread adoption, coordinated efforts are required among governments, agritech startups, research institutions, and farmers to build capacity and develop cost-effective, scalable blockchain-based solutions.

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Potentiality of Northern Telangana Agro-Climatic Zone: A Blooming Opportunity for Floriculture

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INTRODUCTION

With rapid urbanization, flowers have become an integral part of daily life, being used in festivals, social and religious functions, home decorations, balcony gardens and roof gardens. Increased purchasing capacity of individuals, even in peri-urban areas, along with improved transportation facilities and year-round availability of flowers from different parts of the country, has boosted their demand. Traditional flowers such as marigold, chrysanthemum, jasmine and rose are cultivated by small and marginal farmers mainly for supplying loose flowers to nearby markets based on local demand. In Telangana, flower cultivation is largely concentrated around major cities like Hyderabad, Warangal and Khammam. However, cut flower production remains limited, confined mostly to small pockets where rose and gerbera are grown in a small extent under polyhouses. With rising consumer demand for diverse and exotic flowers, there is a growing need to expand production of both loose flowers and cut flowers.

Northern Telangana Zone: A Region with Natural Advantage

The Northern Telangana Zone (NTZ), comprising ten districts - Adilabad, Jagtial, Nirmal, Nizamabad, Kamareddy, Karimnagar, Kumurambheem Asifabad, Mancherial, Peddapalli and Rajanna Sircilla - offers strong potential for flower crops due to its natural resources such as diverse soils, abundant water availability and favourable climatic conditions that support a wide range of flower species.

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❖ **Climate: Supportive for Both Loose and Cut Flowers**

The NTZ experiences a hot and dry climate with well-defined summer, monsoon and winter seasons and an annual average rainfall of around 1060 mm. These climatic patterns create suitable environments for different groups of flowers.

Temperature Suitability

- High summer temperatures (36.8–41.3°C) favour heat-tolerant flowers such as marigold, jasmine, crossandra, bougainvillea and gomphrena.
- Moderate year-round temperatures (27–30°C) are suitable for rose, chrysanthemum, tuberose, gladiolus and China aster.
- Cool winter temperatures (15–18°C) are ideal for chrysanthemum, gladiolus, dahlia and winter annuals.
- Bulbous crops such as gladiolus, tuberose, lily and amaryllis perform exceptionally well due to contrasting summer and winter temperature regimes.

Rainfall Pattern and Crop Performance

Since about 82% of the rainfall occurs during the southwest monsoon, moisture-loving flowers such as marigold, jasmine and tuberose thrive well. The dry conditions of the post-monsoon and winter seasons favour crops requiring regulated irrigation, such as rose, gladiolus and chrysanthemum, as well as seasonal annuals like annual chrysanthemum, gomphrena, ornamental sunflower, petunia, salvia, poppy, calendula and helichrysum.

Seasonal Suitability: Flowers for Every Season

- **Summer (Apr–May):** Jasmine, tuberose and bougainvillea
- **Monsoon (Jun–Sep):** Marigold, jasmine, crossandra and tuberose
- **Winter (Nov–Feb):** Gladiolus, chrysanthemum, calendula.

Gladiolus, in particular, performs best during winter due to its requirement for cool nights and mild day temperatures.

❖ **Soil Diversity : A Major Strength for Floriculture**

The NTZ consists of 16 soil types, dominated by red soils (45%), followed by black soils (24%) and calcareous soils (20%). This diversity supports a broad spectrum of flower crops.

Red Soils (45%)

Well-drained and aerated, these soils are ideal for:

- Marigold, chrysanthemum, rose, jasmine, gladiolus and asters
- Bulbous crops like tuberose, gladiolus, lily and iris

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Black Soils (24%)

With excellent moisture retention:

- Suitable for marigold, asters, chrysanthemum and crossandra
- Deep calcareous black soils support rose, jasmine and tuberose

Calcareous Soils (20%)

These moderately alkaline soils favour jasmine, rose, ornamental shrubs and tuberose.

Alluvio-Colluvial Soils

Fertile and friable soils; ideal for:

- High-value crops such as gerbera, gladiolus, lily and chrysanthemum

Rocky and Saline-Sodic Soils

Although challenging, hardy ornamentals like bougainvillea and oleander can be grown, along with salt-tolerant plants such as canna lily.

❖ **Market Potential: A Growing Scenario**

Demand for traditional loose flowers is more during festivals, marriages and religious ceremonies as this zone is situated at river banks of Godavari. Flowers like rose as well as tuberose have year-round demand while gladiolus is increasingly used in bouquets, decoration and pot culture. Gerbera, orchids have demand during marriage seasons. Rising income levels and growing interest in social celebrations have also boosted demand for exotic flowers. Due to the non-availability from the local farmers, supply of these flowers from cities like Bangalore, Hyderabad, Pune which incurs the cost of middlemen and reflecting the high cost to the consumers. The demand for both loose and cut flowers is rising in the local markets as well as in distant markets and this zone is connected with good road and rail facility gives opportunity to sale for distant markets.

This zone is also a potential source for Farmer Producer Organizations and Self Help Groups which helps them nursery rising, value addition such as flower arrangements, dry flowers and byproducts preparation which provides the opportunity for entrepreneurship.

Conclusion: A Blooming Future with the Right Support

Northern Telangana possesses the entire essential ingredients- **favourable climate, diverse soils, water resources and strong market linkages** to emerge as a major floriculture hub. However, farmers need scientific guidance, government support and access to improved technologies, particularly in:

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- Standardized planting windows
- Suitable flower varieties and planting material
- Post-harvest handling and storage
- Value addition and market linkage

Currently, research studies on bulbous flowers in this zone are limited, highlighting the need for focused investigations. With improved awareness and institutional support, floriculture can become a highly profitable enterprise for farmers of Northern Telangana, opening pathways for employment, entrepreneurship and rural transformation.

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IMPORTANCE OF SEED TREATMENT AND SEEDLING RAISING IN VEGETABLE PRODUCTION

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ABSTRACT

Seed treatment and seedling raising are two vital steps in vegetable production. These practices directly influence the quality, yield, and health of the final crop. Since vegetables are high-value and short-duration crops, ensuring strong and disease-free seedlings from the start is crucial. Properly treated seeds and well-raised seedlings lead to early establishment, uniform growth, and better resistance to environmental stresses and diseases. In horticulture, seed treatment and seedling management are considered the foundation for successful vegetable farming.

IMPORTANCE OF SEED TREATMENT:

Seed treatment plays a critical role in vegetable production by protecting seeds from harmful pathogens, pests, and environmental stresses. Seeds are often carriers of fungal, bacterial, or viral pathogens that can severely affect germination and seedling vigor. Treating seeds with appropriate fungicides, insecticides, or bio-agents ensures that they are clean and healthy before sowing. This not only enhances germination but also prevents early-stage seedling mortality due to soil-borne infections.In addition to protection, seed treatment also enhances physiological functions like water absorption, enzyme activation, and nutrient uptake during

germination. Some treatments are designed to break seed dormancy or stimulate growth using growth regulators such as gibberellic acid or potassium nitrate. In vegetable crops like tomato,

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brinjal, and capsicum, treated seeds germinate faster and more uniformly, giving a head start to the crop. The long-term benefits include better field establishment and higher yields.

METHODS OF SEED TREATMENT:

Different methods are employed for seed treatment based on the crop type and purpose. The most common methods include chemical, biological, and physical treatments. Chemical treatments involve coating seeds with fungicides such as Thiram, Captan, or Carbendazim to control seed-borne fungal pathogens. Insecticidal treatments protect seeds from pests like soil grubs and cutworms. Physical treatments such as hot water or dry heat are used to kill pathogens on the seed surface without affecting seed viability.

Biological seed treatments have gained immense importance in recent years as part of sustainable and organic farming practices. Microbial bio-agents such as Trichoderma harzianum, Pseudomonas fluorescens, and Bacillus subtilis suppress soil-borne diseases and promote root growth. These eco-friendly alternatives improve soil health and reduce dependency on synthetic chemicals, making them ideal for environmentally conscious farming systems.

IMPORTANCE OF SEEDLING RAISING:

Seedling raising refers to the process of nurturing seeds into healthy young plants in a controlled environment before transplanting them into the main field. A well-managed nursery produces vigorous seedlings with strong root systems, capable of adapting quickly after transplantation. This practice ensures uniform growth and high productivity in vegetable crops such as tomato, chili, cabbage, cauliflower, and onion.

Nursery management is especially important in regions with adverse climatic conditions or pest problems. By starting seedlings in a protected area like a greenhouse or shade net house, farmers can control environmental factors such as temperature, humidity, and light intensity. This creates ideal conditions for seed germination and early plant growth, reducing the risk of disease and pest attack. Healthy seedlings result in higher transplant survival rates and better crop establishment in the field.

NURSERY MANAGEMENT PRACTICES:

For successful nursery management, the soil or growing medium must be well-drained, fertile, and free from pests and diseases. Farmers often sterilize nursery soil using methods like solarization, formalin treatment, or steam sterilization to eliminate harmful organisms. The soil mixture usually consists of equal parts of garden soil, sand, and well-decomposed farmyard manure, ensuring proper aeration and moisture retention.

Seedlings require timely irrigation, weeding, and partial shading to ensure optimal growth. Overwatering should be avoided as it encourages fungal infections like damping-off. Nutrient management in nurseries is crucial — foliar sprays of balanced fertilizers or bio-fertilizers help boost seedling vigor. The use of plug trays and cocopeat as a growing medium has become common in modern horticulture, as these materials are lightweight, sterile, and support excellent root development.

HARDENING AND TRANSPLANTATION:

Before seedlings are transplanted into the main field, they must undergo a process called hardening. This involves gradually exposing seedlings to outdoor conditions, reducing watering, and increasing light exposure over several days. Hardening strengthens plant tissues, improves root activity, and enhances the seedlings' tolerance to environmental stress such as wind, heat, or drought. Properly hardened seedlings adapt quickly after transplantation and have a higher survival rate.

Transplantation should be done during the cooler parts of the day, preferably in the evening, to reduce transplant shock. Watering immediately after transplanting helps in quick root establishment. Healthy and well-raised seedlings significantly reduce replanting costs and improve crop uniformity, which ultimately leads to higher yields and better marketable quality.

CONCLUSION:

Seed treatment and seedling raising are indispensable components of successful vegetable cultivation. They ensure healthy crop establishment, minimize disease losses, and enhance yield and profitability. Farmers should adopt appropriate seed treatment methods and nursery practices according to crop requirements and local environmental conditions. Investing time and resources in these early stages of crop production pays off through better growth, resilience, and overall productivity. With modern technologies such as plug tray nurseries, organic bio-agents, and protected cultivation.

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IMPROVED STORAGE TECHNIQUES FOR LEAFY VEGETABLES

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ABSTRACT

Leafy vegetables are highly perishable commodities with a short post-harvest life due to their high moisture content, rapid respiration rate, and susceptibility to microbial spoilage. Effective storage techniques are therefore essential to maintain their freshness, nutritional quality, and market value from harvest to consumption. This paper explores a comprehensive range of improved storage methods traditional, modern, and emerging used to extend the shelf life of leafy vegetables. Key technologies discussed include pre-cooling, cold storage, modified atmosphere packaging (MAP), controlled atmosphere storage, evaporative cooling structures, edible coatings, and hydro-cooling systems. The paper also highlights innovative advancements such as nanotechnology-based packaging, biopolymer films, and smart sensor-based storage systems that monitor temperature, humidity, and respiration changes in real time. Factors affecting storage behavior including temperature, humidity, ethylene sensitivity, and microbial load are analysed in relation to post-harvest physiology.

1. Introduction:

Leafy vegetables occupy a crucial position in the human diet because they are rich in vitamins, minerals, antioxidants, phytochemicals, and dietary fibre. Popular leafy vegetables such as spinach (Spinacia oleracea), amaranthus (Amaranthus spp.), coriander (Coriandrum sativum), curry leaves, fenugreek, and lettuce form an essential component of daily diets in India. Their high moisture content (85–95%), delicate structure, and rapid metabolic activity make them extremely perishable. Post-harvest losses for leafy vegetables in India are estimated to be between 30–50%, mainly due to inadequate cold storage, high temperatures during transport, poor hygiene, inefficient packaging, and lack of awareness about scientific post-harvest handling. These losses significantly affect farmers' income, market availability, and consumer affordability.

2. Physiology and Factors Affecting Storage Life of Leafy Vegetables:

The shelf life of leafy vegetables is governed by physiological and environmental factors. Understanding these helps in designing appropriate storage systems.

2.1 Respiration Rate:

Leafy vegetables exhibit very high respiration rates after harvest. Respiration generates heat and accelerates senescence. For example:Lettuce: 22–28 mg CO_2/kg/hr and Spinach: 30–40 mg CO_2/kg/hr. High respiration leads to wilting, yellowing, loss of chlorophyll, loss of ascorbic acid, and microbial invasion.

2.2 Transpiration and Water Loss:

Leafy vegetables lose water rapidly due to high surface area and thin epidermal layers. A water loss of 3–5% causes visible wilting. 10% water loss makes the leaves unmarketable. Relative humidity <80% drastically accelerates water loss.

2.3 Temperature Sensitivity:

High temperatures increase respiration and microbial spoilage. Ideal storage temperature for most leafy vegetables: 0–5°C. Every 10°C increase doubles the respiration rate (Q_{10} effect).

2.4 Microbial Contamination:

Leafy vegetables carry high microbial loads due to: field dust, irrigation water, soil contact, manual handling. Common pathogens include Pseudomonas spp., Erwinia spp., and fungi like Alternaria and Rhizoctonia.

2.5 Ethylene Sensitivity:

Leafy vegetables are ethylene-sensitive crops.

Exposure to ethylene results in: yellowing, leaf drop, accelerated senescence

Vegetables like spinach and kale must not be stored near bananas or tomatoes.

2.6 Mechanical Damage:

Cuts, tears, bruises accelerate spoilage.

Mechanical damage increases respiration by 50–200%.

3. Traditional Storage Methods in India and Their Limitations:

Traditional storage practices include: sprinkling water, covering with wet cloth, storing under shade, use of bamboo baskets

Limitations:

- No temperature control and No humidity regulation
- Faster microbial growth and High transpiration losses
- 5. Shelf life only 6–12 hours and High contamination risk

Thus scientific, improved storage techniques are essential for commercial handling.

4. Improved Storage Techniques for Leafy Vegetables:

This section presents detailed modern storage technologies using scientific principles taught in the HOR curriculum.

4.1 Pre-Cooling Techniques:

Pre-cooling removes field heat immediately after harvest. This is the first and most important step in storage.

Types of Pre-Cooling:

1. Hydro-Cooling;

Leaves are immersed or sprayed with cold water (0–4°C). Removes heat quickly and also cleans surface dirt. Suitable for spinach, amaranthus, curry leaves.

2. Vacuum Cooling:

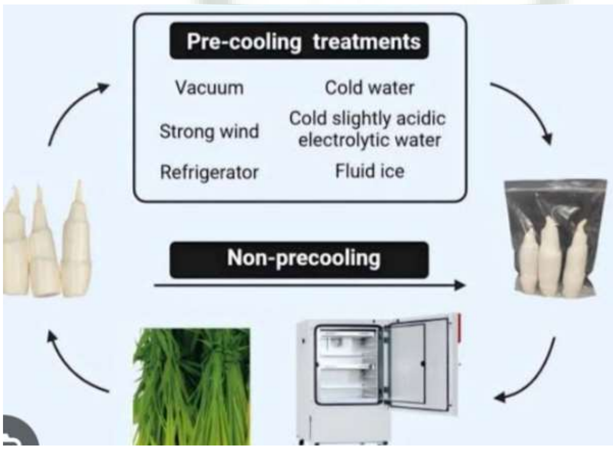
Uses low pressure to evaporate moisture rapidly. Very effective for leafy vegetables with large surface areas. Achieves uniform cooling to 1–3°C within minutes.

3. Forced-Air Cooling:

Cold air is forced through the packed produce. Suitable for bulk storage.

Benefits of Pre-Cooling:

- Reduces respiration by 50–60%
- Maintains firmness
- Reduces microbial load
- Increases shelf life by 2–5 days



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4.2 Low Temperature and Humidity Controlled Storage:

Cold storage is the backbone of modern leafy vegetable preservation.

4.2 Low Temperature and Humidity Controlled Storage:

Low temperature: slows enzymatic reactions, reduces water loss, delays chlorophyll degradation

High humidity: prevents wilting, maintains leaf turgidity

Modern innovations: solar-powered cold rooms, community cold storage units, portable refrigerated boxes for small farmers

Ideal Storage Conditions:

Crop	Temperature	RH%	Approx. Shelf Life
Spinach	0–2°C	95%	10–14 days
Amaranthus	2–5°C	90–95%	7–10 days
Lettuce	0–3°C	95%	15–20 days
Coriander	0–1°C	95%	12–15 days

4.3 Modified Atmosphere Packaging (MAP):

MAP alters the composition of gases around the produce.

Typical MAP composition:

O_2: 2–5%

CO_2: 5–10%

N_2: balance

Effects: lowers respiration, delays chlorophyll loss, inhibits microbial growth, doubles shelf life

Example: Spinach stored in MAP at 4°C can last 12–15 days.

Types of MAP:

- ❖ Passive MAP
- ❖ Active MAP

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- High-barrier films
- Micro-perforated films

4.4 Edible Coatings and Biodegradable Films:

Edible coatings form a thin semi-permeable layer around leaves.

Common coatings:

Aloe vera gel, Chitosan, Beeswax, Starch-based coatings, Pectin coatings

Benefits:

- Reduce transpiration and improve shelf appearance
- Natural antimicrobial properties and eco-friendly alternative to plastics

Research shows:

Aloe vera coated spinach stays fresh for **10–12 days**. Chitosan coating reduces microbial load by **40–60%**

4.5 Natural Antimicrobial Treatments:

Pre-storage dips in natural antimicrobials help prolong shelf life.

Examples: Neem extract (antifungal), Turmeric solution (curcumin action), Vinegar (acetic acid antimicrobial), Saltwater rinse, Lemon extract. These treatments are cost-effective and safe for small farmers

4.6 Cold Chain Management:

Cold chain ensures temperature control from farm to market.

Components:

1. Field pre-cooling
2. Packaging
3. Refrigerated transport
4. Cold storage
5. Retail display chillers

Advantages:

- Reduces wastage by 20–30% and maintains quality
- Reduces contamination and increases farmer income

- This is crucial for urban retail chains.

5. Post-Harvest Handling Techniques (HOR Curriculum Focus):

- Gentle harvesting
- Cleaning and trimming
- Proper grading
- Washing with chlorinated water (100 ppm)
- Rapid drying before packing
- Using food-safe crates instead of sacks

Conclusion:

Leafy vegetables are highly perishable but essential dietary components. Post-harvest handling and improved storage technologies are crucial to reduce losses, maintain nutritional quality, and ensure better marketability. Technologies such as pre-cooling, cold storage, MAP, edible coatings, natural antimicrobials, and nanotechnology-based smart packaging play an important role in extending shelf life. For India, the integration of low-cost and high-efficiency technologies, supported by farmer training and government schemes, will significantly enhance the storage, value, and availability of leafy vegetables. The future of post-harvest storage lies in combining sustainability with advanced technology.

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MEDIA STERILIZATION IN PROTECTED STRUCTURE

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ABSTRACT

Sterilisation of growing media is an essential practice in plant cultivation to eliminate harmful microorganisms and pests that adversely affect plant growth. Soil and soilless media often harbor a range of pathogens, nematodes, insects, and weed seeds, making sterilisation vital for healthy plant establishment. Various physical, chemical, and biological methods are employed for soil disinfestation. Common approaches include soil solarisation using transparent polyethylene films, formaldehyde application, hydrogen peroxide with nano-silver treatment, and the use of fungicides, insecticides, and bio-agents such as *Trichoderma*. Each method has its own advantages, limitations, and suitability depending on the crop, environment, and resource availability. Effective sterilisation enhances plant health, reduces disease incidence, and ensures better crop productivity.

Keywords: Soil sterilization, Soil solarization, Formaldehyde treatment, Hydrogen peroxide, Bio-agents

Introduction:

Sterilisation refers to the process of destroying or removing all forms of microbial life from a medium or surface. In horticulture, soil or soilless media provide mechanical support, moisture, and nutrients to plants but also serve as a favorable environment for microorganisms, including bacteria, fungi, nematodes, and weeds. While some microbes are beneficial, others cause serious plant diseases, leading to yield loss and poor plant vigor. To eliminate these harmful organisms and ensure healthy crop growth, sterilisation or pasteurisation of the growing media becomes essential. Different methods—physical, chemical, and biological—are employed for this purpose, with the choice depending on cost, effectiveness, and safety. Common sterilisation techniques include soil solarisation, steam treatment, and the use of chemical agents like formaldehyde and hydrogen peroxide, as well as biological control through beneficial microbes.

Sterilisation of Growing Media:

Sterilisation can be defined as the process of removal or destruction of all forms of microbial life. Any sterile item in the microbiological sense actually has to be free of any living microorganisms. Micro-organisms can be killed, inhibited or removed by exposing material to lethal agents which may be physical, chemical or ionic in nature or in the case of liquids, physical elimination of cells from the medium.

Soil Sterilisation:

The soil or soilless media are used for growing the plants, supporting the plant, retaining the moisture and providing water and nutrients for the root system. The media used for cultivation of plants are also often congenial for the growth of micro-organisms viz. bacteria, fungi, actinomycetes, protozoa, viruses, insects, nematodes and weed seeds. The microorganisms include beneficial as well as harmful, i.e., soil-borne plant disease causing organisms. To eliminate soil-borne pathogens, nematodes, insects and weeds to obtain healthy growth of plants, it is essential to sterilise or pasteurise the soil or soilless media.

Methods of Soil Disinfestation:

A variety of techniques and agents are available for soil disinfestation. They act in many different ways and each has its own limits of application. The selection of a method depends upon the desired efficiency, its applicability, toxicity, availability and cost and effect on the properties of the object to be disinfested. Among the variety of physical and chemical agents and techniques available, the more commonly used for soil or substrate sterilisation are moist heat, i.e., steam sterilisation and chemicals, i.e., fumigants.

Soil Solarisation:

High intensity solar radiation during summer (April– June) is used as a lethal agent for the control of plant pathogenic organisms, insects, nematodes and weeds through the use of transparent polyethylene films and this is known as soil solarisation. The step-by-step procedure of soil solarisation includes—

(i) Soil should be ploughed first.
(ii) Irrigate the field very ligthly.
(iii) Cover the field with transparent UV-stabilised 25 micron polyfilm for 20–30 days.
(iv) The sides of the film should be covered with soil to avoid entry of outside air.
(v) Soil solarisation is not a foolproof method for sterilisation.

Soil Sterilisation by Formaldehyde:

It is an excellent sterilising agent for controlling harmful soil microbes. It is marketed in aqueous solution as formalin which contains 37–40 per cent formaldehyde. The soil or root substrate to be sterilised is loosened and the solution prepared by mixing 4 L formalin in 19 L of water is poured or sprayed on the soil @5 ml/sq m area. The rate of application depends upon the moisture content, depth of soil and type of soil. The land is covered with thin plastic film to retain the fumes generated. Removal of plastic film (after 7 days), complete evaporation of smell of formaldehyde will take place in about 15–20 days. After that, sowing or planting should be done. It has limited effect against nematodes and should not be used in standing crops. Its use has to be preferably avoided as it is a general biocide (a substance that destroys or inhibits the growth or activity of living organisms), detrimental to the health and safety of the production system.

Soil Sterilisation by Hydrogen Peroxide:

Hydrogen peroxide with nano particle silver can be used for sterilisation. Since this solution is in liquid form, it can be applied using drip irrigation system. The recommended dose of the solution is 35–40 ml/ sq m, however care should be taken that the soil beds are gently watered beforehand. The main advantage of using this solution is that sowing/planting can be done the very next day. Other sterilisation methods include heat or steam sterilisation, which have limitation of application under field conditions due to high expenditure.

Soil treatment by fungicide:

Fungicides like thiram @ 5 g/m2 are used to control soil-borne pathogens. These fungicides can also be used as soil drench by preparing a solution of 2.5−3 per cent and drenching @ 4−5 litre/m2.

Soil treatment by insecticide:

Insecticide, such as chloropyriphos @ 2 ml/litre of water is applied to a depth of 15−20 cm in the soil to kill insects, including ants, white ants and their eggs, nematodes, etc.

Use of bio-agents:

Certain biological agents like *Trichoderma* are used to control soil-borne pathogens.Bio-agents @ 10–25 g/m2 are mixed in the soil, and after 2–3 days, the seeds are sown.

Conclusion:

Sterilisation of growing media plays a crucial role in producing healthy and disease-free plants by eliminating soil-borne pathogens, insects, nematodes, and weed seeds. The choice of sterilisation method depends on factors such as the type of media, availability of materials, cost, and environmental safety. While chemical methods like formaldehyde and hydrogen peroxide are effective, they must be used cautiously due to potential toxicity and environmental concerns. Physical methods such as soil solarisation and steam sterilisation offer eco-friendly alternatives, though they may have limitations in efficiency or cost under field conditions. The integration of biological agents like *Trichoderma* provides a sustainable and environmentally safe approach to soil health management. Therefore, adopting a suitable combination of sterilisation methods ensures improved plant growth, higher productivity, and long-term soil health.

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Management of ectoparasites of Dairy animals to improve their productivity

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ABSTRACT

Ectoparasite infestation is a significant yet often overlooked constraint on livestock production worldwide, adversely affecting animal health, welfare, and economic returns. Ectoparasites such as flies, fleas, mites, ticks, and lice reduce productivity by impairing feed intake and causing physiological stress. They also serve as vectors of multiple diseases. Conventional reliance on chemical acaricides has led to widespread resistance and environmental contamination, necessitating the development of sustainable alternatives. Integrated ectoparasite management, incorporating physical, mechanical, chemical, biological, and botanical control strategies, offers an economically viable and environmentally friendly approach. Promising biological agents such as entomopathogenic fungi (*Metarhizium anisopliae* and *Beauveria bassiana*), phytochemical extracts, sterile insect techniques, improved farm hygiene, and targeted treatment strategies provide effective long-term solutions.
Keywords: *Biological control, Ectoparasite, Sterile insect technique, Vectors, Welfare.*

Introduction

Infestation due to ectoparasites represents a significant and often underestimated constraint on global livestock productivity, with profound implications for food security, economic sustainability, and animal welfare. Ectoparasites are organisms that inhabit the skin or outgrowths of the skin of another organism (the host) and may be detrimental to the host (Sharma et al. 2021). Ectoparasites in livestock can be classified into five main groups: flies, fleas, mites, ticks, and lice. Tick-borne diseases (TBDs) have been recognized as a major cause of production loss, predominantly in tropical and subtropical countries worldwide (Parthiban et al. 2010). Ectoparasite leads to a reduction in milk production by 20 to 30% by influencing the animals' feed intake. They also act as a vector to various diseases in livestock, which are further transferred to the products and by-products of animals, consumed by humans. Due to their persistent associations with decomposing substrates, they carry a rich and diverse bacterial community. Hence, from the public health perspective also there is dire need to check the occurrence of ectoparasites. It has been established that ectoparasite affects the behaviour and welfare of animals, thereby affecting their productivity. The economic burden due to ectoparasites comprises direct production losses and costs associated with control measures, including the growing challenge of anthelmintic resistance. The animals infested by ectoparasites show frequent twitching of skin and muscle, movement of the tail, rapid ear movement, and stomping and lifting of legs. They are found to be more sensitive to the environment. Chemical acaricides are being used extensively to manage ectoparasite populations, which has led to the development of antimicrobial resistance becoming a major problem. Consequently, there is a need for an alternative approach to manage ectoparasite populations.

Figure 1: Milk and Livestock feed contaminated with flies

Figure 2: Egg contaminated with faecal droppings

Factors affecting the ectoparasite population

There are certain factors that affect the population of ectoparasites. El-Ashmawy et al. (2021) described those factors as precipitation, ambient temperature, relative humidity, decaying organic matter, feeding practices, and manure handling. The number of ectoparasites is dependent on seasons, showing greater abundance in summer and autumn seasons as compared to winter and monsoon seasons (Ajith et al. 2020). Other factors that influence the abundance of ectoparasites in livestock are the age of the animal, the sex of the animal and the managemental practices in the farm. Female animals were found to be more infested with ticks as compared to the males because of the hormonal fluctuations, and also the females suffer from more stressful conditions like lactation stress, parturition stress, etc. More number of ticks were observed in the animals that were reared under intensive conditions as compared to the ones reared under semi-intensive and extensive conditions.

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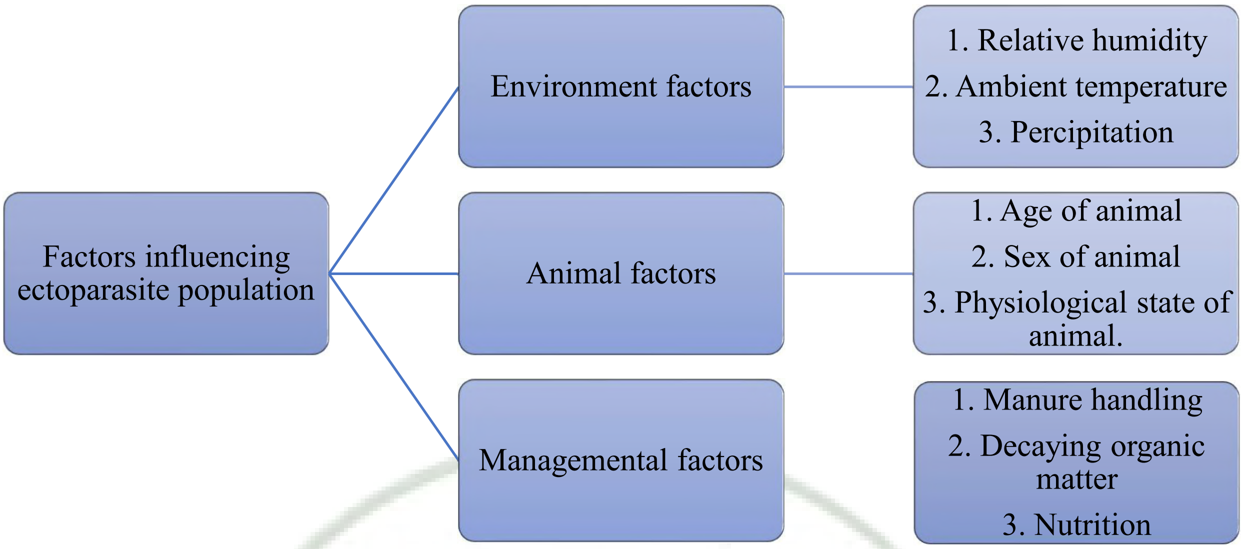

Figure 3: Factors influencing ectoparasite population in livestock

Methods of ectoparasite control

Ectoparasites can be controlled by modification of the host environment by following proper sanitary guidelines, biological agents like the entomopathogenic fungi, using mechanical traps, and using chemicals that are anti-ectoparasitic (mechanical trap materials). A recent approach in controlling the population of ectoparasites is the sterile insect technique. In this technique, sterile male insects are released, and following mating of fertile females with these males leads to a decrease in the population in subsequent generations. Integration of all these methods is necessary to manage the population of ectoparasites in an economically sustainable and environmentally friendly manner. The farmers with a small herd size of 2-5 animals' resort to manual removal of the ectoparasites and burning them. In the rural areas, farmers use smoke to retard fly effects by masking the scent of the livestock and interfering with the respiration of the insect. The most effective and sustainable method of ectoparasite control, which is also economical, is the Integrated Management (IM) of arthropods. It involves the effective, economical, and sustainable combination of mechanical, biological, herbal, and chemical control measures. Reducing the probability of contact between the hosts and ticks can be done by following proper management of pastures, by using bioactive compounds of plants, and by using natural predators like birds and entomopathogenic fungi. Due to resistance towards the commonly used acaricides, to manage the ectoparasite population targeted treatment approach can be followed rather than treating the whole herd. Ectoparasites population can also be controlled by improving the immunity of the host against the ectoparasites, which can be done by routine vaccination, modification of the genetic component, and through a scientific nutritional approach.

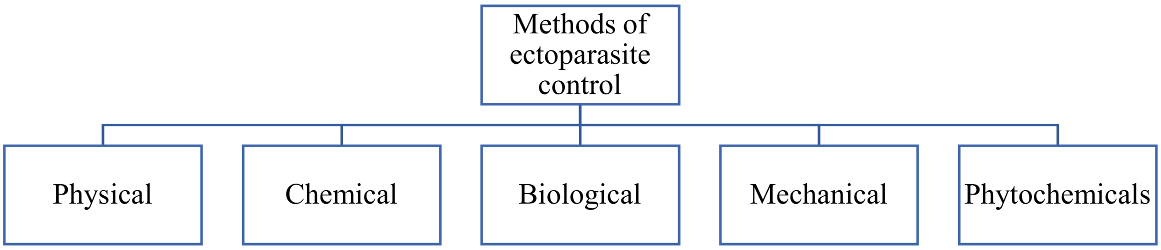

Figure 4: Methods of ectoparasite control

Physical method

Manure management is very important to maintain the hygiene in a farm, which indirectly affects the population of ectoparasites on the farm. Covering of manure pits with polythene sheets such that it is not exposed to air has shown promising results of 86% larval death of *haematoba exigua* flies, indicating that the physical method of covering the dung pits can be inducted in the IM program as one of the effective physical control alternatives (Gudewar et al. 2023). Stationary attracting devices, like some piece of cloth or a target, can also be used, to which some pheromones are fixed. This type of devices attracts the flies and guide them to a non-returning chamber in which they are killed. It has also been found that ectoparasites, mostly flies, can be managed by manipulating their sensory activities. Using blue, red, and yellow colour lights has been proven to attract insects, among which it blue colour was found to attract more than yellow and red. A sticky trap using castor oil illuminated by a blue colour LED bulb was effective in reducing the number of flies in a dairy farm, and such physical methods can be used to manage flies in farms (Praveenkumar et al. 2022). Other methods include the use of a vessel with detergent dissolved in it, which is left in an open area in the farm to which the insects are attracted due to the reflecting surface of the detergent solution. Potable vacuum fly traps have been developed in some countries, which have yielded significant results in reducing the fly load on dairy animals. In such devices, the animal is led to a closed chamber equipped with brushes and flaps to remove the flies, which are then collected by a vacuum attached to the chamber (Kienitz et al. 2016)

Chemical methods

Chemical control of ectoparasites comes in different forms, like dip, spray, topical applications, ear-tags, and injections. They belong to different classes of organophosphates, carbamates, synthetic pyrethoids, formamidines, and macrocyclic lactones. Over the years, there has been extensive use of chemical acaricides, because of which the ectoparasites have developed resistance to them. Chemicals like fipronil and ivermectin remain in animal excreta, contaminating water and soil and damaging non-target organisms like aquatic crustaceans *(Daphnia magna)* and dung beetles *(Scarabaeidae),* which interfere with aquatic ecosystems and nutrient cycling. This also contaminates the fodder and grasses and persists in products and by-products of livestock, which are consumed by humans.

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Biological agents

Traditional chemical acaricides are being replaced by biological agents for ectoparasite management. Through predation, parasitism, pathogenicity, or competition, biological control (BC), also known as biocontrol, acts on ectoparasites. Bio-control uses live organisms, including fungi, bacteria, and predators, to interfere with parasite life cycles, lower population density, or prevent establishment. Indirect agents alter environmental factors to interfere with parasite life cycles, while direct BC lowers parasite numbers by restricting reproduction or inducing mortality. Efficacy is increased by techniques like traditional BC, augmentation, and conservation, which are frequently combined with integrated pest control (IPM) techniques such as rotational grazing and the selective application of anthelmintics. The most promising entomopathogenic fungi appear to be *Metarhizium anisopliae* and *Beauveria bassiana*. These fungi penetrate the integuments of the ectoparasite, leading to systemic infection of parasite. While the BC like virus and bacteria kill the ectoparasites by inducing infection upon ingestion by the ectoparasites. Entomopathogenic nematodes that are pathogenic to ticks can potentially control ticks. Genetically modified organisms are also being developed for insect resistance and are being effectively used at present. Biological control can be classified into two types based on their mode of action: direct and indirect biological control. The direct biological control agents act by limiting the reproduction and causing mortality of the ectoparasites, and the indirect agents act by modifying the environment of the ectoparasite and thereby interrupting their life-cycle. For example, some dung beetles and earthworms disintegrate and relocate the faecal eggs of ectoparasites present in dung (Kumar et al. 2025).

Mechanical methods

Hot and humid conditions are a conducive environment for the development and survivability of larvae. It is important to maintain the micro-climate in the farm sheds. In addition to maintaining ideal air temperatures, eliminating gases like ammonia and supplying fresh air are also important. Ventilation (airflow) lowers the moisture content of manure and keeps the environment clean. Environmentally managed high-rise homes are ventilated by exhaust fans housed in the walls of the manure pit. Inlets and outlets in the shed should be of proper design and at appropriate heights to maintain the required air circulation. Moisture can be decreased by placing fans on either side of the manure pit. In order to control flies, good cleaning techniques using disinfectants and cleaning agents are also crucial.

Phytochemicals

This is another approach of ectoparasite management in livestock. Bioactive compounds of some plants have been found to have acaricidal properties against the tick. *Rhipicephalus microplus* and *Hyalomma anatolicum* are among the most commonly found ticks in the Indian subcontinent. Chrysanthemum *(Dendranthema grandiflora)* extract (0.5mg/ml) and neem *(Azadirachta indica)* oil emulsion (20mg/ml) demonstrated high effectiveness against *Rhipicephalus sp.*, with results indicating strong dose-and time-dependent effects compared to controls. Use of phytochemicals has the advantages of quick action, lack of persistence in the body of livestock, and no accumulation in the environment, unlike the synthetic chemical acaricides.

Conclusion

The concerns due to ectoparasites in livestock are wide in terms of the economics of animal production, animal welfare, public health and environment, due to which there is a dire need to explore sustainable solutions for their management. Integrated management of ectoparasites can be a promising sustainable approach if it is planned and executed scientifically. The use of a specialized fly trap to remove flies from cattle by exploiting the natural behavior of the flies. Management of the factors in the shed and on the farm that influence the lifecycle of ectoparasites should not be overlooked for reducing the ectoparasite load on the farm. Sterile insect technique approaches, which are advances in ectoparasite genomic science can be explored more in dairy animals. Plant plays a significant role in ecosystems and has the potential to be used as substitutes for current insect-control chemicals due to their diverse range of bioactive substances.

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Understanding Value Chain and Supply Chain: A Comparative Analysis from the Dairy Sector

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ABSTRACT

The concepts of supply chain and value are important in understanding the efficiency, competitiveness, and economic performance of agri-food systems, particularly in perishable sectors such as dairy. While the supply chain focuses on the coordinated flow of milk, information, and logistics from producers to consumers, the value chain emphasises value-adding activities, including processing, packaging, branding, and marketing that enhance the quality and marketability of dairy products. This paper provides a comparative analysis of supply chain and value chain frameworks, supported by illustrations from the dairy sector. The study highlights that value chain upgrading through product diversification and processing significantly increases farmers' income and enterprise profitability, whereas supply chain efficiency ensures quality maintenance and timely delivery. The findings highlight the need for integrated approaches that combine efficient supply chain management with strategic value chain development to improve farmer welfare, enhance market competitiveness, and promote sustainable growth in the dairy sector.

Keywords: Consumers, Dairy, Marketing, Supply chain, Value chain

Introduction

The concepts of supply chain and value chain have gained significant importance in the analysis of agricultural and food systems. Although these terms are often used interchangeably, they reflect two different perspectives on how products move, transform, and create value from producers to end consumers. The supply chain emphasises the flow of materials, the transformation of raw materials into semi-finished goods or finished goods (Render and Munsan, 2017), information, and logistics, focusing on timely movement, operational efficiency, and reduction of costs and losses. Although the supply chain is comprised of a number of business components, the chain itself is viewed as a single entity.

Value chain is a concept that comes from the science of business management, developed and popularised for the first time in his book "Competitive Advantage: Creating and Sustaining Superior Performance". Porter defines "value" as the amount of money consumers are willing to pay for what the company or producer provides (Porter, 2008). Value chain highlights the value-adding processes that enhance the quality, utility, and marketability of a product at each stage of its journey. These activities may include cleaning, grading, processing, packaging, branding, and marketing-steps that not only improve the product but also increase the economic value captured by different actors. Value chains therefore, provide a broader, more strategic view by examining how stakeholders can upgrade practices, strengthen coordination, and respond to evolving consumer preferences for quality, safety, and differentiation.

Understanding supply chain and value chain is essential for improving efficiency, competitiveness, and sustainability in agri-food systems. This is particularly relevant for perishable commodities such as milk, fruits, and vegetables, where both rapid movement and value addition are critical. A clear conceptual foundation helps researchers, policymakers, and practitioners design targeted interventions that reduce inefficiencies, promote value creation, and enhance incomes across the system. Against this background, this paper examines the theoretical differences between supply chain and value chain, with specific illustrations from the dairy sector.

Key activities in the supply chain

Planning: It is a critical activity that involves forecasting demand, managing inventory levels, and coordinating resources to ensure that products are available when needed.

Sourcing: It involves identifying and selecting suppliers for raw materials and components. This activity includes negotiating contracts, managing supplier relationships, and ensuring that the materials meet quality standards.

Production: It encompasses the processes involved in transforming raw materials into finished products. This includes manufacturing, assembly, and quality control.

Distribution: It is the process of delivering finished products to customers. This activity involves logistics management, including transportation, warehousing, and inventory management.

Operations: The management involves overseeing the day-to-day activities of the supply chain. This includes monitoring performance metrics, managing workflows, and ensuring that all processes run smoothly.

Aftermarket Services: Aftermarket services include support and maintenance provided to customers after the sale. This involves handling returns, repairs, and customer service inquiries.

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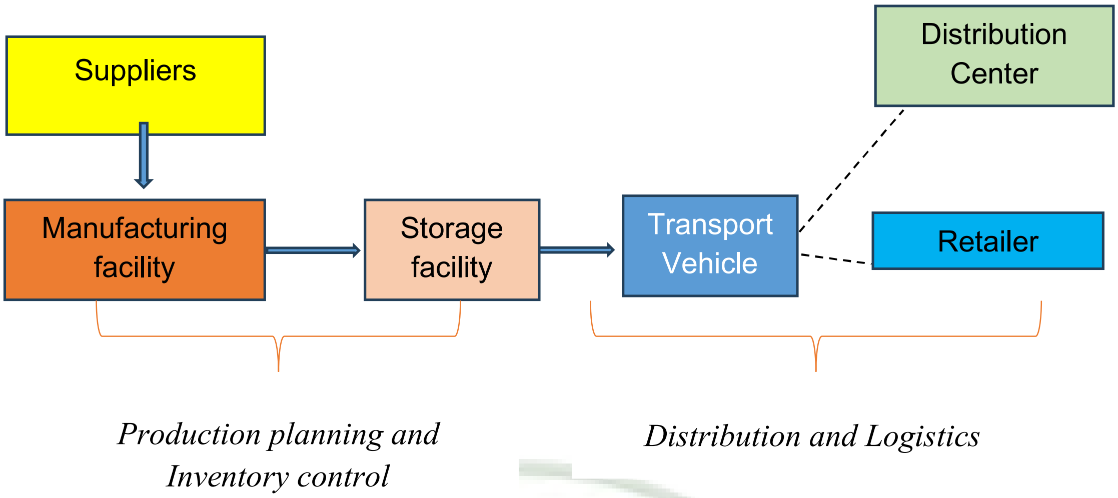

Figure 1: The supply chain process

Primary Activities in a Value Chain

The primary value chain, or the main activity value chain, consists of five dimensions of the main activities involved in the manufacturing process. The five dimensions of the value chain described below are adopted from various sources, especially from (Ketchen and Eisner, 2009; Kuncoro, 2006; Porter, 2008).

Inbound Logistics: Handling and receiving raw materials, impacting cost-efficiency and production timelines. This includes raw material procurement, storage and inventory management, transportation of inputs, quality testing of incoming materials.

Operations: Transforming raw materials into final products with a focus on reducing waste and improving quality. Manufacturing and processing, sorting, cleaning, grading, assembly operations, quality control during production.

Outbound Logistics: Ensuring timely distribution of products to retailers or customers, minimizing delays. Warehousing of finished products, transportation and distribution, cold chain management (for perishables).

Marketing and Sales: Promoting the product's value to potential customers. Advertising and branding, pricing strategies, market research, retail partnerships, packaging designed to attract customers.

Service: After-sales support to maintain customer satisfaction and loyalty. Customer support, product warranty, after-sales service, feedback and complaint handling.

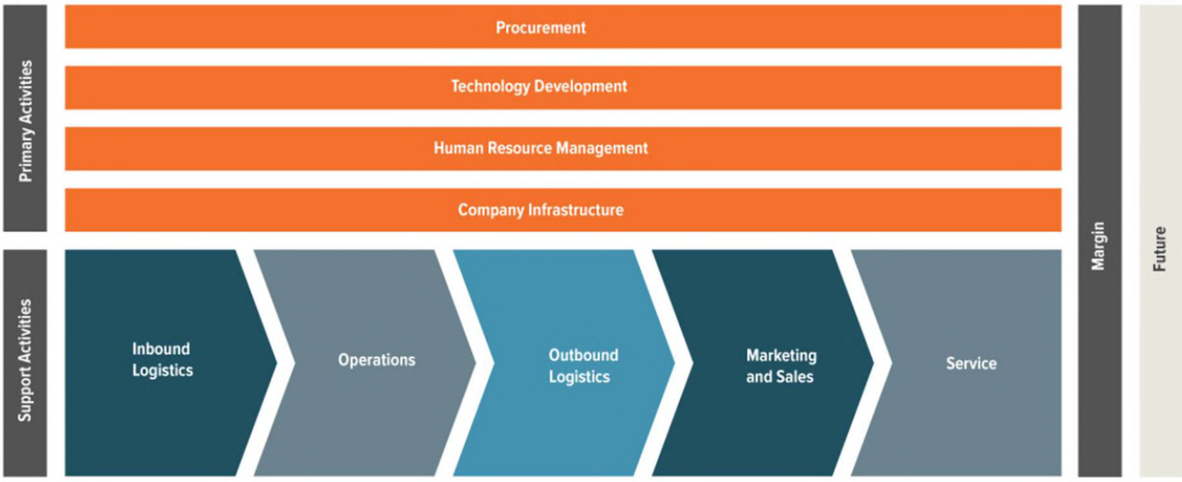

Figure 2: Michael Porter Value Chain

The value chain focuses on how value is added at each stage, from milk production to the final dairy product reaching consumers. It highlights activities that improve product quality, efficiency, and profitability.

Evidence from the dairy sector

The dairy sector indicates that the supply chain primarily ensures efficient milk procurement, chilling, transportation, and distribution to maintain quality. Organized systems, such as those developed by Amul and NDDB, have emphasised transforming raw milk into value added products such as pasteurised milk, ghee, and cheese to enhance economic returns. Studies show that value added dairy products yield higher income profits of dairy enterprises, highlighting the importance of value chain upgrading. However, to be economically profitable, dairy entrepreneurs need not only create greater added value through the processing and sale of dairy products but also expand sales channels and work on product differentiation (Onishi, 2025).

Dairy Supply Chain

The supply chain focuses on the flow of raw materials, products, information, and logistics from the point of origin to the consumer. It highlights movement, transport, storage, and coordination. The activities in the supply chain include;

Milk collection: Farmers deliver milk to village collection centres

Transportation: Milk is transported in tankers to chilling centres

Storage: Chilling and cold storage maintain freshness

Distribution: Processed milk and products moved to distributors/retailers

Retail Sale: Products reach shops and consumers

Focus: Movement, logistics efficiency, timely delivery, cold chain management.

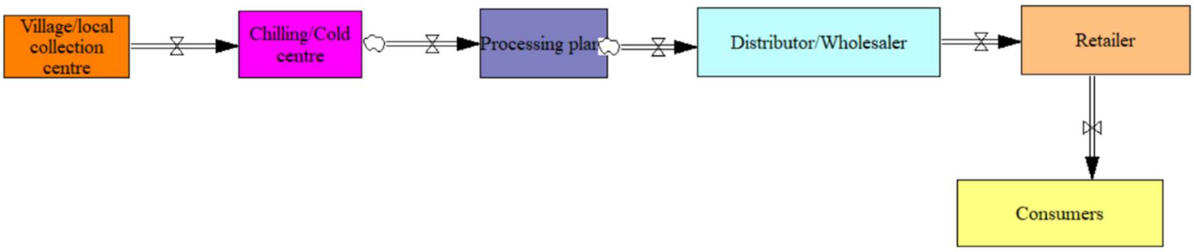

Figure 3: Flow of milk channels in the supply chain

Dairy Value Chain

Milk Production (Farmer): Quality feeding, hygienic milking → improves milk quality

Collection and Chilling: Milk collection centres chill milk to preserve freshness → adds value

Processing: Pasteurisation, homogenization, converting milk into curd, paneer, butter, etc.

Packaging: High-quality packaging increases shelf life

Marketing and retail: Branding Amul paneer, Mother Dairy curd → increases consumer value

Focus: Improving quality, value addition, branding, and efficiency.

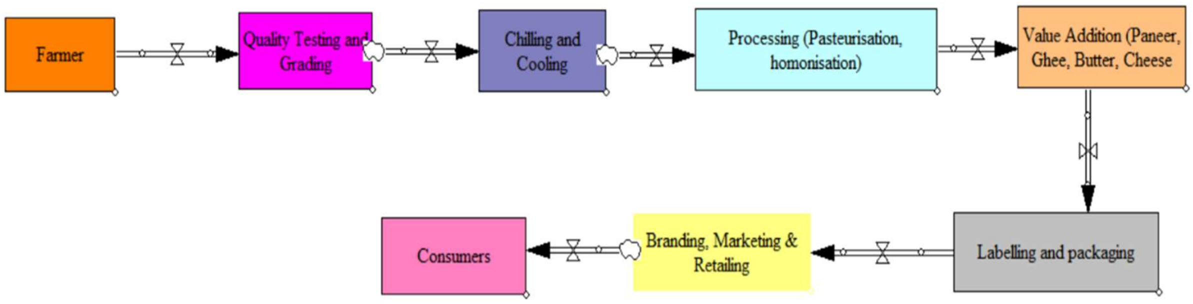

Figure 4: Flow of milk channels in the value chain

Conclusion

Understanding the activities in the supply chain and value chain is essential for businesses looking to optimize their operations and improve overall efficiency. By effectively managing each of these activities, entrepreneurs can enhance their competitiveness and better meet customer needs. While the supply chain ensures the physical availability of milk and dairy products, the value chain ensures quality, value addition, and better economic returns for all stakeholders. In the dairy sector, where perishability, quality, and consumer demand for diversified products are critical, the integration of efficient supply chain logistics with robust value chain development is essential for sustainable growth. Strengthening cold chain infrastructure and ensuring uninterrupted temperature control are essential for both supply chain efficiency and value chain development in dairy. Support for processing units, dairy cooperatives, and FPOs can help farmers capture greater value through diversified milk products.

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Invaders Beneath the Waves: The Economic Toll of Invasive Fish Species in India

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INTRODUCTION

India's freshwater and marine ecosystems are home to an astonishing diversity of more than 2,953 fish species (NBFGR, 2025), many found nowhere else in the world. But beneath the surface, an ecological battle is taking place. Invasive fish species introduced intentionally or accidentally are spreading fast and threatening native biodiversity fishers' livelihoods and the nation's economy (Haubrock *et al*, 2022). The exotic fishes introduced into India for different purposes covers nearly 13.6% of total fish diversity (Joshi *et al,* 2021). Due to wider tolerance limit some alien fish species have acclimatised to diverse eco-climatic conditions.

When Strangers Take Over

Invasive species are non-native organisms that establish spread and cause harm to the environment, economy or human health (Xie J, 2023). In Indian waters, several such species have found a comfortable home. The most notorious include the African catfish (*Clarias gariepinus* or *Thai magur*), common carp (*Cyprinus carpio*), tilapia (*Oreochromis mossambicus*), and more recently, the red-bellied piranha (*Pygocentrus nattereri*) and suckermouth catfish (*Hypostomus plecostomus*) (Bipul Phukan and Niti Sharma, 2020 and Mahapatra and Mohanty, 2023)

While some of these species were brought in with good intentions for aquaculture, weed control and ornamental purposes they have often escaped confinement and multiplied in natural waters, displacing local species.

The Economic Bite

The economic loss from invasive fish species in India is significant though difficult to fully estimate. According to studies by the National Bureau of Fish Genetic Resources (NBFGR), exotic species now constitute over 35% of India's total aquaculture production, but their invasion into natural systems has caused local fish populations to collapse especially in rivers and reservoirs.

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In states such as Tamil Nadu, Kerala and West Bengal, fishers have reported declines in catches of native species such as *Labeo rohita* and *Catla catla*, largely due to competition from invasive species such as tilapia and common carp. These ecological changes have led to reduced catch volumes and economic instability in several inland fisheries (FAO, 2020; CIFRI, 2022).

Invasive predators like the African catfish, which grow fast and eat almost anything, have devastated small-scale fishers' nets and stocks. Meanwhile, the armored suckermouth catfish, often discarded from aquariums, clogs nets and damages riverbeds making fishing labor-intensive and less profitable (Chander, 2016, Singh et al. 2015, and Roy et al. 2022).

A 2022 report by the ICAR-NBFGR estimated that India may be losing hundreds of crores annually in direct and indirect losses due to invasive aquatic species, considering their impact on fish catch, biodiversity, and water ecosystem management costs.

Biodiversity Loss/Economic Loss

The problem isn't just about numbers — it's about ecological balance. Native species like *Tor putitora* (mahseer) and *Mystus cavasius* (tengra) are culturally and economically important but are being pushed out of their habitats. As these native stocks decline, fishers must travel farther, spend more on fuel, and get smaller returns, creating a ripple effect of economic stress.

Tourism and aquaculture sectors also feel the heat. Lakes infested with tilapia or suckermouth catfish lose their scenic value and fish diversity, hurting eco-tourism and recreational angling industries (Tayade, 2023)

How They Sneak In

The pathways are varied like aquaculture escapees, ballast water from ships, ornamental fish trade, or even deliberate release by unaware fish farmers. For instance, tilapia was once promoted for fast growth but its uncontrolled spread into reservoirs now threatens native biodiversity.

Fighting Back the Invaders

India has begun taking action. The ICAR-NBFGR maintains a National Surveillance Programme for Aquatic Animal Diseases and monitors invasive species (MFAH&D, 2025). The farming and breeding of the exotic African catfish is banned in all states and Union Territories across India due to the species' predatory nature and the severe threat it poses to native aquatic biodiversity and ecosystems.

Awareness campaigns, strict regulation of exotic species import, and habitat restoration are steps in the right direction. However, policy enforcement and fisher-level awareness remain weak. Many small-scale fish farmers are unaware of the ecological dangers and continue to stock invasive species for short-term gains.

Conclusion

Managing invasive fish species is not just an environmental issue, it's an economic and livelihood challenge. Protecting native fish populations means protecting the income and food security of millions of fishers across India. India needs stronger biosecurity laws, better screening of exotic species, and promotion of native species in aquaculture. Scientific management combined with local awareness can turn the tide. As India strives toward sustainable fisheries and blue economy goals, keeping invaders in check is essential. After all, the health of our waters determines the health of our communities.

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The Role of Agricultural Statistics in Ensuring Global Food Security

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INTRODUCTION

Reliable agricultural statistics are fundamental to achieving global food security. They provide accurate measures of crop production, trade flows, input usage, and population demand. Policymakers rely on data to design interventions, allocate resources, monitor progress, and respond to shocks. Lack of data or poor-quality statistics undermines early warning systems, hampers market transparency, and weakens food systems' resilience. This article reviews the role of agricultural statistics in ensuring global food security. It examines the definitions of food security and how statistics interact with its dimensions; explores the data lifecycle and institutional frameworks; addresses key applications including monitoring, modelling and early warning; discusses major challenges and data gaps; and presents case studies. The article concludes with recommendations for strengthening statistical capacity and integrating data into decision-making for a secure food future.

Keywords
agricultural statistics, food security, data systems, early warning, agrifood systems

1. Introduction

Food security is widely defined as a situation when "all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." In this context, agricultural statistics refer to systematic collection, analysis, interpretation and dissemination of data on agriculture, food production, trade, inputs, land use, employment and related areas. This article examines how agricultural statistics support global food security. It is structured

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into five major parts: definitions and linkages; statistical frameworks and data systems; applications of statistics; challenges and data gaps; and case studies. It then ends with a conclusion offering actions. The aim is to provide a clear, detailed overview in straightforward language.

2. Food Security and the Role of Data

2.1 Dimensions of Food Security

The four core dimensions of food security are: availability, access, utilisation and stability.

- **Availability**: refers to the supply side (production, stocks, imports).
- **Access**: relates to households' economic and physical ability to obtain food.
- **Utilisation**: involves nutritional value, diet diversity, food safety, storage/preparation.
- **Stability**: means that availability, access and utilisation are reliable over time, and not subject to shocks. For food security policies to succeed, all four must be addressed simultaneously.

2.2 How Agricultural Statistics Connect

Agricultural statistics feed into each dimension:

- **Availability**: Data on crop yields, harvested area, production volumes, stock levels, trade flows. Without accurate production data we cannot estimate supply. For example, Food and Agriculture Organization of the United Nations (FAO) reports that global crop production reached 9.6 billion tonnes in 2022, up 56 % since 2000.
- **Access**: Price statistics, input costs, wage and employment data matter. If data show rising prices or falling incomes, access may be jeopardised. For example, the Global Food Security Index (GFSI) uses availability and affordability as pillars.
- **Utilisation**: Nutrition and diet-related statistics, food safety data, post-harvest loss statistics. The FAO Yearbook links dietary data and employment in agrifood systems.
- **Stability**: Time-series statistics and early warning systems require consistent data over years to detect shocks (weather, pests, price spikes). Without reliable historic data, stability cannot be assessed.

Thus, agricultural statistics are not just measure-keeping. They are fundamental infrastructure. They enable governments, international organisations, researchers and private sector actors to monitor the state of food systems, identify vulnerabilities, design interventions and evaluate outcomes.

2.3 Link to Global Food Security Goals

The global agenda includes Sustainable Development Goal 2 (Zero Hunger) which aims to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture."

Achieving this goal demands measurable progress. Agricultural statistics provide the metrics. For example, FAO's Statistical Yearbook 2024 emphasises that "timely, accurate and high-quality data and statistics are the cornerstone of solid policy design." Without good data, progress cannot be tracked and policy cannot be well-informed. This makes statistics a cornerstone of global food security.

3. Statistical Frameworks, Data Systems and Institutions

3.1 Institutional Frameworks

Many organisations contribute to agricultural statistics. FAO collects, consolidates and disseminates data globally through its FAOSTAT database. National statistical offices gather agricultural data at country level: land use, crop area, yield, livestock numbers, inputs. Donor agencies such as United States Department of Agriculture (USDA) assist countries in building statistical capacity. International frameworks like the World Bank promote data collection and open access. Thus the institutional architecture spans national, regional and global levels.

3.2 Data Lifecycle: Collection, Analysis, Dissemination

- **Collection**: Surveys (farm-level, household), census of agriculture, remote sensing, administrative data (input sales, trade flows).
- **Processing & Analysis**: Minor cleaning, estimation of missing data, benchmarking, aggregation to national/regional levels.
- **Dissemination**: Publication of statistics, yearbooks, open databases (e.g., FAOSTAT), dashboards.
  Example: FAO's Yearbook 2024 includes country-level employment in agrifood systems and new dietary-related data.
  These steps require quality assurance, clear metadata, transparent methodology and timely updates. Without these, statistics lose value.

3.3 Data Quality Standards and Metadata

Quality dimensions include relevance, accuracy, timeliness, consistency, comparability and accessibility.For example, when governments train statistical staff, assess country statistical capacities in agriculture and market information systems (as the USDA did for Ghana, Haiti, Tanzania, Bangladesh) to improve statistics systems.
Good metadata (information about how data were collected, definitions, units) is essential for users to interpret and compare data across countries.

3.4 Case Example: FAO Statistical Yearbook 2024

The Yearbook demonstrates how agricultural statistics are used to reflect trends in food security and agrifood systems. Highlights: global agricultural value increased 89 % in real terms over two decades to $3.8 trillion (2022). The proportion of workforce in agriculture fell from 40 % in 2000 to 26 % in 2022. Hunger remains: in 2023 between 713 and 757 million people were undernourished.
This demonstrates how aggregated statistics provide baseline for policy.

4. Applications of Agricultural Statistics to Food Security

4.1 Monitoring and Reporting

Statistical data allow monitoring of production, stocks and trade. For example, if country data show a drop in staple crop production, it triggers concerns about availability. The World Bank notes that agricultural sector growth is at least twice as effective in reducing poverty compared with other sectors. Example: The GFSI uses data on availability, affordability, quality/safety, sustainability/adaptation to rank 113 countries. It found that affordability and food quality/safety pillars deteriorated in 2022. Thus, monitoring is a key application.

4.2 Early Warning and Risk Assessment

Agricultural statistics support early warning systems for crop failures, pest outbreaks, price spikes, trade disruptions. Without baseline and trend data, detecting anomalies is impossible. Example: The World Bank's recent brief cites hurricanes, droughts, floods disrupting crops (700 000 children affected in Caribbean region) and emphasises data usage for response. Thus data feed risk assessment and resilience planning.

4.3 Planning and Policy Design

Policymakers use agricultural statistics to design interventions: input subsidies, crop insurance, trade policies, nutrition programmes.Example: In Bangladesh, floods destroyed 1.1 million tons of rice, prompting data-driven decisions to import 500 000 tons. Using statistics simplifies resource allocation, targeting of vulnerable groups, and tracking programme impact.

4.4 Market and Trade Analysis

Statistics on production, consumption, inventories, exports and imports support trade policy and market stabilisation. Transparency reduces speculative behaviour and improves efficiency. Financialization of agricultural commodities has been empirically shown to negatively affect food security in developing countries, especially for wheat and soybeans. Thus commodity price and trade data are critical.

4.5 Research, Innovation and Agricultural Productivity

Statistics support agricultural research by providing baseline productivity data, monitoring yield trends, benchmarking countries. For example, analysis showed that accelerated total factor productivity (TFP) growth in Bangladesh and Ethiopia reduced food insecurity. Research outputs are more effective when grounded in good statistics.

5. Challenges, Data Gaps and Future Directions

5.1 Data Gaps and Missing Areas

Many countries have weak agricultural statistical systems. Issues include outdated censuses, incomplete input data, poor monitoring of smallholders, missing nutrition and diet data. The FAO Yearbook flagged emerging dietary data as a major achievement because historically diet data were weak. Some significant gaps: post-harvest losses, on-farm waste, informal trade flows, small-farm productivity, climate risk metrics.

5.2 Quality, Timeliness and Comparability

Data may lack accuracy due to inadequate sampling, inconsistent definitions, or infrequent surveys. Timeliness is a problem: data published with long delay reduce usefulness for rapid response. Comparability across countries suffers if definitions differ (e.g., what counts as harvested area).The USDA found that assessments of agricultural statistics and market information systems in Feed the Future countries identified key areas for improvement.

5.3 Institutional and Capacity Constraints

Many low-income countries lack sufficiently trained staff, funding for surveys, or infrastructure (digital systems, remote sensing capacity). Without investment, statistics will remain weak.For example, agricultural productivity growth in sub-Saharan Africa remains low partly because statistical systems are weak.

5.4 Integration of New Data Sources and Technologies

New technologies (remote sensing, mobile data collection, big data analytics, machine learning) offer opportunities for improved statistics. However, integration remains a challenge. For example, a recent study proposed the "AGRICAF" approach for forecasting agricultural commodity prices using machine learning and econometrics. Harnessing new data sources will be a key future direction.

5.5 Addressing Shocks, Resilience and Climate Risks

Agricultural statistics must increasingly account for climate-related shocks, land degradation, water scarcity, salinity. For instance, 1.4 billion hectares currently affected by soil salinity, threatening yield losses up to 70 % in some areas. Statistics need to integrate environmental indicators with agricultural ones to support resilient food systems.

5.6 Future Directions

- Strengthen national statistical systems, especially in low-income countries, through training, funding, international support.
- Standardise definitions and methodologies to enhance comparability.
- Adopt and integrate new data technologies (satellite, mobile surveys, machine learning).
- Expand statistics to cover nutrition, diet diversity, post-harvest loss, informal trade, labour in agriculture.
- Link agricultural statistics with climate, environmental and socio-economic data to capture systemic risks.

- Promote open access to data for transparency, research and policy use.

6. Case Studies

6.1 Example: FAO Statistical Yearbook Application

The FAO Yearbook 2024 highlighted that although global agricultural value rose 89 % in real terms over two decades to US$3.8 trillion in 2022, the share of the workforce engaged in agriculture declined from 40 % to 26 % over the same period. This kind of statistic helps interpret structural changes in agrifood systems and their implications for food security and rural livelihoods.

6.2 Example: Global Food Security Index

The GFSI in 2022 found that food security performance globally has declined for three years. Affordability dropped due to rising food costs, trade restrictions, and decreased funding for food safety nets. Availability, quality/safety and sustainability/adaptation pillars also weakened. This shows how composite indices built on statistics capture broad food security trends.

6.3 Example: Early Warning – Caribbean Hurricane Impact

The World Bank's food security update in 2025 cited hurricane Melissa which damaged over 16 000 ha of food crops in Haiti and the Dominican Republic and destroyed livestock for nearly 4 000 farming households. Agricultural damage statistics enable timely response such as emergency food aid, imports and rehabilitation of livelihoods.

6.4 Example: Productivity Growth and Food Security

Research shows that countries like Bangladesh and Ethiopia that achieved rapid total factor productivity growth saw declines in food insecurity, stunting and poverty. Here statistical measures of productivity link directly to outcomes in food security.

7. Conclusion

Agricultural statistics are central to ensuring global food security. They underpin all four dimensions of food security: availability, access, utilisation and stability. High-quality, timely and comparable data enable monitoring of food systems, risk assessment, policy design, market transparency, research and resilience building. Current institutional frameworks (FAO, national statistical offices, international agencies) provide platforms for collection and dissemination of data, but significant gaps remain in capacity, data quality, timeliness and coverage of emerging needs (nutrition, post-harvest loss, climate risk and informal trade). Real-world applications show the power of statistics: from yearbooks reflecting structural changes in agrifood systems, to early warning systems responding to natural disasters, to indices tracking global food security trends. Going forward, investment in statistical capacity, standardisation, integration of new data technologies, expansion into under-measured domains and linkage with climate and socio-economic data are critical. For the world to meet goals such as Zero Hunger (SDG 2) and to build resilient, sustainable food systems, statistics must evolve. Without strong

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agricultural statistics, policies will lack grounding, responses to shocks will lag, and progress towards food security will falter. In short, data is not a peripheral tool—it is foundational infrastructure for global food security.

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Mahua-A Tree of Life

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INTRODUCTION

Madhuca longifolia popularly known as Mahua or Mohphul belongs to family Sapotaceae and native to India, Sri Lanka, Nepal, and Myanmar. It is a non-forest timber produce that has significant nutritional and medicinal values. The tree is often referred to as the "Tree of Life of Tribal India". It is also known as Butternut tree, Indian butter tree in English, Madhuka in Sanskrit, Moh in Marathi, Janglimoha, Moha, mohua in Hindi etc. It is a multipurpose tropical tree and thrives well in arid environments. Mahua is a prominent tree in tropical and subtropical regions of Indian mixed deciduous forests is particularly abundant in the central and eastern states like Maharashtra, Madhya Pradesh, Gujarat, Kerala, Uttar Pradesh, Bihar, West Bengal, Jharkhand Chhattisgarh and Orissa.

Taxonomy of Mahua: -

Botanical Name: *Madhuca longifolia*

Family: Sapotaceae

Subfamily: Caesalpinioideae

Tribes: Caesalpinieae

Genus: *Madhuca*

Species: *longifolia*

Order: Ericaleae

Parts Used: Bark, seeds, and flowers

Macroscopy of Mahua: -

Tree is medium to large deciduous shady tree with 16-to-20-meter height. It has short and stout with yellowish-gray to dark brown colour stem. Leaves are thick, short, lanceolate to ovate, 11-15 cm long, 5-8 cm wide, green in colour with bitter taste. Flowers are dull or pale white in

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colour, small fleshy caduceus in shape and bloom in April-May. Ovoid, fleshy, 2-6 cm long, green when young and turn pink after ripening with 1-4 brown colour seeds inside it.

Composition of Mahua flowers: -

Sr. No	Constituents	Fresh Flowers	Dry Flowers
1	Moisture	73.6-79.82 (%, d.b.)	11.61-19.8 (%, w.b)
2	pH	4.6	…..
3	Starch (g/100 g)	0.94	…..
4	Ash (%)	1.5	1.4-4.36
5	Total sugars (g/100 g)	47.35-54.06	41.62
6	Total Inverts (%)	54.24	…..
7	Cane sugars (%)	3.43	…..
8	Reducing sugars (g/100 g)	36.3-50.62	28.12
9	Proteins (%)	6.05-6.37	5.62
10	Fats (%)	1.6	0.09-0.06
11	Fibers (%)	10.8	…..
12	Calcium (mg/100 g)	45	0.14-8
13	Phosphorus (mg/100 g)	22	0.14-2
14	Carotene (μg/100 g)	307	…..
15	Vitamin-C (mg/100 g)	40	7

Composition of Mahua Seeds:-

It is also called Butter tree because the seeds are used to produce butter. The mahua seeds yield 35 to 47% of oil, Total fats – 50-31%, Proteins – 16.9%, Carbohydrates – 22% and Total fiber – 3.2% mahua seeds per 100 grams. It has great application in different industries.

It is admired for its sweet flowers with an intoxicating sweet fragrance. It contains numerous phytochemicals, so it had a wide range of therapeutic applications traditionally. These flowers have a lot of ethnic values among the tribal people. Due to the immense benefits of Mahua flowers tribals develop a wide range of fermented and non-fermented food products. The Mahua flowers are also used to produce Mahua or Daru, a popular fermented drink that is consumed by tribal communities across India. Mahua is made by fermenting the flowers in water for several days and then distilling the resulting mixture to produce a potent alcoholic beverage. This daru has a sweet and fruity taste, and is often consumed during social ceremonies and festivals. In addition to its use as a food and beverage, Mahua also has medicinal properties and is used in traditional Ayurvedic medicine to treat a variety of ailments. The flowers and leaves of the Mahua tree are used to treat fever, cough, diarrhea, dysentery, and other respiratory and digestive disorders. The seeds of the Mahua tree are also used to produce oil that is used in cooking, as well as in the treatment of skin ailments and rheumatism.

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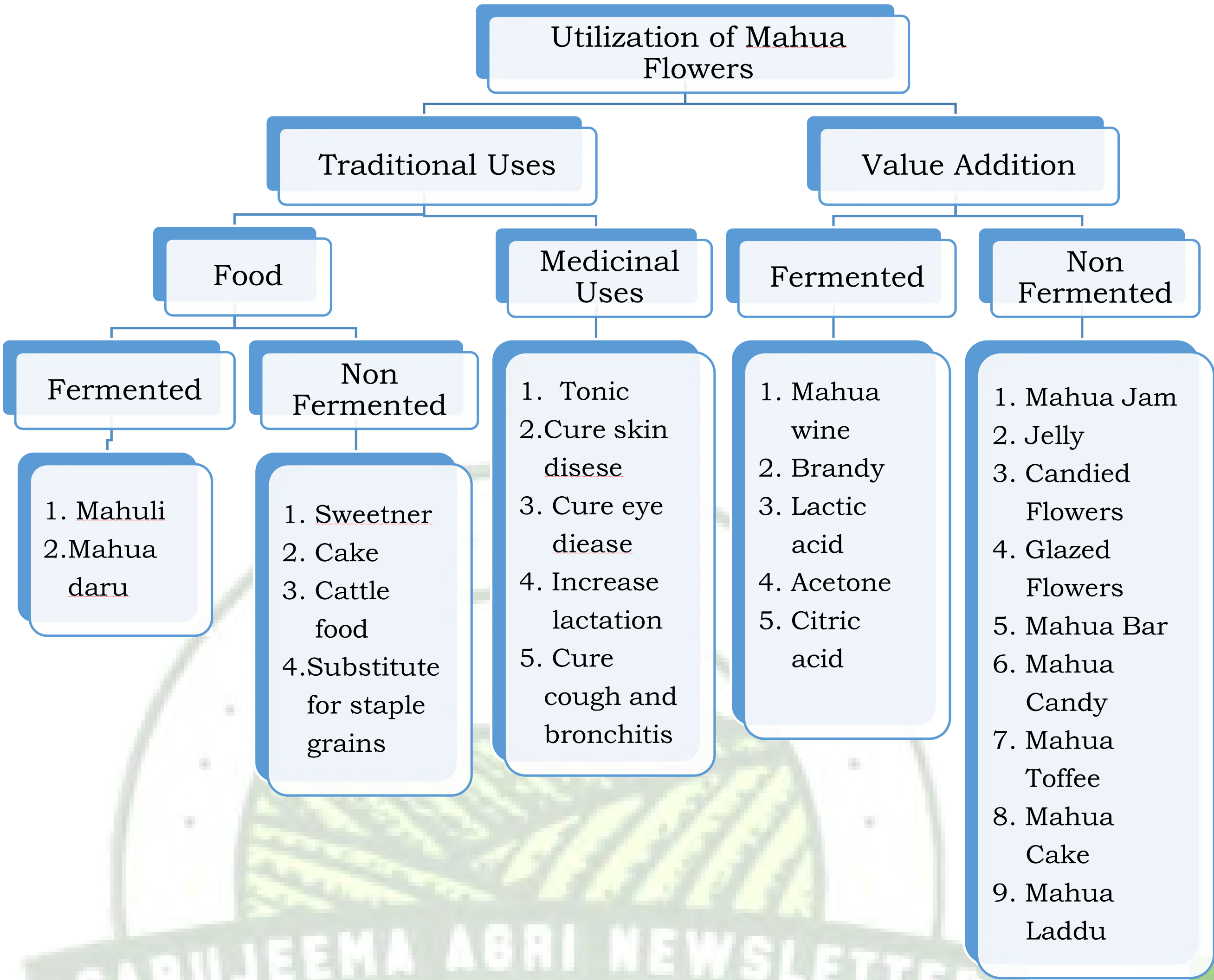

Utilization in Food Production: -

Due to high content of sugar (sucrose, glucose, fructose, arabinose, few amounts of maltose and rhamnose) tribal people are utilizing mahua flowers as a sweetening agent in numerous local and traditional dishes like halwa, meethi puri, kheer and burfi.

Medicinal Properties of Mahua Flowers: -

- Antibacterial activity
- Antihelmenthic activity
- Antioxidant activity
- Anti-cancer activity
- Analgesic activity
- Aphrodisiac
- Astringent
- Demulcent
- Expectorant
- Hepatoprotective activity

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Use of Mahua oil: -

Tribal communities of India use the oil for quick relief from the pain of insect bites. It treats rashes and redness caused by insect bites. Tribal people of Odisha burn mahua oil to repel mosquitos. It is a natural remedy that doesn't cause any problem to the lungs, unlike harmful chemical repellents. Mahua is a great laxative. Consuming it in any form at night before bed will absorb water from the stomach and improve digestion. The seeds also have laxative properties. It reduces stiffness in stools and helps in smooth pass through. Mahua oil is a chemical-free skincare product that provides glowing skin. Massaging with mahua oil will treat acne or blemishes and give clear, soft, and radiant skin. The anti-inflammatory activity in mahua prevents entry of foreign particles to the body thus preventing infection and pain. Mahua oil promotes hair growth

Other common uses of Mahua:

The leaves, flowers, and fruits of trees are fed to sheep and goats. The seed cake prepared from mahua is given to cattle. The reddish-brown color wood is strong, hard, and durable. It can be used for door and window frames, naves, house construction and felloes of cartwheels. It controls soil erosion due to very large superficial root system and its spread that can hold soil. The crown of a tree is wide and spread that provides shade and shelter to animals and human beings. The seed cake prepared from mahua act as fertilizer.

Demerits:

The major factors affecting the quality of mahua flowers and their food products, are poor post-harvest storage and lack of modern technologies for the value addition of mahua flowers. As a result, the poor tribal people and small local entrepreneurs are facing lots of economic problems due to low profit market of mahua flowers and their products. The possible side effects of mahua are as follows: Mahua naturally has a hypoglycemic activity which means it can reduce sugar levels in the blood. It is not recommended for diabetic patients. Animal studies have shown that mahua has immunosuppressive properties. So, if you are suffering from autoimmune disease or taking drugs for the disease, avoid mahua.

Summary

The demand of mahua is increasing gradually because of enormous potential for commercial exploitation aiming to improve the economic status of the poor and marginal farmers. An area which needs immediate attention is the collection, documentation, conservation and post-harvest management for their sustained production. The plant genetic resource (PGR) research needs to be undertaken on the classification of the genetic diversity through use of the morphological, biochemical & molecular techniques. Promising genotypes having tolerance to the biotic & abiotic stress should be selected. Model nurseries for the local supply of quality planting material should be established. Agro-techniques like integrated nutrient management, diversified farming system, high density planting system, weed management, canopy management and irrigation management should be standardized under different ecosystem of

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the country. Maturity, harvesting, grading packaging and storage system should be standardized.

Mahua Flowers, fruits and seeds

Different Products Mahua

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From Symptoms to Sequences: Pathogen Profiling with PCR

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ABSTRACT

In plant pathology, polymerase chain reaction (PCR) facilitates pathogen profiling from symptom observation to genetic sequencing. When plants exhibit symptoms like wilting or lesions, samples are collected, and DNA or RNA is extracted from affected tissues. PCR amplifies specific pathogen genetic markers, enabling sensitive detection of fungi, bacteria, or viruses, even at low levels. Sequencing the amplified products identifies the pathogen's species, strain, or resistance traits, aiding in understanding disease epidemiology and management. Real-time PCR offers rapid, specific results, while multiplex assays detect multiple pathogens simultaneously. This approach enhances diagnostic accuracy, informs targeted control measures, and supports sustainable agricultural practices.

Keywords: Polymerase chain reaction (PCR), Pathogen detection, Molecular technique

Introduction:

The Polymerase Chain Reaction (PCR) is a powerful molecular technique widely used in plant pathology to detect, identify, and study plant pathogens, including fungi, bacteria, viruses, viroid, and nematodes. PCR revolutionized plant pathology since its 1983 invention by **Kary Mullis**. By the 1990s, it enabled sensitive detection of *Phytophthora* species. Real-time PCR (2000s) quantified pathogens like *P. infestans*. Multiplex and nested PCR enhanced specificity, while 2010s digital PCR and 2020s portable/CRISPR-PCR systems advanced rapid, field-based diagnostics. By amplifying specific DNA or RNA sequences, PCR enables rapid and sensitive diagnosis of plant diseases, even when pathogens are present in low quantities or in asymptomatic plants. The process involves extracting nucleic acids from plant tissue, soil, or water, followed by thermal cycling to denature DNA, anneal specific primers, and extend new DNA strands using a heat-stable polymerase. Techniques like reverse transcription PCR (RT-PCR) for RNA-based pathogens, quantitative PCR (qPCR) for pathogen quantification, and multiplex PCR for detecting multiple pathogens enhance its versatility. In plant pathology, PCR is critical for early disease detection, monitoring pathogen spread, identifying strains, and ensuring quarantine compliance. For example, it can detect *Phytophthora infestans* in potatoes or Citrus tristeza virus in citrus. Despite its high sensitivity and specificity, PCR requires specialized equipment, skilled personnel, and careful sample preparation to avoid contamination or inhibition by plant compounds. Its applications have revolutionized plant disease management, improved crop health and supporting global food security through timely and accurate diagnostics.

What is PCR?

Polymerase Chain Reaction (PCR) is a widely used molecular technique that enables the amplification of specific DNA sequences from minute samples. It operates through a cyclical process involving three key steps: denaturation, annealing, and extension. First, the DNA is heated to separate its strands. Then, short primers bind to the target sequences during the annealing phase. Finally, a thermostable enzyme, typically Taq DNA polymerase, synthesizes new DNA strands by extending from the primers. This cycle repeats multiple times, exponentially increasing the DNA quantity. PCR requires a DNA template, primers, nucleotides, buffer solution, and the polymerase enzyme. Its speed, sensitivity, and specificity make it indispensable in fields like molecular diagnostics, forensic science, genetic research, and pathogen detection. Variants such as reverse transcription PCR (RT-PCR) allow RNA analysis, while quantitative PCR (qPCR) enables real-time measurement of DNA amplification. PCR has revolutionized biology by making genetic analysis rapid, reliable, and highly accessible.

Types of PCR:

In plant pathology, various PCR techniques are employed for detecting and studying pathogens like *Phytophthora*. **Conventional PCR** amplifies DNA using pathogen-specific primers, ideal for identifying species like *P. ramorum* in infected tissues. **Real-time PCR (qPCR)**, using fluorescent probes (e.g., TaqMan), quantifies pathogen DNA in real-time, as seen in *P. infestans* soil monitoring, offering high sensitivity and speed without post-PCR processing. **Multiplex PCR** simultaneously detects multiple pathogens, such as *P. nicotianae* and *P. cactorum* in strawberries, reducing costs and time. **Nested PCR** enhances sensitivity for low-abundance DNA, used in *P. cinnamomi* forest surveys, by employing two primer sets to minimize non-specific amplification. **Digital PCR (dPCR)** provides absolute quantification, valuable for precise *Phytophthora* load assessment in complex samples. **Reverse Transcription PCR (RT-PCR)** targets RNA, detecting active viral or oomycete infections. **Loop-mediated Isothermal Amplification (LAMP)**, though not strictly PCR, is a field-friendly alternative for rapid *P. infestans* detection. **RAPD-SCAR PCR** develops specific markers for pathogens like *P. infestans* in resource-limited settings. These techniques, often combined with sequencing or CRISPR, enable rapid, sensitive, and specific pathogen diagnostics, revolutionizing plant disease management.

How PCR works?

Polymerase Chain Reaction (PCR), is a revolutionary in vitro technique for exponentially amplifying specific DNA segments from minute quantities. It mimics DNA replication in a controlled, cyclical process using a thermal cycler to automate temperature shifts.

Key Components:

- **Template DNA**: This is the starting material containing the target DNA sequence to be amplified. It serves as the blueprint for replication. The template, which can be genomic DNA, plasmid DNA, or even a tiny amount from a sample provides the specific region that PCR will copy. Its quality and purity are crucial to avoid inhibitors that could disrupt the reaction.

- **Primers**: These are short, synthetic single-stranded DNA fragments (18-25 nucleotides) designed to be complementary to the 3' ends of the target DNA sequence. Primers act as starting points for DNA synthesis by providing a free 3' hydroxyl group for Taq polymerase to begin adding nucleotides. A pair of primers (forward and reverse) flanks the target region, defining the exact segment to be amplified. Their specificity ensures only the desired DNA region is copied, and their melting temperature (Tm) dictates the annealing temperature.

- **dNTPs**: These are the building blocks of the new DNA strands. During the extension step, Taq polymerase incorporates these nucleotides into the growing DNA strand by forming phosphodiester bonds. The availability and concentration of dNTPs (typically 200-250 µM each) are critical for efficient amplification, as depletion can limit the reaction.

- **Taq Polymerase**: This heat-stable DNA polymerase, derived from the thermophilic bacterium *Thermus aquaticus*, catalyses the addition of dNTPs to the 3' end of the primer, synthesizing a new DNA strand complementary to the template. Its stability at high temperatures (up to 95°C) allows it to withstand denaturation without losing activity. Taq's optimal activity at 72°C and its rapid synthesis rate (~1000 nucleotides/sec) make it ideal for PCR's cyclic nature.

- **Buffer**: The PCR buffer maintains optimal conditions for Taq polymerase activity. It provides a stable pH (around 8.3) and contains magnesium ions (Mg^{2+}, typically 1.5-2.5 mM), which are essential cofactors for Taq polymerase's catalytic function. Mg^{2+} stabilizes the interaction between the enzyme, dNTPs, and the DNA template. The buffer also prevents inhibition by contaminants and ensures consistent reaction efficiency.

The Three-Step Cycle:

1. **Denaturation (94-98°C, 15-30 sec)**: High heat disrupts hydrogen bonds, separating double-stranded DNA (dsDNA) into single strands (ssDNA). This yields two templates per original molecule. No enzymatic activity occurs here.

2. **Annealing (50-65°C, 20-40 sec)**: Temperature drops, allowing primers to hybridize specifically to complementary sequences on ssDNA via base pairing (A-T, G-C). Annealing temperature is primer-specific, calculated as Tm = 4(G+C) + 2(A+T) °C, ensuring specificity and avoiding non-specific binding.

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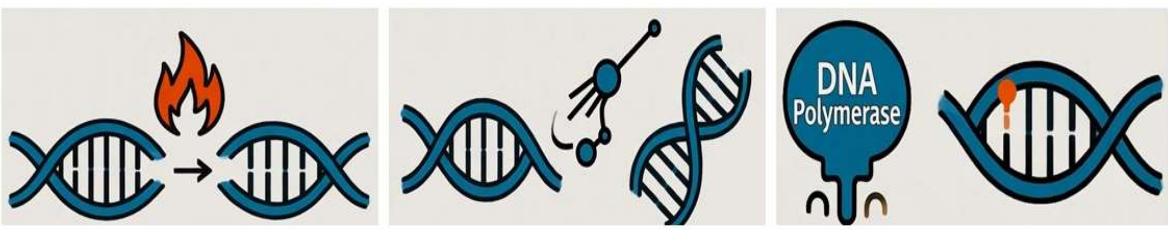
3. **Extension/Elongation (72°C, 30 sec - 2 min/kb)**: Taq polymerase binds to primer-template hybrids at the 3' OH end of the primer. It catalyses phosphodiester bond formation, adding ~1000 nucleotides/sec, synthesizing new strands complementary to the template. Extension time depends on amplicon length (e.g., 1 min for 1 kb).

These three steps—denaturation, annealing, and extension—form one cycle, typically lasting a few minutes. The process is repeated for 25-40 cycles in a machine called a **thermal cycler**, which precisely controls the temperature changes. Each cycle doubles the amount of target DNA, leading to exponential amplification. For example, after 30 cycles, a single DNA molecule can theoretically produce over a billion copies. The amplified DNA can then be analysed for various purposes, such as detecting pathogens, identifying genetic mutations, or cloning genes.

After PCR, Agarose Gel Electrophoresis is performed where the amplified DNA (amplicons) is separated by size on an agarose gel to visualize the results.

Interpreting PCR Results:

Assessing band presence and size in endpoint PCR is a critical step in interpreting results, performed by analysing PCR products on an agarose gel. After amplification, the PCR reaction mixture is loaded onto a 1-2% agarose gel stained with a DNA-binding dye and subjected to electrophoresis. DNA fragments migrate based on size, with smaller fragments moving faster. A DNA ladder, containing fragments of known sizes (e.g., 100 bp, 500 bp), is run alongside samples for size reference. A clear band at the expected amplicon size, determined by primer design (e.g., 400 bp), confirms successful amplification of the target DNA, indicating the presence of the target sequence in the sample. Absence of a band suggests no target DNA, PCR inhibition, or technical issues like degraded Taq polymerase, incorrect annealing temperature, or poor primer specificity. Unexpected bands, such as small ones (< 100 bp), often indicate primer-dimers, while bands of incorrect sizes suggest non-specific amplification due to low annealing temperature or mis designed primers. Smearing indicates degraded DNA or over-amplification. Band intensity, visualized under UV or blue light, roughly correlates with amplicon yield. Comparing band positions to the ladder ensures accurate size determination, critical for validating results against controls.



A B C

A: Denaturation separates double-stranded DNA at high temperature,
B: Annealing allows primers to bind to complementary sequences on single strands, and
C: Extension uses DNA polymerase to synthesize new DNA strands from the primers

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Evaluating PCR Against Other Diagnostic Techniques:

Attribute	PCR (Polymerase Chain Reaction)	ELISA (Enzyme – Linked Immunosorbent Assay)	LAMP (Loop – Mediated Isothermal Amplification)
Principle	Amplifies specific DNA/RNA segments using thermal cycling, primers, and Taq polymerase.	Detects proteins (antigens/antibodies) via enzyme-linked antibodies and colorimetric signals.	Isothermal DNA amplification using multiple primers and a strand-displacing polymerase.
Target	DNA or RNA (via RT-PCR).	Proteins (e.g., viral antigens, antibodies).	DNA or RNA (via RT-LAMP).
Sensitivity	High (detects < 10 copies of target nuclei acid.	Moderate (ng/mL range, less sensitive than PCR).	High (comparable to PCR, detects low copy numbers).
Specificity	Very high (primer-specific, confirmed by sequencing or melting curves).	High but prone to cross-reactivity (e.g., similar antigens).	High (multiple primers ensure specificity).
Speed	2-4 hours (endpoint PCR); 1-2 hours (real-time qPCR).	2-6 hours (including incubation steps).	30-60 minutes (isothermal, no cycling).
Equipment Needed	Thermal cycler, gel electrophoresis, or qPCR machine.	Plate reader, incubator.	Simple heat block or water bath.
Cost	Moderate to high (reagents, equipment, primers).	Moderate (cheaper reagents, widely available).	Low to moderate (no thermal cycler needed).
Quantitative Ability	Yes	Yes	Less
Uses	Pathogen detection, genetic testing, forensics, mutation analysis.	Antibody/antigen detection, biomarker analysis.	Rapid pathogen detection in resource-limited settings.

PCR in Integrated Disease Management:

Polymerase Chain Reaction (PCR) is pivotal for Integrated Disease Management (IDM) by enabling rapid, sensitive, and specific detection of plant pathogens, including viruses, bacteria, fungi, and nematodes. PCR amplifies pathogen-specific DNA/RNA, allowing early diagnosis

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before symptoms appear, which is critical for timely intervention. It identifies pathogen strains, monitors disease spread, and guides targeted control measures like resistant cultivars or chemical treatments. Real-time qPCR quantifies pathogen load, aiding in assessing disease severity. PCR's high specificity reduces misdiagnosis, while its speed (1-4 hours) supports proactive IDM strategies, minimizing crop losses and optimizing sustainable disease management.

Application of PCR:

Polymerase Chain Reaction (PCR) is a cornerstone in plant pathology for detecting and managing plant pathogens, including viruses, bacteria, fungi, and nematodes. It amplifies specific DNA/RNA sequences, enabling early, sensitive diagnosis of diseases in crops, even before symptoms manifest. PCR identifies pathogen species and strains, aiding in epidemiological tracking and resistance screening. Real-time qPCR quantifies pathogen levels, informing disease severity and treatment efficacy. Applications include certifying disease-free planting material, monitoring soil or water for pathogens, and guiding breeding for resistant varieties. Its speed, specificity, and sensitivity enhance disease control, supporting sustainable agriculture and reducing crop losses.

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Host and Spray Induced Gene Silencing (HIGS/SIGS) for Plant Pathogenic Fungi: Advanced RNAi Approach to Crop Sustainability

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INTRODUCTION

World agriculture faces significant threats from both abiotic and biotic stresses. Among the biotic factors, plant pathogenic fungi are the most prevalent and destructive agents, posing a continuous and severe risk to global crop production. A modern, innovative approach to mitigating these fungal threats is "Gene Silencing" through RNA interference (RNAi). This advanced biotechnology technique enables the precise targeting of fungal genes involved in disease progression, offering an effective method for disease control. Gene silencing refers to the process by which gene expression is down regulated or suppressed, preventing the formation of proteins from specific RNA molecules. It is often equated with gene knockdown.

When a gene is silenced, its corresponding RNA is rendered unable to synthesize a protein, halting its biological function. Gene silencing can occur at various stages, including transcription or post transcription. RNAi, a post-transcriptional gene silencing mechanism, operates by introducing double stranded RNA (dsRNA) into the system, which triggers the degradation of target messenger RNA (mRNA). This process ultimately blocks the expression of disease-related genes, providing a powerful tool for managing fungal pathogens in plant.

Components of RNAi mechanism (Agrawal et al., 2003)

1. Dicer or Dicer-like Protein
2. RNA Induced Silencing Complex (RISC)
3. Argonaute (AGO) protein
4. RNA dependent RNA polymerase (RdRp)
5. siRNA

General mechanisms of RNAi

- Introduction of dsRNA into the cell. Dicer enzyme cleaves the dsRNA into short fragments of 21-23 nucleotides (siRNAs).
- Unwinding of these siRNA into two single stranded RNA substituted as the passenger strand (sense) and the guide strand (antisense). The sense strand gets cleaved by the protein Argonaute 2 (Ago2) whereas the antisense guide strand is incorporated into an RNA-induced silencing complex (RISC).
- This RISC gets binded to target mRNA and degrades it.
- This degradation is achieved by guide RNA which binds with mRNA's complementary sequence and it gets cleaved with the help of Ago 2 protein which itself is a component of RISC.

Methods of delivering dsRNA in to the host plant for gene silencing (Sang and Kim, 2020)

1. **Host Induced Gene Silencing (HIGS):**

A transgenic expression method that uses dsRNA to silence genes in plant pathogens. It has been used to protect crops from viruses, nematodes, insects and fungi. HIGS relies on host plant's ability to produce mobile small interfering RNA (siRNA) molecules, generated from long dsRNA, which are complementary to targeted fungal genes. These molecules are transferred from host to invading fungi via nutrient transport or vesicle trafficking mechanism to cause gene silencing.

❖ **HIGS mechanism**

1) Transgenic plants expressing sequence specific dsRNAs targeting fungal gene(s) are generated.
2) The dsRNAs produced by transgenic plants are cleaved into siRNAs by the plant Dicer-like (DCL) proteins and both dsRNAs and siRNAs are transferred into fungal cells when a fungal pathogen infects.
3) dsRNAs are also cleaved into siRNAs by the fungal DCL proteins.
4) The siRNAs in the fungal cells degrade the fungal pathogen mRNAs to counteract pathogen virulence.

2. **Spray Induced Gene Silencing (SIGS):**

Technology based on RNAi, called spray-induced gene silencing (SIGS), as an alternative or adjunct to breeding for manipulation of endogenous gene expression in plants for pathogen control. A spray application method that uses dsRNA to silence genes without the need for genetically modified (GM) transgenic plants. SIGS is an eco-friendly strategy that can be combined with nano bioconjugates to improve protection. SIGS based on exogenous application of RNA molecules on plants may be especially useful in reducing pest or pathogen impacts, thereby ameliorating biotic stresses and increasing the agronomic performance of crops. Spraying of double-stranded RNAs (dsRNAs) and small RNAs (sRNAs) that target essential pathogen genes on plant surfaces confer efficient crop protection.

Conclusion

With the increasing population, the demand for food grains is rising at a faster pace than production. Additionally, significant crop yields are lost each year due to various pests and diseases. Although chemical pesticides remain the primary method for disease control, over-reliance on them harms both the environment and human health. Furthermore, the growing

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resistance of phytopathogens to these chemicals threatens agricultural sustainability. To address these challenges, gene-silencing technologies, particularly RNA-based methods, offer better ways to protect crops and ensure sustainable food production. The advanced strategies like HIGS and SIGS represent powerful and promising tools for managing many plant pathogenic fungi. These gene-silencing technologies can efficiently target specific genes in pathogens, providing a novel and environmentally friendly alternative to traditional chemical-based disease management.

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Endophytes in Plant Disease Management: Nature's Silent Protectors

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INTRODUCTION

Endophytes—microorganisms that live symbiotically within plant tissues without causing harm—have emerged as promising tools in sustainable agriculture, particularly in plant disease management. These naturally occurring fungi and bacteria enhance host resistance through mechanisms like antibiosis, competition, and induction of systemic resistance. By suppressing pathogens internally, endophytes offer an eco-friendly alternative to chemical pesticides, reducing environmental impact and supporting crop resilience. This article explores the biology of endophytes, their role in disease suppression, and their application across crops like rice, banana, tomato, and grapevine. Despite challenges in formulation, colonization consistency, and regulatory hurdles, advances in microbiology and biotechnology are driving their commercial viability. Endophyte-based solutions present a powerful, nature-based strategy for integrated plant health management and sustainable food production.

Introduction: The Microbial Allies Inside Plants

Modern agriculture is in a delicate balancing act—feeding a growing population while preserving soil, water, and biodiversity. One of the biggest concerns in this equation is plant disease. Each year, fungi, bacteria, viruses, and nematodes cause devastating losses in agriculture, wiping out nearly 20–40% of global crop yields. In response, farmers have long depended on chemical pesticides. But with increasing resistance, environmental contamination, and health risks, the need for a safer, more sustainable alternative is urgent.

One such promising alternative is surprisingly quiet and invisible—endophytes, microorganisms that live within plants. Unlike pathogens, these microbial inhabitants are beneficial, helping their host plants resist infections, tolerate stress, and even enhance nutrient

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uptake. They offer an eco-friendly, long-term strategy for biological disease control, and they are reshaping how we think about plant protection in the 21st century.

What Are Endophytes?

Endophytes are microorganisms—mostly fungi and bacteria—that inhabit the internal tissues of plants without causing any immediate negative effects. These microbes can live in the roots, stems, leaves, and even flowers and seeds, often entering through root hairs or natural openings. Unlike external microbes that reside in the rhizosphere (soil around the roots), endophytes live inside plant tissues, forming symbiotic relationships. They gain shelter and nutrients from the plant, and in return, they offer several services—from enhancing growth to protecting against pathogens.

Scientific studies have revealed that nearly all plant species host a wide range of endophytes, but their populations and effects vary depending on species, location, and environmental conditions. Some of the most researched endophytes include Bacillus, Pseudomonas, Trichoderma, Clonostachys, and Fusarium (non-pathogenic strains).

Mechanisms of Disease Suppression

One of the most exciting aspects of endophytes is **their multifaceted role in** protecting plants from diseases. They use a variety of natural methods to suppress pathogens:

1.Antibiosis

Many endophytes produce secondary metabolites—chemical compounds such as alkaloids, peptides, or phenolics—that have strong antimicrobial properties. These compounds inhibit or kill pathogens, sometimes even before they enter plant tissues. For instance, *Trichoderma harzianum*, a fungal endophyte, secretes enzymes that break down the cell walls of plant pathogens, effectively killing them.

2.Competition for Resources and Space

Endophytes colonize the same internal spaces where pathogens would usually invade. By occupying these niches first, they reduce the chances of successful pathogen colonization. This principle of **niche exclusion** is a key biological control mechanism.

3. Induction of Plant Défense Mechanisms

Some endophytes act as internal trainers for the plant's immune system. They stimulate the plant to produce defence-related enzymes, phytoalexins, or signalling molecules such as salicylic acid and jasmonic acid. This process, called **induced systemic resistance (ISR)**, prepares the plant to respond more effectively to future pathogen attacks.

4. Degradation of Pathogen Toxins

Certain endophytes can detoxify harmful substances produced by pathogens. This reduces the damage done during infection and allows the plant to continue growing even when exposed to stress.

Real-World Applications and Success Stories

Research across the globe has shown that endophytes can be powerful tools in the management of plant diseases, especially in economically important crops.

In rice, endophytic strains of *Pseudomonas fluorescens* and *Bacillus subtilis* have been successfully used to suppress bacterial leaf blight and blast disease, two of the most common and destructive infections in Asia. In some trials, yield improvements of 10–20% were observed with endophyte treatments compared to untreated controls.

In banana plantations, one of the most feared diseases is Fusarium wilt, caused by *Fusarium oxysporum f. sp. cubense*. Endophytic *non-pathogenic Fusarium* strains have been used as biological competitors that protect plants from the pathogenic form. They colonize the same root tissues and activate host resistance, significantly reducing infection levels.

Tomatoes have also benefited from endophytic applications. *Bacillus amyloliquefaciens* and *Trichoderma spp.* have been shown to reduce the severity of early blight and wilt diseases, while also promoting root development and fruit quality.

In vineyards, *Epichloë* fungal endophytes have helped reduce Botrytis cinerea infections, which are responsible for bunch rot. These endophytes not only reduce disease incidence but also contribute to grape quality by influencing secondary metabolite pathways.

Advantages Over Chemical Pesticides

Unlike chemical fungicides and bactericides, endophytes do not pollute the environment or disrupt ecological balance. They are biodegradable, safe for human health, and do not accumulate in the food chain.

Furthermore, since endophytes live within the plant, they offer continuous internal protection, unlike external sprays that wash off or degrade quickly. This internal presence is particularly valuable during periods of high humidity or rainfall, when surface treatments are less effective.

Another major advantage is that endophytes do not contribute to the rise of resistant pathogen strains, a growing concern in intensive farming systems. Because they work through multiple mechanisms and adapt alongside the plant, endophyte-based solutions are more sustainable in the long term.

Challenges and Future Directions

Despite their promise, the widespread adoption of endophytes in mainstream agriculture is still in its early stages. One major challenge is the variability in effectiveness across different crops and environments. An endophyte that performs well in one geographic region may not do the same elsewhere due to soil type, climate, or plant genotype.

There is also the issue of mass production and shelf-life. For commercial use, endophytes need to be formulated into stable products that can be stored, transported, and applied conveniently. Maintaining the viability and colonization ability of endophytes through seed coatings or liquid formulations is a technical hurdle currently under study.

Moreover, regulatory frameworks in many countries are not yet fully developed for microbial inoculants. Endophytes need to undergo safety and efficacy testing, and registration processes can be slow and expensive.

However, advances in metagenomics, synthetic biology, and formulation technology are helping overcome these barriers. With growing interest from the biotech industry and support from agricultural extension services, it is likely that endophyte-based products will become more widely available in the near future.

Conclusion: A Natural Revolution in Plant Protection

Endophytes represent one of nature's most subtle yet powerful innovations. These tiny microbial inhabitants offer a sustainable, effective, and environmentally responsible approach to managing plant diseases. They reduce our dependence on synthetic chemicals, improve plant health, and can even boost crop productivity under stress.

As we look toward a future of climate-resilient, sustainable farming, endophytes may become essential partners in the journey. With further research, supportive policies, and increased

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awareness, these hidden allies could help us cultivate healthier crops, richer soils, and more secure food systems—naturally and quietly, from within.

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AI-Based Flowering and Fruit Set Prediction in Tropical and Subtropical Horticulture Crops

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Abstract

Accurate prediction of flowering and fruit set is critical for maximising yield in tropical and subtropical horticultural crops. Traditional predictions rely on manual observation and historical data. These methods are slow, subjective, and often inaccurate under variable environmental conditions. Advances in artificial intelligence (AI) and machine learning (ML) now allow precise phenological forecasting using weather, remote sensing, and image data. AI systems can detect flowering intensity, predict flowering time, and forecast fruit-set patterns with high accuracy. Tropical fruits like mango, banana, and papaya benefit from data-driven prediction systems integrated with sensor networks and computer vision models. These tools help farmers adjust irrigation, manage labour, and plan market logistics. AI-based models improve decision-making for sustainable horticultural practices in regions with complex climatic variability.

Keywords
Artificial intelligence, machine learning, flowering prediction, fruit set forecasting, horticulture

1. Introduction

AI and machine learning use algorithms that learn patterns from data. These patterns can be environmental variables, images, or time series. AI has emerged as a significant tool in agriculture. It is now used to optimise crop management, disease detection, and yield forecasting. In horticulture, two of the most critical processes are **flowering** and **fruit set**. Flowering marks the onset of reproductive development. Fruit set determines final yield. Errors

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in timing predictions lead to losses. Tropical and subtropical regions have variable weather patterns. These variations make traditional prediction methods unreliable.

AI can integrate environmental data, remote sensing, and phenological records. It can generate accurate predictions for flowering and fruit set. Accurate prediction enables better irrigation scheduling, fertilisation planning, and labour allocation. For fruit crops, early prediction of flowering intensity helps estimate yield months before harvest. New AI systems use image analysis to count flowers and estimate yields with high accuracy. These technologies reduce guesswork and improve outcomes. (Bhattarai et al., 2024)

2. Biological Basis of Flowering and Fruit Set in Horticulture Crops

2.1 Phenology and Crop Reproduction

Flowering and fruit set are plant phenological events. Phenology is the study of recurring biological events and their relationship with the environment. For most crops, flowering depends on:

- Temperature accumulation
- Day length
- Water availability
- Nutrient status

Environmental stress can delay or accelerate flowering. It also impacts fruit set and quality.

2.2 Characteristics of Tropical and Subtropical Crops

Tropical and subtropical horticulture crops include:

- Mango
- Banana
- Papaya
- Citrus
- Guava

These crops have long, variable flowering periods influenced by irregular rains, high temperatures, and humidity. Flowering patterns in these regions are complex. Manual scouting and historical calendars often fail to capture this variability. (Bhattarai et al., 2024)

2.3 Fruit Set Dynamics

Fruit set follows pollination. If flowers do not successfully set fruit, yield is lost. Predicting fruit set requires understanding:

- Pollination success
- Weather during flowering
- Tree health
- Stress events like heat waves or drought

In apples and other temperate fruits, research divides the growth cycle into three phenological stages: flowering, fruit setting, fruit expansion, and colouring-maturity, each with specific water and climate requirements.

3. AI and Machine Learning Overview

3.1 Definitions

Artificial intelligence (AI) refers to computer systems that perform tasks requiring human intelligence. Machine learning (ML) is a subset of AI in which models learn from data without being explicitly programmed. Deep learning (DL) is a subset of ML that uses neural networks with many layers.

3.2 AI Techniques Used in Predictions

Standard AI models include:

- **Random Forests (RF):** Ensemble of decision trees for prediction.
- **Support Vector Machines (SVM):** Classification and regression.
- **Neural Networks:** Including recurrent (RNN), convolutional (CNN), and long short-term memory (LSTM). These models handle complex patterns.
- **Computer Vision:** Detects features in images (flowers, leaves).
- **Time-series models:** Forecast phenological events using sequential data.

Each model type has strengths and limitations that depend on the data type and prediction goals. Ensemble learning often yields better performance in complex agricultural datasets. (A Lightweight Exponential-Weighted Ensemble for Crop Recommendation, 2025)

3.3 Data Sources for AI Models

AI models use:

- Weather data (temperature, rainfall)
- Soil moisture data
- Sensor network outputs
- Satellite and drone imagery
- Ground truth phenology observations
- Historical yield records

Integration of multimodal data improves prediction accuracy.

4. AI in Flowering Prediction

4.1 Computer Vision for Flower Detection

Computer vision systems detect and count flowers from images. These systems have been deployed in orchards. Vision models such as YOLO (You Only Look Once) can detect flowers in complex scenes. A recent study showed that AI-based flower intensity estimation outperformed manual scoring, achieving high accuracy (0.995 mAP@50). (Kodors et al., 2025) These systems enable large-scale monitoring of flowering intensity without manual counting. Flower count data is directly linked to potential yield estimates.

4.2 Time-Series Prediction Models

Time-series models use historical weather and growth data to forecast flowering dates. Deep learning models like LSTM and GRU (Gated Recurrent Units) effectively learn seasonal patterns. A study using GRU models predicted the initial flowering period with over 98% accuracy compared to regression models. (A Study of Forest Phenology Prediction Based on GRU Models, 2023)

These forecasts are valuable for planning irrigation and nutrient applications.

4.3 Multimodal Deep Learning Models

Some advanced AI frameworks fuse image and environmental data. For example, models like GSP AI combine drone imagery with climatic datasets to predict vegetative-to-reproductive transitions. These multimodal systems improve reliability across environments.

5. AI in Fruit Set Prediction

5.1 Direct Fruit Set Estimation

Fruit set prediction is more complex than flowering. It depends on pollination outcomes, weather events, and crop health. Image-based systems can count fruits at early stages to estimate a set percentage. Machine vision can track flowers and then detect fruits on the same branches over time.

5.2 Integration with Yield Prediction

Flower count is correlated with fruit count. AI systems that count flowers can estimate the final yield. For example, a commercial AI flower-counting tool helps fruit farmers predict harvest sizes months in advance, supporting logistics planning.

5.3 Remote Sensing and Multiscale Data

Remote sensing platforms provide canopy-level data on vegetation status. Combined with AI, these data help identify crop stress that reduces fruit set. Satellite and drone imagery analysts use deep learning to map variations in canopy indices.

6. Conclusion

AI-based prediction of flowering and fruit set has matured rapidly. Methods that integrate image analysis, remote sensing, and environmental data provide precise phenological forecasts. These models outperform traditional manual prediction methods. Tropical and subtropical horticulture stands to benefit significantly due to climate variability and complex flowering patterns. Early prediction of flowering intensity and fruit set enables optimised resource use, improved planning, and higher yields. Challenges remain, particularly in data availability and model transferability. Continued research must focus on expanding datasets, hybridising models, and improving real-world deployment. With these developments, AI will become a standard tool in horticultural production systems.

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EFFECT OF DIFFERENT HOUSEHOLD'S SOLUTION ON ENZYMATIC BROWNING OF VEGETABLES AND FRUITS

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Abstract

An experiment was conducted on investigate the effect of different household's solution on enzymatic browning of vegetables and fruits at CHRS, Bilaspur, Chhattisgarh. We taken piece of different vegetable and fruit like brinjal , banana, apple ,potato and dip in different treatment (tap water, milk ,vinegar solution , 1 % sugar solution), result was revealed that among the all treatment vinegar showed the highest effectiveness in slowing browning in apple, potato, banana, and brinjal. We also revealed that when cut piece of vegetable and fruit was dip in different treatment enzymatic browning of potato was delayed 242 min by vinegar solution. Enzymatic browning because of polyphenol oxidases (PPOs) contributes to the color quality of fruit and vegetable (FV) products. Physical and chemical methods have been developed to inhibit the activity of PPOs, and several synthetic chemical compounds are commonly being used as PPO inhibitors in FV products. We tend to urge the use of natural and environment-friendly PPO inhibitors. The purpose of this article is to summarize the mechanisms underlying the anti-browning action of chemical PPO inhibitors and current trends in the research on these inhibitors. Based on their mechanisms of action, chemical inhibitors and household solution can be categorized as antioxidants, reducing agents, chelating agents, acidulants, and/or mixed-type PPO inhibitors. Here, we focused on the food ingredients, dietary components, food by-products, and waste associated with anti-browning activity.

Keywords: natural anti-browning agents, polyphenol oxidase, PPO inhibitor, sustainability, food waste utilization, nutritional values

Introduction

Enzymatic browning is a common phenomenon that occurs in many fruits and vegetables after they are cut or damaged. When the inner tissues are exposed to air, an enzyme called polyphenol oxidase (PPO) reacts with oxygen and produces brown-coloured pigments. This not only affects the appearance of the produce but can also reduce its nutritional quality and consumer acceptability.

To prevent browning, various household liquids—such as lemon juice, vinegar, salt solution, and sugar solution—are commonly used. These liquids work by either lowering the pH, blocking oxygen, or slowing enzyme activity.

In this experiment, different liquids were tested to compare their effectiveness in reducing or delaying enzymatic browning in fruits and vegetables. The findings help in understanding simple, practical methods for preserving the freshness and visual appeal of cut produce

Method to control enzymatic browning

1. **pH control**

In general, phenolase is active between pH 5 and 7 and does not have a very sharp pH optimum. At lower pH values of approximately 3 the enzyme is irreversibly inactivate

2. **Exclusion of oxygen**

This is the most common method of controlling enzymic browning. One general practice is dipping potato slices in water before frying to avoid enzymic browning of potato.

3. **Use of sulphur dioxide or sulphite**

This is method is useful for the product which can undergo textural or flavour changes upon heating. It is the powerful inhibitors of polyphenol oxidase.

Treatment is either in the form of gaseous sulphur dioxide or as a dilute solution of sulphites. Its mode of action is in two ways. First changes in the protein conformation of polyphenol oxidase. Secondly, it forms a colourless complex with quinone thus preventing the polymerization into melanin

4. **Application of heat**

Application of heat to the food article at a high temperature for an adequate length of time inactivates phenolase and all other enzymes present.

Heat applied such as blanching and high temperature- short time (HTST) pasteurization used respectively in the pre-treatment of vegetables for canning, freezing preservation or dehydration, or in the manufacture of fruits juice and purees.

5. Exclusion of oxygen

The simplest application of this method of phenolase inhibition is often found in the home at a time when it is convenient to peel and cut potatoes sometime before cooking. During the intervening time interval, they are submerged in water, thus limiting the oxygen which can reach the cut potato tissue

6. Inhibition by Sodium Chloride

This method of inhibition of phenolase has had comparatively limited use being employed mainly for holding peeled fruits of processing. A model system demonstrated that 0.1% sodium chloride significantly inhibited browning. The reaction mixtures contained 0.4% chlorogenic acid buffered at pH 5.0, water or sodium chloride solution and preparation of phenolase from apples.

7. **Methylation of phenolase substrates**

The fact that substances such as guaiacol and ferulic acid will not function as phenolase substrates have already been mentioned. A method for preventing enzymic browning in F&V has been developed based on the enzymic methylation of the o-methyltransferase. o-methyltransferase is believed to be involved in the biosynthesis of lignin and other aromatic compounds. The enzymes will function in the presence of a methyl donor such as S-adenosylmethionine and a methyl acceptor such as an o-diphenol.

8. Application of acids

This is a widely used method for the control of enzymic browning. The acids employed are among those which occur naturally in tissues, particularly citric, malic, phosphoric, and ascorbic acids. In general, their action is to lower the tissue pH and thus to decrease the rate of browning.

9. Boric acid and borate

Browning was completely inhibited by treatment with 1.5% sodium tetra borate and with 1.5% sodium metaborate.

Materials Required

1. Fresh fruits and vegetables:
   - Apple slices
   - Potato slices
   - Banana slices
   - Brinjal slices
2. Different liquids used for treatment:
   - Plain water
   - 1% Sugar solution
   - Milk
   - Vinegar
   - Knife and cutting board
   - Bowls or beakers (for each liquid)
   - Tissue paper or plate for placing treated slices
   - Timer or stopwatch
   - Observation notebook and pen

Procedure

- Wash all selected fruits and vegetables (apple, potato, banana, and brinjal) thoroughly.
- Using a clean cutting board and knife, cut each item into equal-sized slices (approximately 1 cm thick). Prepare at least one slice for each treatment and one untreated slice as the control
- Label five separate bowls or beakers for the different treatments: Water, Sugar Solution, Milk, Vinegar, and Control.
- Prepare the liquids as follows:
- **Water:** plain tap water (about 100 mL).
- **Sugar solution:** prepared by dissolving sugar in water (1% solution; approx. 1 g sugar in 100 mL water).
- **Milk:** 100 mL of regular milk.
- **Vinegar:** 100 mL of household white vinegar.
- Dip one slice of each fruit/vegetable into each liquid for 1–2 minutes, ensuring the entire surface is completely covered.

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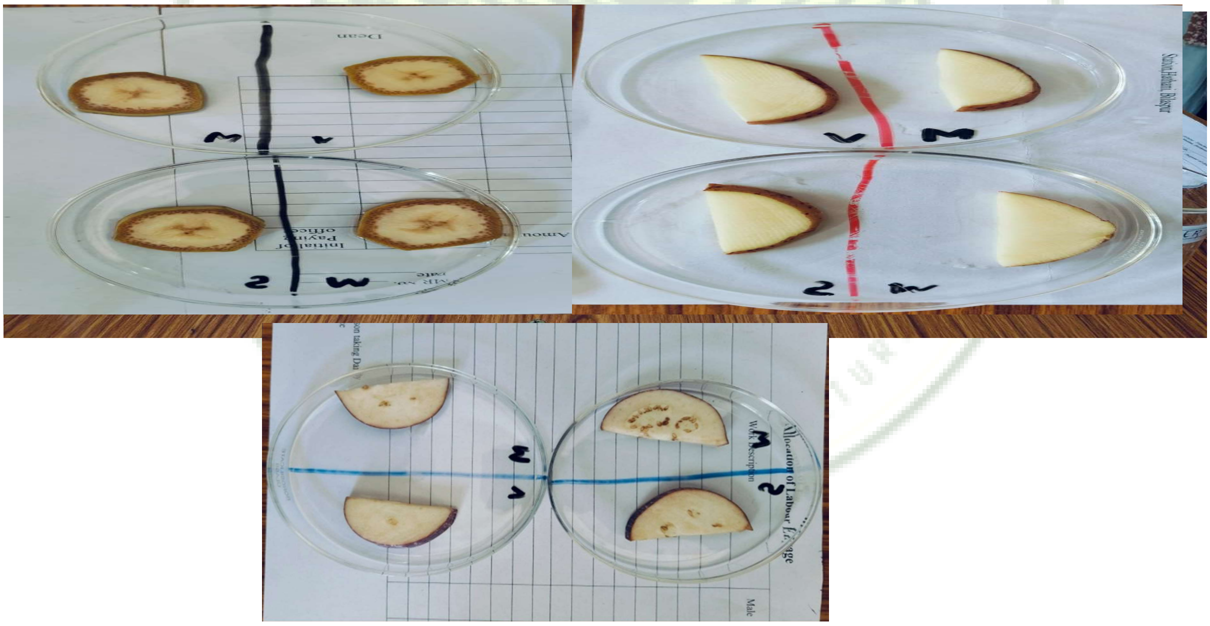
- Remove the slices and place them on clean, labelled plates. Gently blot excess liquid with tissue paper.
- Place the control slices directly on a plate without dipping them in any liquid.
- Keep all plates at room temperature, away from direct sunlight.
- Observe the colour changes at regular time intervals: 0 minutes, 5 minutes, 10 minutes, 20 minutes, 30 minutes, and 60 minutes.
- Record browning intensity for each treatment at each time point using a simple scoring scale.
- Compare the treatments to identify which liquid most effectively reduced or delayed enzymatic browning.

Effect of different liquid on delayed enzymatic browning

Fruit /veg.	Water	Sugar solution	Milk	Vinegar
Apple	47 min	48 min	50 min	55 min
Potato	154 min	52 min	220 min	242 min
Banana	47 min	48 min	49 min	51 min
Brinjal	44 min	46 min	47 min	59 min

Fig: Vegetable & fruit cutting dip in different treatments



Result

The effect of different liquids on enzymatic browning varied across the tested fruits and vegetables. Among all treatments, vinegar showed the highest effectiveness in slowing browning in apple, potato, banana, and brinjal. We also revealed that when cut piece of vegetable and fruit was dip in different treatment enzymatic browning of potato was delayed 242 min by vinegar solution .The acidic nature of vinegar inhibited the activity of the

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polyphenol oxidase (PPO) enzyme, resulting in noticeably lighter colour compared to the other treatments.

milk provided moderate protection. Both treatments delayed browning for some time, most likely due to their lower pH and protein interaction with the enzyme, but browning gradually appeared after longer intervals.

The sugar solution showed mild reduction in browning. It formed a slight protective coating but was not strong enough to suppress enzymatic activity for long durations.

Slices dipped in plain water showed little to no protection against browning and turned brown quickly.

The control (untreated slices) browned the fastest among all samples.

Overall, the experiment clearly demonstrated that vinegar was the most effective liquid in reducing or delaying enzymatic browning, followed by milk, sugar solution, water, and control.

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